



Low-emissions economy

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Final report

August 2018

The New Zealand Productivity Commission

Te Kōmihana Whai Hua o Aotearoa¹

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Disclosure

The Chair of the Productivity Commission, Murray Sherwin, has a financial interest in the forest sector via part ownership of a forestry block.

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NZ Productivity Commission

¹ The Commission that pursues abundance for New Zealand.

Foreword

Being asked to advise on how New Zealand can best make the transition to a low emissions economy, while at the same time continuing to grow incomes and wellbeing, is perhaps the most profound and far-reaching mandate the Commission could be tasked with.

After an extensive inquiry process, we conclude that New Zealand can indeed make this transition. But there will be tough challenges along the way. It will require consistent and concerted effort across government, business, households and communities – up to and beyond 2050.

Among the numerous changes that will be required across the economy – some disruptive some less obvious – three particular shifts must happen for New Zealand to achieve its low-emissions goals: 1) we stop burning fossil fuels and where possible, switch to use of electricity and other low-emission energy sources; 2) we undertake substantial new afforestation; and 3) we make changes to the structure and methods of agricultural production.

What is clear from this inquiry is that delaying action will compound the transition challenge. Delay is potentially costly, disruptive and may limit viable and cost-effective mitigation options in the future. If New Zealand fails to act promptly, it risks being locked into a high-emissions economy and missing potential future opportunities.

We are confident the steps recommended in this report will put New Zealand on a solid footing to efficiently make this transition. But the journey will be long and punctuated by change and uncertainty. Technological advances are critical to success in this global challenge. Some of the regulatory and market design issues are complex and contain risks of unintended and unhelpful consequences if not done very well.

Since this is truly a global challenge, the climate-change policies of other countries will determine the exposure that New Zealand faces from disruptive changes to climate patterns. The efforts that New Zealand makes will have a very small direct influence on what we experience by way of climate change. We make that effort as a member of a global community with a shared interest in overcoming this challenge to our collective well-being. We cannot expect to influence others of the need to change if we cannot ourselves demonstrate the willingness and ability to play our part, to offer our assistance and to share the benefits of our experience.

We have had overwhelming interest in this inquiry, from many quarters. The Commission received 403 submissions from a wide and diverse group of interested parties. These submissions, together with views expressed in 155 stakeholder engagement meetings, seminars, roundtables, and numerous workshops have assisted the Commission in understanding the complex issues in this area and formulating our advice. I would like to express my thanks to all those who provided this valuable information and insight.

Dr Graham Scott, Professor Sally Davenport and I oversaw the preparation of this report. The Commissioners would like to acknowledge the work and commitment of the inquiry team: Steven Bailey (inquiry director), Dr Ron Crawford, Terry Genet, Geoff Lewis, Tim Maddock, Dr Amelia Sharman, Teresa Weeks, and Paul Young. Thanks also to valuable contributions from Judy Kavanagh and Nik Green. Our report has also benefited immensely from the work of expert consultants. Thanks to the consortium of consultants who carried out the transition pathways modelling: Vivid Economics (London), Concept Consulting and Motu Economic and Public Policy Research. And also to Sapere Research Group who provided advice on the electricity sector. I would also like to acknowledge the advice provided by Dr Kennedy Graham on our Draft Report.



Murray Sherwin
Chair, Productivity Commission
August 2018

Terms of reference

NEW ZEALAND PRODUCTIVITY COMMISSION INQUIRY INTO THE OPPORTUNITIES AND CHALLENGES OF A TRANSITION TO A LOWER NET EMISSIONS ECONOMY FOR NEW ZEALAND

Issued by the Minister for Climate Change Issues, the Minister of Finance, and the Minister for Economic Development (the "referring Ministers"). Pursuant to sections 9 and 11 of the New Zealand Productivity Commission Act 2010, we hereby request that the New Zealand Productivity Commission ("the Commission") undertake an inquiry into how New Zealand can maximise the opportunities and minimise the risks of transitioning to a lower net-emissions economy.

Context

New Zealand is part of the international response to address the impacts of climate change and to limit the rise in global temperature, requiring a transition of the global economy to one consistent with a low carbon and climate resilient development pathway.

New Zealand has recently formalised its first Nationally Determined Contribution under the Paris Agreement to reduce its emissions by 30 percent below 2005 levels by 2030. The Paris Agreement envisages all countries taking progressively ambitious emissions reduction targets beyond 2030. Countries are invited to formulate and communicate long-term low emission development strategies before 2020. The Government has previously notified a target for a 50 per cent reduction in New Zealand greenhouse gas emissions from 1990 levels by 2050.

New Zealand's domestic response to climate change is, and will be in the future, fundamentally shaped by its position as a small, globally connected and trade-dependent country. New Zealand's response also needs to reflect such features as its high level of emissions from agriculture, its abundant forestry resources, and its largely decarbonised electricity sector, as well as any future demographic changes (including immigration).

The government is already taking action to support meeting the 2030 target. This includes reviewing the New Zealand Emissions Trading Scheme (NZ ETS), encouraging the up-take of electric vehicles and other energy efficiency technologies, and developing links with emerging international carbon markets. It has also founded the Global Research Alliance to fund research into emissions mitigation in pasture based livestock systems.

However in the long-term - 2030 and beyond - New Zealand will likely need to further reduce its domestic emissions in addition to the use of forestry offsets and international emissions reduction units, although these will continue to remain an important part of the country's climate change response for meeting targets at least cost.

This has the potential to influence the direction and shape of the New Zealand economy as the country seeks to balance the need to reduce domestic greenhouse gas emissions with preserving and enhancing economic wellbeing.

Taking action to transition to a low net emissions economy would involve a gradual change to the country's pattern of economic activity in order avoid a potentially costly and disruptive economic shift in the future. How such a change occurs, however, will not necessarily be linear.

Scope and aims

The purpose of this inquiry is identify options for how New Zealand could reduce its domestic greenhouse gas emissions through a transition towards a lower emissions future, while at the same time continuing to grow incomes and wellbeing.

Two broad questions should guide the inquiry:

What opportunities exist for the New Zealand economy to maximise the benefits and minimise the cost that a transition to a lower net-emissions economy offers, while continuing to grow incomes and wellbeing?

To answer this, the inquiry will need to examine New Zealand's current patterns of economic activity and the ways in which these are contributing to the country's greenhouse gas emissions.

It will then need to consider the different pathways along which the New Zealand economy could grow and develop so as to achieve New Zealand's emissions targets, as well as respond to the physical effects of a changing climate.

The inquiry will then need to analyse the respective opportunities and risks offered by these pathways, and identify which pathways offer the best outcomes in terms of both growing incomes and wellbeing and reducing domestic net-emissions.

This will require the Commission to consider how patterns of economy activity may need to change, including over what timeframe and at what cost, to achieve the potential benefits of these future pathways, and what strategies the government could use to maximise these benefits through regulatory systems, behavioural change, and economic incentives.

As part of analysing these pathways, the inquiry should also examine how they could affect broader economic objectives for increasing wellbeing and achieving higher living standards, including sustainability, economic growth (including productivity growth), increasing equity, social cohesion, and resilience to risk.

How could New Zealand's regulatory, technological, financial and institutional systems, processes and practices help realise the benefits and minimise the costs and risks of a transition to a lower net emissions economy?

The inquiry should examine the range of current and potential government interventions that could both support a transition to a lower net emissions economy and support growth of incomes and wellbeing.

In particular the inquiry should include the following:

- a. the role of the NZ ETS in supporting New Zealand to transition to a lower net emissions economy, building on the Ministry for the Environment's Stage II review
- b. the role of other market-led solutions, direct regulation (such as minimum fuel efficiency standards) and non-regulatory interventions (including aspirational targets) in a low net emissions transition
- c. how the science and innovation systems (including research and design) could better support the development of low emissions technologies, and whether there are any barriers (regulatory or otherwise) to the deployment and uptake of these technologies
- d. whether there are any barriers in New Zealand to undertaking domestic investment to reduce net emissions, and what the government could do to reduce or remove these barriers ((e.g. green bonds, public private partnerships, risk-sharing finance, climate-related disclosure requirements)
- e. how to encourage efficient land-use decisions that take into account the costs and benefits of greenhouse gas emissions and abatement (including how costs and benefits may be affected by applying carbon prices or other interventions to different activities) and concerns about international competitiveness
- f. how to maximise New Zealand's comparative advantages in a carbon constrained world, including the timeframes for any relative advantages from market premiums or market access risks.

Report and recommendations

The inquiry should explore New Zealand and international research and experience related to both the questions above. However, the focus should be on practical applications relevant to New Zealand's circumstances.

The inquiry should have a long-term focus, while being cognisant of New Zealand's 2030 and 2050 emissions reduction targets.

The final report should provide credible recommendations for how New Zealand should manage a transition to a lower net emissions economy, while still maintaining or improving incomes and wellbeing.

Exclusions

This inquiry should not focus on the suitability of New Zealand's current, or any future emissions reduction target. In addition, the inquiry should not focus on the veracity of anthropogenic climate change, and should only consider the implications of a changing climate to inform consideration of different economic pathways along which the New Zealand economy could grow and develop.

Consultation

Given that climate change is an economy wide-issue, the Commission should consult with a broad range of stakeholders including: central and local government, the Climate Change Iwi Leadership Group, relevant industry and NGO groups, scientific and academic bodies and the general public.

This inquiry is intended to complement and take account of existing policy work (particularly the Stage II review of the NZ ETS) and other current evidence gathering groups exploring issues related to climate change, including the Biological Emissions Reference Group, the Forestry Reference Group, and the GLOBE-NZ commissioned work by Vivid Economics.

Timeframes

The Commission should present a final report to referring Ministers by 30 June 2018.

HON PAULA BENNETT, MINISTER FOR CLIMATE CHANGE ISSUES

HON STEVEN JOYCE, MINISTER OF FINANCE

HON SIMON BRIDGES, MINISTER FOR ECONOMIC DEVELOPMENT

Office of Hon James Shaw

Minister for Climate Change
Minister of Statistics

Associate Minister of Finance



22 DEC 2017

Dear Murray

It was a pleasure to meet you, Graham and the team to discuss the Productivity Commission's progress on the inquiry into a low emissions economy.

This Government is committed to taking decisive action on climate change and transitioning New Zealand to a low emission economy by 2050. This week the Prime Minister and I announced the Government's intention to consult the public in 2018 on a Zero Carbon Bill. The Zero Carbon Bill will set a more ambitious target for emissions reductions by 2050, and establish an independent Climate Change Commission to provide advice and scrutiny to ensure that future governments are taking actions consistent with meeting this target.

It is clear that New Zealand needs to do more to meet our commitments under the Paris Agreement. As I set out in my letter to you in May, the Paris Agreement commits all countries, including New Zealand, to achieve a net-zero emissions economy by the second half of this century.

While the Government is yet to define the level of the emissions target for 2050, it would be helpful for the Commission to take into consideration the Government's intention to set a more ambitious emissions target for 2050. This may include setting a zero net emissions target for 2050. I have discussed this with my colleagues the Minister of Finance and the Minister for Economic Development who support this approach.

As a developed country, New Zealand will be expected to take the lead on actions to reduce emissions and to transition to a zero net emissions economy sooner than others. I encourage your inquiry to consider the full range of potential benefits and opportunities which might arise from New Zealand taking the global lead on reducing emissions.

Finally, I have been encouraged to see that you received such a high number of detailed and considered submissions in response to your issues paper. I believe this reflects the importance that New Zealanders place on making progress on such an important issue as climate change.

I look forward to receiving the final report of the Commission's inquiry.

Yours sincerely

A handwritten signature in blue ink, appearing to read 'James Shaw', with a long horizontal stroke at the end.

Hon James Shaw
Minister for Climate Change

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KEY

F	Findings
R	Recommendations

Commonly used terms

Term	Description
Agriculture	Activities including pastoral farming (ie, livestock farming), horticulture and arable farming.
Carbon dioxide equivalent (CO ₂ e)	CO ₂ e equalises the warming potential of different types of greenhouse gases, using carbon dioxide as the base for comparisons.
Emission leakage	This refers to the situation whereby reducing emissions in location A through a reduction in output leads to an increase in output in location B and an increase in its emissions. Where location B is a higher-emitting producer than location A, total emissions may rise.
Global Warming Potential (GWP ₁₀₀)	The most commonly-used metric (also used under the UNFCCC) to compare the warming potential of different greenhouse gases. GWP ₁₀₀ compares the cumulative warming of a greenhouse gas over a 100-year period with the warming of carbon dioxide.
Gross emissions	The total of a country's emissions across all sources, <u>excluding</u> offsets (and emissions) from land use, land-use change and forestry.
Industrial process heat	The heat generated to power industrial plants for purposes including converting raw products such as liquid milk into powder and wood pulp into paper, and chemical production.
Industrial processes and product use	A category used for UNFCCC reporting, this refers to emissions from industrial activities (eg, from steelmaking) that are not a direct result of consuming energy, and emissions from using greenhouse gases in products (eg, from the use of refrigeration systems).
Intergovernmental Panel on Climate Change	An international scientific and intergovernmental body that assesses and evaluates global research on climate change. Every five to seven years, the IPCC publishes an "assessment report", synthesising the most recent climatic research and data.
Kyoto Protocol	Adopted in 1997 (and entered into force in 2005), the Kyoto Protocol is a global climate treaty, alongside the UNFCCC. A key focus of the Protocol is the obligation on developed countries to reduce their emissions. These countries are required to set non-binding emissions reduction targets for two commitment periods between 2008 and 2020. The Protocol will soon be superseded by the Paris Agreement.
Land use, land-use change, and forestry (LULUCF)	A category used for UNFCCC reporting, this refers to emissions (and offsets) resulting from changes in the stock of greenhouse gases stored in different types of land (eg, forestry, grassland). For example, CO ₂ emissions released after a forest is deforested are reported under the LULUCF category.
Long-lived greenhouse gas (GHG)	A greenhouse gas that remains in the atmosphere for a relatively long period of time (eg, carbon dioxide is a long-lived GHG, which can persist for hundreds of years).
Long-term	2050 and beyond.

Term	Description
Low-emission vehicles	Vehicles that produce zero, or near-zero greenhouse-gas tailpipe emissions (eg, battery EVs, plug-in hybrid EVs, and hydrogen fuel cell vehicles).
Medium-term	2030 to 2050.
Nationally determined contributions (NDCs)	NDCs communicate a country's pledged short-term contribution to emissions reductions, to achieve the goal of the Paris Agreement. Under the Agreement, countries are required to submit a new or updated NDC by 2020 and every five years after that.
Net emissions	The total of a country's emissions across all sources, <u>minus</u> offsets from land use, land-use change and forestry.
Net-zero	Net-zero emissions describes a situation whereby the amount of greenhouse gases emitted into the atmosphere is equal to the amount sequestered or offset (eg, by forestry).
New Zealand Emissions Trading Scheme (NZ ETS)	New Zealand's main tool for reducing emissions, the NZ ETS is an emissions trading system requiring all sectors (excluding agriculture) to purchase and surrender emissions units (called New Zealand Units) in order to emit greenhouse gases.
New Zealand Units (NZUs)	The "currency" or permits used to trade in the NZ ETS. Each NZU represents one tonne of CO ₂ e.
Sequestration	The process whereby forests remove CO ₂ from the atmosphere and store it through photosynthesis. Sequestration can offset greenhouse gas emissions.
Short-lived GHG	A greenhouse gas that remains in the atmosphere for a relatively short period of time (eg, methane is a short-lived gas, which fully dissipates within a few decades after entering the atmosphere).
Short-term	The present to 2030.
The Paris Agreement	The most recent global climate change agreement, signed by 195 parties. The agreement sets out a goal of limiting temperature rise to 2°C (with an ambitious target of 1.5°C), through reaching net-zero emissions in the second half of this century.
United Nations Framework Convention on Climate Change (UNFCCC)	Adopted in 1992, the UNFCCC is an international climate change treaty, that provides the framework for global mitigation efforts, including negotiating specific climate-change agreements (eg, the Paris Agreement), and the reporting of greenhouse gas emissions.

Acronyms and abbreviations

Term	Description
AGS	Afforestation Grants Scheme
BERG	Biological Emissions Reference Group
CCC	UK Committee on Climate Change
CCGT	combined-cycle gas turbine
CCRA	Climate Change Response Act 2002
CCS	carbon capture and storage
CH ₄	methane
CO ₂	carbon dioxide
CO ₂ e	carbon dioxide equivalent
DER	distributed energy resources
DR	demand response
DSO	distribution system operator
EA	Electricity Authority
EDB	electricity distribution business
EECA	Energy Efficiency and Conservation Authority
EITE	emissions-intensive, trade-exposed
ETS	Emissions Trading Scheme
EV	electric vehicle
F-gas	fluorinated gas
GDP	Gross Domestic Product
GHG	greenhouse gas
GIB	green investment bank
GWP	global warming potential
HFC	hydrofluorocarbon
HWP	harvested wood product
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPPU	industrial processes and product use
kt	kilotonne

Term	Description
MBIE	Ministry of Business, Innovation and Employment
MfE	Ministry for the Environment
NLTF	National Land Transport Fund
MBIE	Ministry of Business, Innovation and Employment
MPI	Ministry for Primary Industries
Mt	megatonne
MW	megawatt
MWh	megawatt hour (= 1 000 KWh)
NDC	nationally determined contribution
NZAGRC	New Zealand Agricultural Greenhouse Research Centre
NZPC	New Zealand Productivity Commission
NZU	New Zealand Unit
NZVIF	New Zealand Venture Investment Fund
NZX	New Zealand Stock Exchange
N ₂ O	Nitrous oxide
OECD	Organisation for Economic Co-operation and Development
PCE	Parliamentary Commissioner for the Environment
PFC	Perfluorocarbon
R&D	research and development
RMA	Resource Management Act 1991
RSNZ	Royal Society of New Zealand
SF ₆	sulphur hexafluoride
TCFD	Task Force on Climate-related Financial Disclosures
TWh	terrawatt hour (= 1 000 GWh or 1m KWh)
WMA	Waste Minimisation Act 2008
WtE	waste-to-energy
WWTP	wastewater treatment plant

Overview

Climate change: A threat to wellbeing

The impacts of climate change threaten the wellbeing of all humanity. Global temperatures are already more than 1°C warmer than pre-Industrial Revolution levels (WMO, 2016). As warming increases, widespread impacts on human, economic and natural systems that are already occurring will worsen. Impacts include heatwaves and extreme rainfalls, more frequent droughts and cyclones, water scarcity, threats to food security, flooding caused by sea-level rise, ocean acidification, and extinction of species of flora and fauna. The damages expected from only a small rise in the global temperature are severe.

It is difficult to estimate accurately the economic costs of climate change, due to many uncertainties. Even so, broad estimates of the economic costs of escalating climate risks are daunting. Even at 2°C of warming, the Intergovernmental Panel on Climate Change (IPCC) estimates the annual economic cost at between 0.2% to 2% of global GDP, even if strong measures are taken to adapt to such change (IPCC, 2014). This could be an underestimate, given that climate change is likely to undermine the core economic assets that drive growth and productivity, particularly in infrastructure and natural and human capital (Dietz & Stern, 2015).

The effects of climate change are inextricably entwined with human health. The work of the 2015 Lancet Commission on Health and Climate Change concluded that anthropogenic climate change threatens to undermine the past 50 years of gains in public health, and, conversely, that a comprehensive response to climate change could be “the greatest global health opportunity of the 21st century” (Watts et al., 2018, p. 584).

Transitioning to a low-emissions economy

New Zealand is committed to be an active participant in the international response to the challenge of climate change (through the 2015 Paris Agreement), principally by making substantial reductions in its greenhouse gas (GHG) emissions. In 2017, the Government asked the Productivity Commission to “identify options for how New Zealand could reduce its domestic GHG through a transition to a lower emissions future, while at the same time continuing to grow incomes and wellbeing”. In 2018, Hon James Shaw, as the incoming Government’s Minister for Climate Change, signalled a more ambitious agenda and asked the Commission to include the target of achieving net-zero emissions by 2050 in its analysis.

The transition will mean that the New Zealand economy will look very different in 2050, and even more transformed by 2100. During the transition, action to mitigate GHG emissions will require real and significant changes impacting on households, businesses, industries, cities and regions. A shift from the old economy to a new, low-emissions economy will be profound and widespread, transforming land use, the energy system, production methods and technology, regulatory frameworks and institutions, and business and political culture. Of course, this transformation is a global phenomenon. It is one of the “mega-trends” that will reshape the global economy over the next several decades (OECD, 2016c; PwC, 2017).

Successful economies are adaptive in the face of change. A flexible and responsive economy can more readily and efficiently re-allocate productive resources from low-value firms to high-value firms and activities. Such an economy has low barriers to firms absorbing and benefiting from new technologies as they become available. Likewise, the education and skills systems are responsive to industry needs and opportunities. These overarching economic competencies will play key roles in determining the success of New Zealand’s transition to low emissions. Yet the Commission has previously found that, in general, the New Zealand economy is not as nimble and productive as it could be. This will need to change.

In the coming years, New Zealand’s governments (central and local), businesses and society will make a series of choices that will influence the structure of the economy and the cost of reducing GHG emissions. The broad purpose of the Commission’s inquiry is to recommend actions that current and future governments might take to reduce New Zealand’s emissions given the levers within their control, and recognising that some influential factors are outside their control. This report provides guidance on how and

where the country can best achieve emissions reductions in the most efficient way and the types of policies required to drive the transition. It explores the challenges, opportunities, benefits and costs of alternative transition pathways and makes specific policy recommendations.

Among the numerous changes – some disruptive some less obvious – that will be required across the economy, three particular shifts must happen for New Zealand to achieve its low-emissions goals:

- a transition from fossil fuels to electricity and other low-emission fuels across the economy;
- substantial afforestation; and
- changes to the structure and methods of agricultural production.

The transition from fossil fuels entails a rapid and comprehensive switch of the light vehicle fleet to electric vehicles (EVs) and other very low-emissions vehicles, and a switch away from fossil fuels in providing process heat for industry, particularly for low- and medium-temperature heat users.

Large-scale afforestation will be critical for offsetting New Zealand's remaining emissions. A planting rate similar to the highest ever recorded in New Zealand will likely need to be sustained over the next thirty years. Planting will mostly take place on land currently used for sheep and beef farming.

Other changes in the way land is used will also be necessary, such as an expansion in horticulture and cropping, and greater adoption of low-emission practices on farms.

New Zealand's role in tackling global climate change

New Zealand's GHG emissions are among the highest per person in the world. This is despite having an electricity system that is overwhelmingly powered by renewables. The explanation for such high per person emissions lies substantially with New Zealand's large agricultural sector, which accounts for nearly half of New Zealand's total emissions and which exports a very high proportion of its output. Yet the growth in New Zealand's emissions since 1990 is primarily a result of increased use of fossil fuels, particularly for road transport and industrial heat.

While per person emissions are high, New Zealand's total emissions make up less than 0.2% of global emissions. Actions in New Zealand will not make an appreciable difference to the global climate-change trend. This exemplifies the public policy challenge of climate change. It is a classic example of the "tragedy of the commons", in which individuals acting in their own interests damage resources belonging to the wider community. The "commons" in this case is a truly global resource – the shared atmosphere upon which life depends – and its limited ability to absorb GHG emissions without giving rise to climate disruptions. So, while it is small, New Zealand's size does not justify inaction – despite the incentives to free-ride. Indeed, quite the opposite. Around a quarter of global emissions come from small emitters (countries with emissions less than 1% of global total). Collectively, small emitters do matter and a global, concerted effort is needed.

Further, by achieving a successful transition to a low-emissions economy, New Zealand has an opportunity to influence others in pursuing a low emissions economy. That influence can help reduce the risk of other countries failing to pursue mitigation pathways because they either do not know how to, or do not think it can be done while continuing to grow incomes and wellbeing. Such influence is likely to be particularly relevant in areas where New Zealand has expertise and experience (eg, techniques for pastoral GHG mitigation) and by implementing innovative policy solutions (eg, to reduce biogenic methane (CH₄)). New Zealand's capacity to influence will be the greater if it can point to its own credible and substantial mitigation progress.

Overcoming myopia and managing uncertainty

The climate change problem

Climate change is a problem unlike any other, both because of its scale and because it is about the near and far future. The low-emissions transition has some unique characteristics that distinguish it from other

transitions that have come before, and which combine to create a problem for policy making (Levin et al., 2012).

- Time is running out. Unlike other issues, climate change is a “one-shot” problem with no luxury of “coming back” to the political system for a re-try. The problem “will, at some point, be too acute, have had too much impact, or be too late to reverse” (p.127).
- Everyday activities are major culprits – even people who choose to lower their emissions will still be causing some emissions of some kind.
- Decision makers in the public sector do not control all the choices required to reduce emissions. Further, even if a strong global agreement could be achieved, mechanisms and programmes are likely to operate simultaneously at a multitude of scales.
- Discounting climate change pushes responses to it into the future. There is a tendency to punt policy choices into the future because of near-term costs and a belief that some disincentives will reduce in the future (eg, cheaper technology or increased cost of inaction). Yet as the future approaches (when action was due to occur), the salience of the short-term costs returns, creating a vicious cycle.

Together, these elements combine to provide a unique challenge to public policymaking as political and governance institutions (and resulting policies) tend to give greater weight to immediate interests and delay change, even when doing so is clearly contrary to a country’s long-term interests. The Governor of the Bank of England, Mark Carney (2015), puts it this way, “climate change will be felt beyond the traditional horizons of most actors – imposing a cost on future generations that the current generation has no direct incentive to fix”.

So, an important theme in this inquiry is that the long-term perspective must be introduced into politics and policymaking, domestically and internationally. Added to the long horizon is deep uncertainty about many aspects of the future. The combination of these two features requires political commitments and durability that spans many generations. Without durable and ambitious policies now, the signals for firms and households to move their production and consumption towards less emissions-intensive options will be weak, at best. The challenge is therefore how best to design the political and governance architecture in a way that effectively signals future policy intentions and provides a commitment to such intentions.

Stable and credible settings for climate policy

Stable and credible settings for climate policy, starting now, must lie at the heart of a transition to a low-emissions economy. The private sector and civil society must be able to plan and make long-term decisions with confidence. Certainly, business participants in this inquiry were emphatic on the need for clear signals from government on future policy settings for climate change so as to provide the necessary certainty to invest in low-emissions technology and innovation.

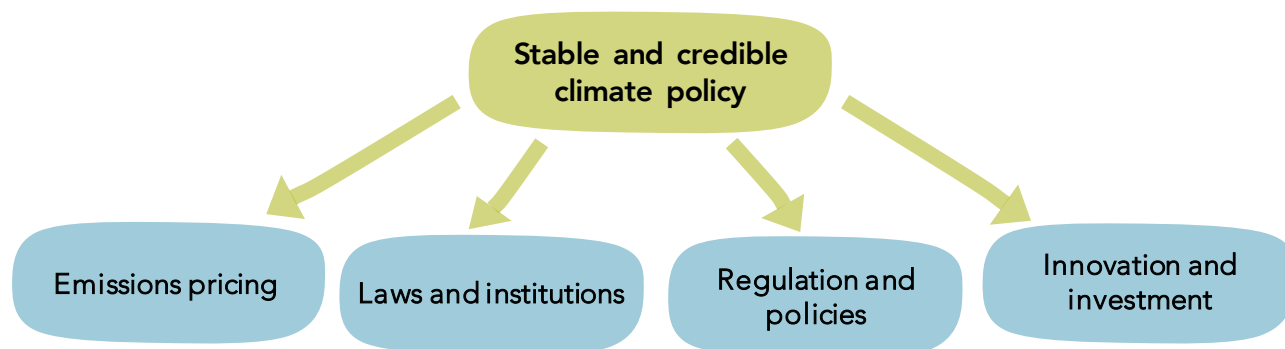
This report makes concrete proposals for a stable and credible policy environment and a set of actions to enable New Zealand to transition to a low-emissions economy. These proposals are that the Government should:

- send a strong signal that it is committed over the long term to the transition to a low-emissions economy and provide transparency about future policies to achieve this;
- enact laws and build institutions that underpin policy settings, with clear targets, transparency and accountability for action, and that act as a commitment device for future governments to continue developing and implementing long-term policies to combat climate change;
- use emissions pricing to send the right signals for investment, innovation and mitigation;
- harness the full potential of innovation by making it a priority and devoting significantly more public resources to low-emissions research, and to the deployment and adoption of low-emissions innovations;

- ensure other supportive regulations and policies are in place, to address non-price barriers, and accelerate the transition; and
- support investment in low-emissions technology, infrastructure, and other activities, through leadership and by mobilising new sources of finance.

Together, the above proposals will provide an enabling platform that will shape incentives on producers and consumers to reduce their emissions, make the right investments, and come up with new ideas.

Figure 0.1 Achieving a low-emissions economy



Getting emissions pricing right

An emissions price is the price an emitter pays for each unit of GHG they release to the atmosphere. With no price on their damaging effects, excessive GHG emissions are all but guaranteed. It is therefore important that people and firms both see and pay the full costs of their choices, and that their incentives are aligned with the social good.

Properly designed and implemented, emissions pricing is a powerful policy instrument to reduce emissions. Emissions pricing provides strong incentives to reduce emissions at least cost. It decentralises decisions to invest, innovate and consume across the economy to people who have the best information about opportunities to lower emissions given their circumstances. An emissions price is also pervasive through the whole economy – shaping resource and investment decisions across all emitting sectors and sources. Ensuring that emissions are appropriately priced is an essential step in New Zealand’s efforts to reduce its emissions.

Treating gases differently – A “two baskets” approach

GHGs have different atmospheric lifetimes. Some gases, such as carbon dioxide (CO₂), are long-lived. They accumulate in the atmosphere so any current emissions irreversibly warm the planet. Others, such as methane (CH₄), are short-lived so that the bulk of the warming effect of current emissions lasts for less than 20 years.

The relative proportion of a country’s short- to long-lived gas emissions has implications for its choice of mitigation targets, emission-reduction trajectories, and policy frameworks. In thinking about these choices, various factors such as the abatement costs of different GHGs, and the flexibility to adjust policy over time, must be considered.

The emissions profiles of most other developed countries are dominated by CO₂. As such, their focus is on mitigating long-lived gases. In comparison, New Zealand has a high proportion of short-lived gases (mainly biogenic CH₄ from livestock production). This distinctive emissions profile means that the question of the relative priority for mitigating short- and long-lived gases is of special interest.

New Zealand should establish separate long-term emissions-reduction targets for short- and long-lived gases, as well as separate emissions “budgets” for short- and long-lived gases. All long-lived gases should be included within the New Zealand Emissions Trading Scheme (NZ ETS). However, biogenic CH₄ from agriculture and waste would be better treated in a separate emissions-pricing scheme. This scheme, either a

dual-cap NZ ETS or an alternative methane quota system (MQS), will separately incentivise emissions reductions of biogenic CH₄ in recognition of its nature as a short-lived GHG.

This “two-baskets” approach provides an opportunity for a distinctively New Zealand solution to its emissions profile. It would align New Zealand’s mitigation policy more closely with the underlying science of warming, address the country’s distinctive emissions profile, and could become a world-leading policy exemplar.

The emissions price needs to rise

The emissions price created through the NZ ETS needs to rise considerably. Previous prices have been too low to make the scheme effective in changing firm and household behaviour. Just what level of pricing will be required cannot be known precisely. However, specialised modelling and other available evidence suggests that New Zealand’s emissions price will need to rise to levels of the order of \$75 a tonne of carbon dioxide equivalent (CO_{2e}) and possibly over \$200 a tonne over the next few decades to achieve the domestic emissions reductions needed to meet New Zealand’s international commitments. Robust and transparent domestic caps on the supply of New Zealand Units (NZUs) (one NZU is a permit to emit one tonne of CO_{2e}) are needed to drive a higher emissions price to materially influence production and consumption decisions.

Expectations about future emissions prices are important for driving investment in new technologies. To ensure clear and credible investment signals, the Government needs to set a clear, long-term emissions target and use emissions budgets as stepping stones to the target. In turn, the budgets need to translate to short-term quantity caps on emissions with clear guidance about the future supply of NZUs over the following five to ten years.

An efficient and effective trading market in NZUs is essential. Government will need to become a more active participant in the existing market when it begins to auction NZUs. This should be done through a new independent agency that operates within a clear government mandate and is responsible for market stability, transparency and forward guidance to support efficient decision making by market participants and others to lower their net emissions.

Stable and enduring laws and institutions

There are strong political incentives to avoid making long-term policy decisions that will have short-term cost and impacts, but benefits that manifest well into the future. Well-designed laws and institutions can play a critical role in providing a strong signal about future policy intentions and act as a “commitment device” to help drive the development and implementation of a long-term policy response to climate change.

New Zealand has an existing climate-change regulatory framework, but it is not underpinned by a credible commitment to a low-emissions transition. New Zealand needs a reformed statutory framework – one that will lock-in long-term thinking, encourage policy stability and provide the right signals, yet allow flexibility about the precise path to the long-term goal. Essentially ensuring an eye is kept on the long-term compass while letting the tiller be adjusted along the way. A new architecture for New Zealand’s climate change legislation should be built on principles of transparency and accountability, with a backbone based on mandatory processes. It should include the following mutually reinforcing elements:

- Legislated and quantified long-term GHG emissions reduction targets to clearly signal the policy destination. Targets should be informed by science. This is central to the credibility of the climate-change statutory and institutional framework. Mitigation targets should distinguish between short-lived and long-lived GHGs, recognising that GHGs have different atmospheric lifetimes and impact on warming.
- A system of successive “emissions budgets” that translate long-term targets into clear short to medium-term emissions reduction goals. Short- and long-lived gases should have separate emissions budgets. These budgets provide visible stepping stones to achieving the long-term targets and help reinforce steady action on, and accountability for, achieving them. The emissions budgets would also guide the

allowable quantity levels for both short- and long-lived gases in emissions pricing mechanisms (eg, the caps in the NZ ETS, or the total quota allocation in an MQS).

- An independent expert advisory body (a Climate Change Commission) to provide objective analysis and advice to the Government on the scale of emissions reductions required over the short to medium term (ie, by recommending emissions budgets) to meet long-term targets, reflecting scientific evidence as well as considerations of economic and social impacts. A Climate Change Commission, set up as an independent Crown entity, would help to insulate policymaking from short-term political pressures, promote stability and predictability, expand climate policy debate, and improve transparency and accountability. Decision-rights should not be delegated to the Climate Change Commission, but it would have a role in identifying regulatory and other barriers, or opportunities and priorities, to reduce emissions. It will also regularly assess New Zealand's progress towards meeting agreed budgets and targets. Effectively, a Climate Change Commission would be the custodian of New Zealand's climate policy and long-term, climate-change objectives.

Inquiry participants broadly endorsed these legislative and institutional arrangements. Ultimately though, laws and institutions will not endure unless underpinned by political consensus. Support across political parties is therefore vital; climate change is the ultimate intergenerational issue, and governments change. So, substantial cross-party support for the core elements of statutory and institutional arrangements will help provide policy permanence regardless of the make-up of the Government.

Developing the government response to the Climate Commission's recommendations to meet emissions budgets and targets will be a substantive and challenging policy process and will present major coordination issues. This will require a high level of coherence between overall policy and regulatory frameworks and low-emissions goals. A key obstacle to the effectiveness and acceptability of core climate policies is the number of regulatory and policy frameworks outside the climate policy portfolio that are not aligned with the low-emissions objectives. Identifying and addressing these misalignments systematically will enhance the responsiveness to the climate-change agenda. Ongoing leadership from the centre of government is critical, but it will need to be more than this. Achieving policy alignment across fragmented government machinery really means that every aspect of government policy will need to be framed with the low-emissions goal in sight.

Harnessing the full potential of innovation

Innovation comes in many forms and is unpredictable. Yet it is the closest thing to a "silver bullet" to enable humanity to meet the challenge of avoiding damaging climate change. It also holds out the opportunity to combine the transition to low emissions with dynamic and creative improvements in national wellbeing. While the form, timing and impact of innovation are highly uncertain, a country's policies and institutions significantly affect its innovation performance. They need to enable and encourage researchers and businesses to both create new low-emissions technologies and deploy existing low-emissions technologies.

The processes of innovation and economic change are strongly path-dependent. This can make it difficult to shift an economy from polluting to clean technologies. An early start in supporting innovative low-emissions technology will put it on a path to compete in productivity with existing high-emissions technology. This will speed the transition and lower its cost.

New Zealand's record as an innovative economy is mixed. Lacklustre productivity growth in the economy partly reflects low investment in research and development (R&D) for business and other issues in its innovation ecosystem, including a patchy record at commercialising research and skill shortages. Yet within this broad picture, pockets of successful innovation exist.

Transitioning to a low-emissions economy calls for directed technical change in New Zealand's energy and transport systems, land use, buildings and industrial processes. In many areas New Zealand will be a technology taker. This requires capacities and resourcing to identify, absorb, adapt and deploy technologies from offshore. Yet in certain areas, New Zealand should invest in the full menu of basic and applied research, commercialisation, infrastructure and skills.

Given the imperative to reduce emissions, the Government should devote significantly more resources to low-emissions innovation than the modest current allocation. Well-designed and implemented support for low-emissions innovation can have payoffs for New Zealand's wider economic performance and its capacity to influence international progress. The right climate policies are likely to trigger new waves of global investment, innovation, and discovery. If New Zealand designs its policies to foster learning and flexibility, then new opportunities will arise.

Mobilising capital toward low-emissions investment

Transitioning to a low-emissions economy requires a re-orientation of public and private investment away from emissions-intensive activities and towards those that support and catalyse low-emissions energy, land use and other activities. Sufficient capital is available to meet low-emissions goals, but it is fundamentally about redirecting that capital to investments consistent with the transition. Investors will be motivated to respond to the challenge of climate change where it offers a strategy to avoid risk, to pursue profit opportunities, and a means to achieve goals related to socially responsible investment.

Stable and credible climate policy, underpinned by enduring institutional arrangements such as effective emissions pricing, provides the basis for a well-functioning investment system. This will likely be enough to enable certain types of investment funding, such as green bonds or commercial equity, to occur. Yet additional barriers to low-emissions investments exist and require attention. These include information and inertia barriers, coordination failures, technology and market risks, and scale of investment barriers. These barriers can cause a disconnect between standard commercial decision making and the public interest in avoiding climate change.

Introducing mandatory climate-related financial disclosures would encourage investment that supports the transition to a low-emissions economy. These disclosures can help overcome information and inertia barriers that prevent entities from adequately addressing climate risk and capitalising on low-emissions opportunities. They can also help to stop investors valuing assets or investment opportunities incorrectly, resulting in misdirected finance or stranded assets. Other possible actions for Government include providing targeted grants and loans (which can play an important catalytic role in reducing market risk for the development and deployment of new low-emissions technologies), and implementing the proposed Green Investment Fund.

Emission sources and opportunities

While emissions pricing is needed to change behaviour and promote investment, it will not be sufficient to promote a fair and efficient transition, or to maximise New Zealand's opportunities from the transition. This is because of market or government failures, or because a market-only solution could involve unacceptable costs or distributional consequences. Complementary regulation and policies can help to create and deploy mitigation technologies, support behaviour change by firms and households, and manage risk. Such complementary measures can also lower the emissions price that would otherwise be needed. This inquiry traversed the sources of emissions in the New Zealand economy and found areas for complementary regulation and policies for achieving emissions reductions.

Land use

Land use will need to change substantially if New Zealand is to transition to a low-emissions economy. Modelling undertaken for the Commission suggests that land planted in forests over the next three decades will need to increase by between 1.3 million and 2.8 million hectares, mostly converted from marginally profitable beef and sheep farms. Growth in horticulture (from a relatively small base) could also play a meaningful role in reducing agricultural emissions. Overall, the needed rate of land-use change is comparable to the rate at which, over the last 30 years, beef and sheep farms have converted to forestry, dairying and other uses. However, the nature of change needed is quite different. In particular, the average rate of forest planting New Zealand needs to sustain over the next thirty years is comparable to its highest ever planting rate in a single year.

Reducing agricultural emissions, particularly from dairying, will also be important. Scope exists for further modest reductions in emissions intensity, through higher productivity and wider adoption of current low-emissions practices. Research into new technologies has the (uncertain) potential to further reduce agricultural emissions in the medium to long term. The potential payoff to successful research justifies scaling up current efforts.

Pricing emissions across all land uses, including agriculture, will drive more efficient decisions around how land is used. For instance, a well-designed and stable NZ ETS will incentivise land-use change, including more afforestation. Introducing agriculture to an emissions price will also incentivise the search for, and adoption of, low-emissions practices and technologies. As noted, the short-lived nature of biogenic methane calls for a separate pricing system (such as an MQS) that reflects this property, while long-lived nitrous oxide emissions should be included in the NZ ETS. To reflect the trade-exposed nature of the sector, current technological limits, and the challenges around measuring on-farm emissions, a pricing system involving agriculture emissions needs to be carefully designed.

The Government can best support the rural transition through stable policy, pricing emissions and supporting innovation, and making sure its investments in skills development, infrastructure and innovation are alert to the needs of emerging rural low-emissions industries. Transparency and advanced notice will provide clear signals while helping avoid significant economic and social dislocation in the transition to a low-emissions rural economy over the next three decades.

Transport

Transport is New Zealand's second largest source of GHG emissions, contributing nearly 20% of gross emissions (and about one third of long-lived GHG emissions). New Zealand's transport system is dominated by private road transport. Compared to other developed countries, vehicle ownership rates are high, public transport use is low, and the vehicle fleet is old with poor fuel economy. Rapid population growth and a decline in prices for fossil-fuel vehicles have caused the vehicle fleet to greatly expand. New Zealand's transport emissions have risen more than any other emissions source since 1990.

Adoption of EVs represents the most significant opportunity to reduce transport emissions in New Zealand. EV uptake is rising and costs will continue to fall, though price remains a key barrier as well as the limited travel range of current EV models. Fast uptake will be critical to achieve a low-emissions economy. For the bulk of light vehicles to be electric by 2050, nearly all vehicles entering the fleet would need to be EVs by the early 2030s. To encourage EV uptake, and catalyse the transformation to a low-emissions transport system, the Government should:

- introduce a "feebate" scheme, in which importers would either pay a fee or receive a rebate, depending on the emissions intensity of the imported vehicle;
- continue to provide funding for some EV infrastructure projects, to fill gaps in the charging network that are commercially unviable for the private sector;
- raise awareness and promote uptake of low-emissions vehicles through leadership in procurement; and
- require imported new and used fossil-fuel vehicles to meet fleet-wide emissions standards. New Zealand is one of a handful of developed countries without vehicle emissions standards, and risks becoming a dumping ground for high-emitting vehicles from other countries that are decarbonising their fleets.

Decarbonising heavy transport (such as trucks, planes and ships) is more challenging than for light vehicles. Large reductions will rely on further advances in technology. Some of the key mitigation opportunities are electrification and switching to drop-in biofuels. However, the most effective solution is not yet clear, and may involve a mix of fuel sources. The Government should pursue a mix of policies that provides even-handed support for these technologies.

Inadequate pricing of vehicle externalities (including emissions), and the tendency of the funding system for land transport to skew investments towards roading, stifles the potential for mode shifting and leads to excessively high vehicle travel and inefficient vehicle choices. Levelling the playing field for infrastructure

investments and more cost-reflective pricing of vehicle externalities (such as air pollution and congestion) would help to better support low-emissions modes of transport. The Government Policy Statement (GPS) on Transport needs to include a focus on reducing emissions.

Electricity

Electricity is another area where well-designed regulation will complement an emissions price. An efficient and well-functioning electricity system will play a central part in the transition to a low-emissions economy. New Zealand's largely decarbonised electricity sector is a major advantage. Yet considerable scope exists to further increase the supply of electricity from renewable sources, such as wind and solar (the cost of both have been falling rapidly) and geothermal (which still produces some emissions). The Government should review and amend national planning instruments under the Resource Management Act, to better facilitate the large expansion of renewable electricity generation required to electrify light transport and other parts of the economy.

Distributed electricity generation and the ability of some consumers to reduce their demand when electricity supply is short will also play an increasingly important part in reducing the need for fossil-fuelled generation. But additional steps will be needed to manage growing complexity and risks to system stability, and to ensure a level playing field for different types of technology and service providers. The regulatory framework governing the electricity market should be updated to allow consumers to both become more informed and have the potential to become active buyers and sellers of electricity.

The mix of monopoly and network-based contestable services is changing rapidly in electricity distribution networks. This is a highly complex area and is posing a challenge to the role of regulatory agencies (the Commerce Commission and the Electricity Authority) in promoting competition and innovation in the provision of network-based services. The Government should amend the statutory framework to maintain strong incentives for current and potential service providers to innovate for the benefit of consumers (and at the same time reduce emissions from electricity generation).

Waste

There are also opportunities to use regulation to reduce emissions from waste, which represents about 5% of New Zealand's GHG emissions. It is estimated that only around one-third of waste emissions are covered by existing waste-management or climate-change policies. A major issue is that waste emissions data is highly uncertain, particularly for emissions from unmanaged waste disposal (including on-farm disposals known as farm dumps). As a result, the ability to clearly identify or quantify opportunities to reduce emissions is limited.

Given what is known about waste emissions, higher prices (eg, under the waste-disposal levy) will be the most effective means to reduce emissions. These higher prices will help to reduce emissions in current landfills as well as incentivise a more transformative and innovative circular economy approach in New Zealand. To make the waste disposal levy more effective, it must be extended to all unmanaged, yet known and consented, facilities for disposing of solid waste, and the rate (especially for "active" waste) increased over time. Local government should also be supported (such as through consenting or bylaw processes) to encourage emissions reductions at the remaining unmanaged solid waste sites. Any inclusion of wastewater treatment plants into emissions pricing schemes should occur only after consideration of relevant recommendations from the Department of Internal Affairs' review of the three waters (drinking, storm and wastewaters).

Heat and industrial processes

Finally, industrial emissions (heat and industrial processes) account for around 15% of New Zealand's gross GHG. Rising emissions prices will be central to driving emissions-reducing investments in industrial heat plant. For many heat users, potential exists to materially reduce emissions through measures to reduce the energy requirements associated with a process, such as energy and process efficiency improvements. More substantive emissions reductions will require conversion to lower-emissions fuel sources. Electricity and biomass appear to be the two options with the widest applicability and potential to reduce emissions,

although the technical and commercial viability of low-emissions fuels varies case-by-case depending on factors such as geographic location and the nature of the heat required.

The Government should provide leadership through its procurement guidelines to limit the installation of any new fossil fuel-powered plant for low-temperature heat in publicly owned buildings. The mandate of the Energy Efficiency and Conservation Authority (EECA) should also be extended to focus on lowering GHG emissions and promoting low-emissions materials. As part of this, EECA should continue work to address any information and coordination barriers that are hindering the uptake of low-emissions fuels for heat.

Pathways to a low-emissions economy

Several pathways to a low-emissions economy are possible, and many factors, which cannot be predicted with any accuracy, could affect the rate and scale of change. This uncertainty calls for analysis to be undertaken across a range of plausible scenarios. These scenarios can be useful for informing policy decisions about priorities and trade-offs, and for gauging the implications of different rates and types of change in technology and other economic factors.

Modelling can throw light on whether an emissions target is feasible, the measures needed to achieve a target at least economic cost, the character of alternative pathways, and a quantitative picture of what needs to happen by when to reach a target. Yet modelling has well-known limitations and is not prediction. The transition to a low-emissions economy for any country will be a long journey to a known and desired destination, but through very uncertain terrain.

Three scenarios have been modelled for this inquiry. These vary in the extent and type of technology changes that reduce emissions, and the impact of those changes on the structure of the economy. The 'Policy Driven' scenario assumes that technologies are slow to develop and reductions in emissions must rely on strong policy such as high emissions prices. The 'Disruptive Decarbonisation' scenario assumes that technological change is fast, and it disrupts existing industries. The 'Stabilising Decarbonisation' scenario assumes that technological change is also fast, but it reduces emissions in existing industries.

The modelling suggests that New Zealand can move to a low-emissions economy (ie, 25 megatonnes of net CO₂e emissions by 2050) at an emissions price rising to between \$75 and \$150 a tonne of CO₂e by 2050 (Concept Consulting et al., 2018a). New Zealand could reach the more ambitious target of net-zero GHG emissions by 2050, with emissions prices rising to between \$150 and \$250 a tonne of CO₂e by 2050. While far above the current level of around \$24 a tonne of CO₂e, these prices are comparable with the emissions prices that it is estimated will be needed in other developed countries to deliver the objectives of the Paris Agreement to limit global temperature rise to under 2°C.

For either emissions target, the emission prices required are lower under conditions where technological development is fast and disrupts existing industries and economic structures (eg, uptake of EVs and synthetic protein). Higher prices are required when technological change is slow or when it simply reduces the emissions intensity of existing industries. The modelling also indicates that stronger government action in the near term can help to constrain future costs, irrespective of how technologies develop. Stronger near-term action also reduces potential risks of long-term targets becoming unattainable if technological progress is slow.

The modelled pathways reveal that reducing New Zealand's emissions at least cost will require three drivers: 1) a transition from fossil fuels to electricity and other low-emissions fuels across the economy, particularly in transport and process heat; 2) substantial afforestation on a scale not previously experienced in New Zealand; and 3) changes to the structure and methods of agricultural production. Emissions reductions in agriculture can come from both technological and structural change. For example, synthetic protein could disrupt traditional farming and, even in its absence, large shifts in land use could occur – mostly away from marginal beef and sheep farming toward forestry, and possibly from pastoral farming to horticulture.

The fact that there are three broad areas of the economy where lower emissions occur in response to a strong, single emissions price indicates that a portfolio of mitigation options is least cost. It is not the case

that the best mitigation opportunities lie in just one part of the economy. Diverse parts of the economy can and do need to make their contributions if New Zealand is to reach its ambitious targets.

Expanding forestry can achieve large reductions in net emissions up to 2050. Yet heavy reliance on forestry will create challenges in the longer term because it is not possible to expand without limit the land area under forest. With continued emissions reductions required after 2050 to achieve and maintain net-zero or negative emissions, New Zealand will need to find mitigation options for hard-to-reduce emissions sources. But it has time to consider options and seek new technological solutions.

A powerful insight from the modelling analysis is the potential value of early, strong action in the form of higher emissions prices in the period from now to 2030. This action can provide insurance against future events, offer protection against high-carbon investments that lock-in emissions for many years into the future; and stimulate valuable afforestation and low-emissions innovation.

Many benefits from the transition

Investment and job opportunities

While the momentum around the opportunities in a renewable economy is growing internationally, in New Zealand the emphasis has largely been on the costs to transition. Many estimates of the scale of expenditure necessary to drive a transition to a low-emissions economy are in the range of 1% to 3% of GDP a year (Stern, 2015). An important framing point is to think about the potential cost of transitioning to a low carbon economy as an investment, rather than as a net-cost on the economy and taxpayers. With all nations playing their part, the return in the form of avoiding damaging climate damage is substantial.

Much of the needed investment will come from the private sector. For example, the International Energy Agency (IEA) estimates that, globally, to have a 50-50 chance of limiting warming to 2°C, investments of US\$40 trillion to meet energy needs, and US\$35 trillion in energy efficiency, will be required by 2040 (IEA, 2016d). For New Zealand, it is clear that electrification across the economy, and specifically in transport and process heat, will be needed to achieve a low-emissions economy. The modelling undertaken for this inquiry finds that electricity generation will likely need to increase by between 45% and 65% by 2050. Modelling undertaken for Transpower predicts electricity demand will more than double by 2050 (Transpower, 2018). This additional demand will likely be met through a portfolio of renewable generation sources, including wind, geothermal and solar.

If New Zealand businesses are to the fore in tackling their emissions, investment opportunities will surely arise for them domestically and globally. Areas could include low-emissions technologies in electricity, transport, heating and cooling, industrial processes and agriculture.

A low-emissions economy has the potential to be a major source of jobs growth in the future, with many jobs yet to be defined. The International Labour Organisation (ILO), for example, says that taking action in the energy sector alone to limit global warming to 2°C by the end of century can create around 24 million new jobs by 2030, more than offsetting losses in traditional industries (ILO, 2018). Studies such as these suggest that the path towards environmental sustainability, including climate-change mitigation, is compatible with improvements in work. But the job-creating potential of transitioning to a low-emissions economy is not a given. The right policies are needed to allow workers to transition to new sectors – such as retraining and skills development – and social support for those that need it.

Significant co-benefits

There are significant co-benefits from investing in cutting GHG emissions, beyond reducing climate risk. These co-benefits include:

- Cleaner air, and reduced rates of illness and mortality caused by air pollution. Pollutants from fossil-fuel vehicles (particularly those that run on diesel) are associated with respiratory illnesses such as asthma, impaired lung development and function, heart and brain problems, and other general health issues. A shift to a low-emissions vehicle fleet would remove these pollutants.

- Cleaner water, and less harm to biodiversity. As an emissions price is progressively extended to agriculture, and farmers take greater steps to use nitrates effectively, water pollution will reduce. Greater afforestation could also help reduce soil erosion and the resulting siltation of waterways.
- Discovery and learning will see the emergence of new technologies and firms. These will provide opportunities for employment, exports and productivity gains. A higher emissions price will foster greater demand for emissions-reducing technologies. A reinvigorated and refocused innovation system will put more effort into developing and applying new ideas that offset, reduce or remove GHGs. New Zealand has already proved a fertile ground for developing such technologies, and scope exists to considerably expand New Zealand's contribution to global knowledge.

An inclusive transition

A well-paced transition should give firms and consumers predictability about the direction of change and the time not only to adjust but also to identify and take the opportunities that the transition offers. This will depend on well-established emissions targets and budgets, stable governance and free emissions allowances for emissions-intensive, trade-exposed businesses but with a measured phase out to ease the transition.

However, as with previous economic transformations, the shift to a low-emissions economy will create both opportunities and downsides. Some existing firms and jobs will disappear, while new business and occupations will emerge. Some workers will be especially vulnerable to changes in employment and should be given the opportunity to acquire new skills.

Risks can be minimised and opportunities maximised if government and private investments in innovation, skills and infrastructure are well coordinated and responsive to emerging opportunities. Building coalitions across central and local government, industry organisations and iwi will help share information and intentions. Regions will need to be alert to new opportunities but may need external help. Governments (central and local) can build support for the transition by promoting the co-benefits (such as improved water and air quality) and reducing the co-harms (such as waterways becoming clogged by forest debris) of reducing emissions. These actions will complement other initiatives such as emissions pricing and the regulation of emissions.

Some emissions-reducing policies are likely to increase the cost of some essential household goods and services, such as food, transport and energy. These items make up a larger share of expenditure for people on lower incomes. These individuals could suffer disproportionately in the transition. This burden can be eased through existing policies, such as the benefit and tax credit system. Other existing policies, such as targeted subsidies for household insulation, and regulatory interventions to raise the quality of rental housing, may also assist by allowing people to substitute away from higher-emitting forms of consumption (as well as creating other benefits, such as better health).

Where the impacts from climate change mitigation policies create significant 'shocks' to communities (eg, the loss of a major employer) interventions should focus on the employment and skills needs of individuals, and should be targeted to those who will have the most difficulty gaining new employment. Yet the Commission has previously found that the current education and training system is not well set up to meet the needs of people seeking mid-career retraining.

Meeting the challenge

New Zealand can achieve a successful low emissions economy, but there will be tough challenges. Delaying action will compound the transition challenge, making it more costly and disruptive, and limiting viable and cost-effective mitigation options in the future. If New Zealand fails to act, it risks being locked into a high-emissions economy and missing potential future economic opportunities.

While emissions pricing is a critical component of the low emissions strategy offered in this report, it is not sufficient to achieve the scale and pace of transition required. A portfolio of complementary mitigation

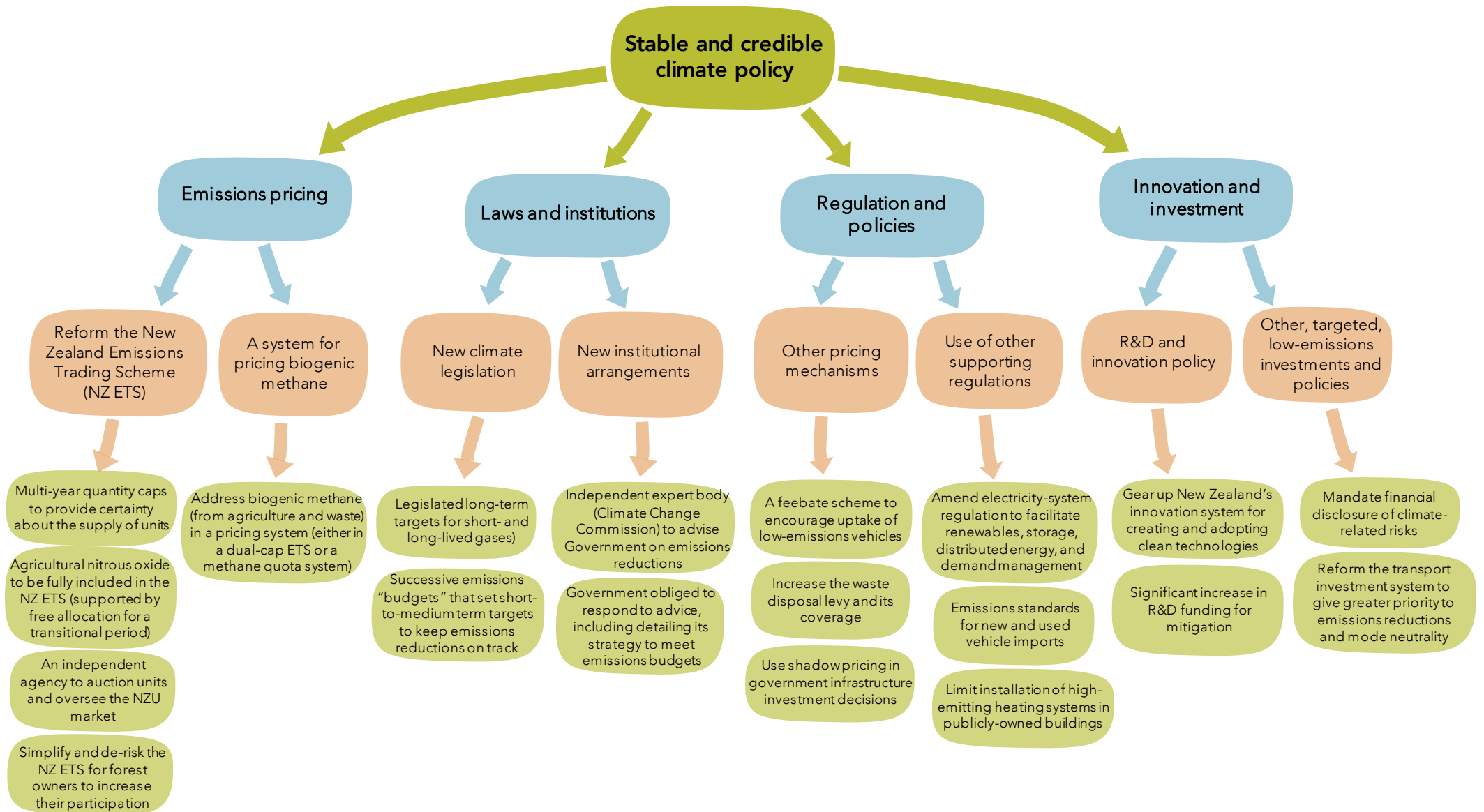
measures also is required to achieve the shifts in an economic system and ways of living that have high emissions deeply embedded within.

Transitions are fundamental shifts in economic structure, involving the cumulative effects of major changes in supply and demand. They are different to the normal processes of economic change where jobs and businesses are created and disappear every day. New Zealand has experienced economic and social transformations before, and the scale of change involved in the transition to a low-emissions economy looks comparable to some of those earlier transitions. This is a 30-year transition. Looking back in history, other examples of profound change occurred over similar timeframes. Moreover, these changes eventually enhanced community wellbeing despite, at first, appearing disruptive and threatening. That is not to deny there will be challenges and obstacles along the way. Transitioning to a low emissions economy is a major policy driven task of decoupling the economy from combusting fossil fuels and other high-emitting activities. This will require skilful government attention and commitment over many years.

A shift to a low-emissions trajectory will need strong and far-sighted political leadership. Existing policy frameworks and economic interests geared to emissions intensive assets and activities will resist change and encourage inertia. A significant part of the challenge will be communication and conveying the advantages and opportunities of transformational change to people and businesses.

To succeed and realise the potential benefits of the transition, careful policy design will be critical. This report sets out a policy architecture for New Zealand to transition to a low-emissions economy, while continuing to grow income and wellbeing (Figure 0.2). Of course, much uncertainty exists about what lies ahead, how a low-emissions economy will evolve, and what this will mean for New Zealand. An important task of Government is to be clear on New Zealand's ambition to achieve a low-or zero-emissions economy, providing a counter-weight to the path-dependence on current high emissions infrastructure, institutions and technology. Government needs to establish credible and stable policies and institutions so that businesses, households and consumers can plan, invest, and embrace the opportunities of a low-emissions future. There does not need to be a harsh trade-off between economic prosperity and a healthy and sustainable environment. Rather, success requires that they go together.

Figure 0.2 Achieving a low-emissions economy



Part One:

Setting the scene

The Government has asked the Productivity Commission to provide advice on how New Zealand should transition to a low-emissions economy.

Part One sets out how the Commission is approaching this task, and provides a guide for reading the rest of this report. It also provides important context for New Zealand's low-emissions transition, including explaining the global challenge of tackling climate change, identifying New Zealand's key emitting sources and trends, and outlining New Zealand's commitments to reducing emissions.

1 About this inquiry

Key points

- New Zealand is committed to be an active participant in the international response to the challenge of climate change (through the 2015 Paris Agreement) principally by making substantial reductions in its greenhouse gas (GHG) emissions.
- In 2017, the Government asked the Productivity Commission to “identify options for how New Zealand could reduce its domestic GHG emissions through a transition to a lower emissions future, while at the same time continuing to grow incomes and wellbeing”. In 2018, Hon James Shaw, as the incoming Government’s Minister for Climate Change, signalled a more ambitious agenda and asked the Commission to include the target of achieving net-zero emissions by 2050 in its analysis.
- Transitioning to a low-emissions economy requires effort on two fronts: a fundamental reduction in high-emissions sources and improving the emissions efficiency in production and consumption. This report provides insights into how and where emission reductions can be achieved and policies that will be required to drive the transition. It identifies the challenges, opportunities, benefits and costs of alternative transition pathways.
- At the heart of a transition to a low-emissions economy is the need for stable and credible climate policy settings. The private sector and civil society must be able to plan and take long-term decisions with confidence. Businesses, households and consumers will be better able to manage the risks of moving to a low-emissions economy and plan for the behavioural and structural changes required in a stable and credible policy environment.
- This report makes concrete proposals for a stable and credible policy environment and a set of actions to enable New Zealand to transition to a low emissions economy. These proposals are that the Government should:
 - send a strong signal that it is committed long-term to the transition to a low-emissions economy and provide transparency about future policies to achieve this;
 - enact laws and build institutions that underpin policy settings, with clear targets, transparency and accountability for action, and that act as a commitment device for future governments to continue the development and implementation of a long-term policies to combat climate change;
 - use emissions pricing to send the right signals for investment, innovation and mitigation;
 - harness the full potential of innovation by making it a priority and devoting significantly more public resources to low-emissions research, and to the deployment and adoption of low-emissions innovations;
 - ensure other supportive regulations and policies are in place, to address non-price barriers and accelerate the transition; and
 - support investment in low-emissions technology, infrastructure, and other activities, through leadership and by mobilising new sources of finance.
- Together, these steps will provide an enabling platform that will shape incentives on producers and consumers to reduce their emissions, make the right investments, and come up with new ideas.

1.1 Climate change: A threat to wellbeing

The impacts of climate change threaten the wellbeing of all humanity. Global temperatures are already more than 1°C warmer than pre-Industrial Revolution levels (WMO, 2016). As warming increases, widespread impacts on human, economic and natural systems that are already occurring will worsen. Impacts include heatwaves and extreme rainfalls, more frequent droughts and cyclones, water scarcity, threats to food security, flooding caused by sea-level rise, ocean acidification, and extinction of species of flora and fauna. The damages expected from only a small rise in the global temperature are severe.

It is difficult to estimate accurately the economic costs of climate change, due to many uncertainties. Even so, broad estimates of the economic costs of escalating climate risks are daunting. Even at 2°C of warming, the Intergovernmental Panel on Climate Change (IPCC) estimates the annual economic cost at between 0.2% to 2% of global GDP, even if strong measures are taken to adapt to such change (IPCC, 2014). This could be an underestimate, given that climate change is likely to undermine the core economic assets that drive growth and productivity, particularly in infrastructure and natural and human capital (Dietz & Stern, 2015).

The effects of climate change are inextricably entwined with human health. The work of the 2015 Lancet Commission on Health and Climate Change concluded that anthropogenic climate change threatens to undermine the past 50 years of gains in public health, and, conversely, that a comprehensive response to climate change could be “the greatest global health opportunity of the 21st century” (Watts et al., 2018, p. 584).

1.2 What we have been asked to do

New Zealand is committed to be an active participant in the international response to the challenge of climate change (through the 2015 Paris Agreement) principally by making substantial reductions in its greenhouse gas (GHG) emissions. In 2017, the Government asked the Productivity Commission to “identify options for how New Zealand could reduce its domestic greenhouse gas emissions through a transition to a lower emissions future, while at the same time continuing to grow incomes and wellbeing”. In 2018, Hon James Shaw, as the incoming Government’s Minister for Climate Change, signalled a more ambitious agenda and asked the Commission to include the target of achieving net-zero emissions by 2050 in its analysis.

Two broad questions guide this inquiry:

- What opportunities exist for the New Zealand economy to maximise the benefits and minimise the cost of transitioning to a lower net-emissions economy, while continuing to grow incomes and wellbeing?
- How can New Zealand’s regulatory, technological, financial and institutional systems, processes and practices help realise the benefits and minimise the costs and risks of a transition to a lower net-emissions economy?

1.3 The Commission’s approach

Transitioning to a low-emissions future requires effort on two fronts: a fundamental reduction in high-emissions sources and, at the same time, improving the emissions efficiency in production and consumption. This report aims to provide policy decision-makers insights to how and where emission reductions can be achieved, the emissions-pricing and other regulatory policies that will be required to bring about the transition, and the challenges, opportunities, benefits and costs of alternative pathways.

Future action on climate change is subject to uncertainty; it is both reasonable and appropriate for New Zealand to adapt its policies in response to changed circumstances and a changing evidence base over time, and to take steps to avoid adverse outcomes. Different transition pathways for the economy have been modelled along with different low-emission targets. The modelling for this inquiry provides some insight into how different decisions are likely to impact important outcomes related to wellbeing, such as economic activity, land use and GHG emissions, under uncertain future states of the world.

In the coming years, a range of choices will be made by the New Zealand government, businesses and society that will influence the structure of the economy and the cost of reducing GHG emissions. The broad purpose of this inquiry is to recommend the actions the government might take to reduce New Zealand's emissions given the range of choices in its control, recognising that some of the factors that will influence the desirability of those choices are beyond its control.

Importantly, the Government has asked the Commission to look at actions that will maximise the benefits and minimise the cost of the transition, while continuing to grow incomes and wellbeing. Wellbeing is a very broad concept that encompasses a range of dimensions, including current quality of life and material conditions as well as sustaining the resources needed for future wellbeing (OECD, 2017b).

At the core of sustaining future well-being are four types of "capital" – natural, human, economic and social (OECD, 2017b). Mitigating climate change is, of course, central to preserving natural capital for future generations. Taking opportunities to maintain and build all these types of capital in the transition will contribute to future quality of life and material wellbeing. Innovation will be central, by finding ways to reduce emissions at low cost, while providing a means to develop new enterprises and ways of living that are consistent with a low-emissions economy. Re-skilling will build the human capital needed; actions to reduce emissions will have other environmental benefits (such as improved water and air quality). Developing formal and informal institutions and organisations to set common goals and gain commitment will build social capital. Making sure the costs and benefits of the transition are understood and shared fairly, and that they unfold in a measured way, will also contribute to social capital.

The climate change problem

Climate change is a problem unlike any other, both because of its scale and because it is about the near and far future. The low-emissions transition has some unique characteristics that distinguish it from other transitions that have come before, and which combine to create a problem for policy making (Levin et al., 2012).

- Time is running out. Unlike other issues, climate change is a "one-shot" problem with no luxury of "coming back" to the political system for a re-try. The problem "will, at some point, be too acute, have had too much impact, or be too late to reverse" (p.127).
- Everyday activities are major culprits – even people who choose to lower their emissions will still be causing some emissions of some kind.
- Decision makers in the public sector do not control all the choices required to reduce emissions. Further, even if a strong global agreement could be achieved, mechanisms and programmes are likely to operate simultaneously at a multitude of scales.
- Discounting climate change pushes responses to it into the future. There is a tendency to punt policy choices into the future because of near-term costs and a belief that some disincentives will reduce in the future (eg, cheaper technology or increased cost of inaction). Yet as the future approaches (when action was due to occur), the salience of the short-term costs returns, creating a vicious cycle

Together, these elements combine to provide a unique challenge to public policy making as there is the tendency for political and governance institutions (and resulting policies) to give greater weight to immediate interests and delay change, even when doing so is clearly contrary to our long-term interests. An important theme in this inquiry is that the long-term perspective must be introduced into politics and policy-making, domestically and internationally. The deep uncertainty about many aspects of the future requires political commitments and durability that spans many generations. The challenge is therefore how the political and governance architecture can be designed in a way that effectively signals future policy intentions and provides a commitment to such intentions.

Stable and credible climate policy settings

At the heart of a transition to a low-emissions economy is the need for stable and credible climate policy settings. The private sector and civil society must be able to plan and take long-term decisions with confidence. Businesses, households and consumers will be better able to manage the risks of moving to a

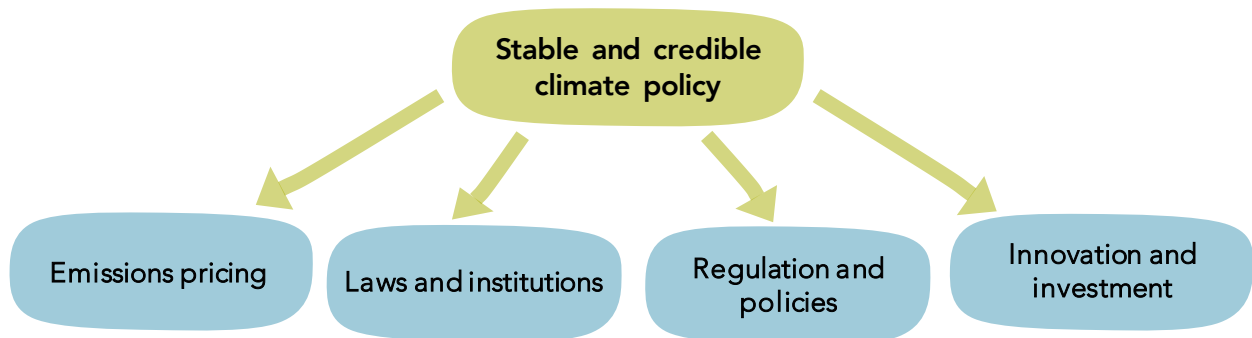
low-emissions economy and plan for the behavioural and structural changes required in a stable and credible policy environment. From a business perspective, there is considerable evidence that environmental policy uncertainty has negative effects at both firm level (lower investment and hiring) and economy wide level (loss of GDP, unemployment) (Zenghelis, 2016).

This report makes concrete proposals for a stable and credible policy environment and a set of actions to enable New Zealand to transition to a low emissions economy. These proposals are that the Government should:

- send a strong signal that it is committed long-term to the transition to a low-emissions economy and provide transparency about future policies to achieve this;
- enact laws and build institutions that underpin policy settings, with clear targets, transparency and accountability for action, and that act as a commitment device for future governments to continue the development and implementation of a long-term policies to combat climate change;
- use emissions pricing to send the right signals for investment, innovation and mitigation;
- harness the full potential of innovation by making it a priority and devoting significantly more public resources to low-emissions research, and to the deployment and adoption of low-emissions innovations;
- ensure other supportive regulations and policies are in place, to address non-price barriers and accelerate the transition; and
- support investment in low-emissions technology, infrastructure, and other activities, through leadership and by mobilising new sources of finance.

Together, these steps will provide an enabling platform that will shape incentives on producers and consumers to reduce their emissions, make the right investments, and come up with new ideas.

Figure 1-1 Achieving a low-emissions economy



The Commission's approach to this inquiry is to take the above cross-cutting themes and examine opportunities across the various emitting sources and sectors to transition to a low-emissions economy; specifically, the opportunities regarding land use, transport, electricity, heat and industrial processes, waste and the built environment.

The opportunities to lower emissions need to be considered within the wider policy and institutional framework because:

- each technology or production process has unique characteristics, requiring the right mix of institutions and policies;
- some technologies and processes may offer greater opportunities for cost-effective reductions in emissions than others – so policies need to provide incentives for businesses, households, and consumers to find these opportunities; and
- actions to reduce emissions may also involve a variety of co-benefits or costs.

Action to lower emissions also needs to operate within several complex and interacting systems. These include the domestic and global economies, the physical environment, and social systems shaped by beliefs, social norms and values. Adding to this complexity is uncertainty about future technological change. The choice of options to lower emissions will need to take account of this uncertainty, using data on emerging developments and analysis to feed back into ongoing policy design and implementation.

The Commission's approach to identifying opportunities to transition to a low-emissions economy recognises that GHGs have different atmospheric lifetimes. Some are long-lived and accumulate in the atmosphere, such as carbon dioxide which is the dominant driver of temperature. Others are short-lived such as methane, and only influence temperature in relation to their flows in and out of the atmosphere. The relative proportion of short- to long-lived gases has implications for countries' transitions, including the make-up of mitigation targets and policy frameworks. This issue is examined in detail in Chapter 9.

1.4 The scope of the inquiry

The science of climate change

The inquiry does not focus on the science of anthropogenic climate change (change that is caused by humans): the science is broadly given. New Zealand's international commitments reflect the acceptance by successive Governments of the need to join international efforts to reduce GHG emissions.

New Zealand's commitments to emissions reductions

Under the Paris Agreement, New Zealand has committed to reduce its emissions to 30% below 2005 levels by 2030, and under the Climate Change Response Act 2002 it has committed to reduce its emissions by 50% below 1990 levels by 2050 (Chapter 2). The Paris Agreement commits all countries, including New Zealand, to achieve a net-zero emissions economy in the second half of this century.²

Since receiving the Terms of Reference (TOR) the Government has changed. The new Government has not yet formulated a net emissions target for 2050 and beyond. However, it has publicly signalled its intention to take decisive action on climate change and set a more ambitious target for emissions reduction by 2050. While not yet legislated, the Government has announced intentions of setting a net-zero emissions target by 2050 (Office of the Minister for Climate Change, 2017). This intention has been reiterated to the Commission in a letter from the new Minister for Climate Change.³

While the TOR exclude an exploration of the suitability of New Zealand's current or any future emissions reduction target, in modelling commissioned for this inquiry the Commission investigated both a low (25 megatonnes of carbon dioxide equivalent) and net-zero GHG emissions target by 2050 (Chapter 3).

International trading in carbon credits

For a period, New Zealand was able to acquire specified emissions reduction credits generated in other countries to meet its international commitments. Yet New Zealand closed the New Zealand Emissions Trading Scheme to international emissions units in 2015.

A viable and credible international carbon-trading arrangement might emerge in the future that is suitable for helping New Zealand meet its future international GHG emissions commitments. Yet the TOR requests the Commission to look at options to reduce New Zealand's "domestic" GHG emissions. While the possibility of international trading is relevant to how institutions and policies to reduce emissions are designed in New Zealand, the primary focus of this inquiry is on transitioning to a low-emissions economy through reducing domestic emissions.

Adaptation to climate change

The TOR requires that the Commission "should only consider the implications of a changing climate to inform consideration of different economic pathways along which the New Zealand economy could grow and develop" (TOR, p. 4). As a result, the Commission has not, in general, considered adaptation to climate

² Net-zero emissions occurs when the amount of GHG emitted into the atmosphere is equal to the amount sequestered or offset (eg, by forestry).

³ Letter to Chair of Productivity Commission, Murray Sherwin, dated 22 December 2017 (see the front of this report).

change during the inquiry. However, it has been important to be aware of climate change effects on the future economy, for example as regards to sources of energy or the suitability of land for different uses.

1.5 Guide to this report

This draft report is structured as follows:

Chapter	Description
Part 1: Setting the scene	
Chapter 1	<i>About this inquiry</i> – outlines what the Commission has been asked to do, the approach to the inquiry and its scope.
Chapter 2	<i>Climate change, emissions and the New Zealand context</i> – provides important context for New Zealand’s low-emissions transition, including explaining the global challenge of tackling climate change, identifying New Zealand’s key emitting sources and trends, and outlining New Zealand’s commitments to mitigating emissions.
Part 2: Low-emission pathways	
Chapter 3	<i>Mitigation pathways</i> – reports the findings of the modelling the Commission undertook for the inquiry. It examines pathways for New Zealand to transition from the present to two low-emissions targets in 2050. The modelling throws light on the feasibility of the targets, emissions prices needed to achieve them, and the opportunities and risks of alternative pathways, including under uncertainty.
Chapter 4	<i>Transitions</i> – discusses the nature of the low-emissions transition and, using examples from history and from different parts of the New Zealand economy, aims to illustrate the likely changes occurring to 2050 and how policy can respond.
Part 3: Policies and institutions	
Chapter 5	<i>Emissions pricing</i> – examines emissions pricing as a crucial policy lever to incentivise businesses and individuals to make decisions that lower their GHG emissions, and recommends reforms to the New Zealand Emissions Trading Scheme.
Chapter 6	<i>Innovation</i> – examines how and why innovation should play a central role in New Zealand’s transition to a low-emissions economy. It assesses New Zealand’s current support for low-emissions innovation and the need to strengthen and prioritise this support.
Chapter 7	<i>Investment</i> – investigates the capital available for New Zealand’s transition to a low-emissions economy and explores policies and funding options available to Government.
Chapter 8	<i>Law and institutions</i> – examines the role of laws and institutions in supporting a low-emissions transition and recommends reforms to New Zealand’s statutory and institutional architecture.
Chapter 9	<i>Short-lived and long-lived gases</i> – explores the different atmospheric lifetimes of GHGs and explains why different scales of emissions reductions are needed between short- and long-lived gases to limit peak warming to well below 2°C. It recommends treating short- and long-lived gases separately in the New Zealand context.
Chapter 10	<i>An inclusive transition</i> – examines how government and private investments can respond flexibly to the opportunities that will arise in the transition to a low-emissions economy; and how social support for the transition can build on interest in the co-benefits and avoiding the co-harms of mitigation policies. It also looks at policies to address the disproportionate impact of climate-related policies on lower-income households.
Part 4: Emissions sources and opportunities	
Chapter 11	<i>Land use</i> – investigates the changes in land use (particularly large-scale afforestation) and the reductions in agricultural emissions (through better farm management and new technology) needed to reach New Zealand’s emissions reduction targets.

Chapter	Description
Chapter 12	<i>Transport</i> – explores the significant role that transport can play in achieving large emissions reductions (and valuable co-benefits), in particular through the adoption of low-emission vehicles, reducing the emissions of fossil-fuel vehicles, and shifting to lower-emissions modes of transport.
Chapter 13	<i>Electricity</i> – shows how electricity emissions can be substantially reduced over the next thirty years while electricity supports emissions reductions in other parts of the economy.
Chapter 14	<i>Heat and industrial processes</i> – examines options and opportunities to reduce emissions in process heat and industrial processes (such as the production of aluminium, iron, steel and cement). It also considers the potential of carbon capture and storage (CCS) and the suitability of current legislative frameworks for governing CCS activities.
Chapter 15	<i>Waste</i> – reviews mitigation opportunities for emissions from waste.
Chapter 16	<i>The built environment</i> – examines the potential for reducing emissions within the built environment, specifically buildings, urban areas, and infrastructure.
Part 5: Achieving a low-emissions economy	
Chapter 17	<i>Achieving a low-emissions economy</i> – brings together the Commission’s main findings regarding opportunities and challenges New Zealand faces in transiting to a low emissions economy. The essential actions the Government must take immediately are identified.

2 Climate change, emissions and the New Zealand context

Key points

- The international scientific community has firmly concluded that human-induced greenhouse gas (GHG) emissions are causing global temperatures to rise. Temperature rise has widespread impacts on human and natural systems. The most relevant impacts for New Zealand are sea-level rise, a warmer climate, ocean acidification, and more frequent extreme weather events, such as droughts and cyclones.
- It is possible to limit the severity of future impacts by achieving a substantial and sustained reduction in global emissions. The 195 signatories to the Paris Agreement, including New Zealand, are committed to achieving net-zero global GHG emissions in the second half of this century. The central aim of the Agreement is to limit temperature rise to well below 2°C, with an aspirational target of 1.5°C.
- New Zealand contributes about 0.2% of global emissions, but its emissions per person are high. New Zealand is yet to see a decline in its emissions. Gross and net emissions have flattened over the last decade after steadily increasing before the mid-2000s. Historically, population and economic growth have been key underlying drivers of growing emissions.
- New Zealand's emissions profile differs markedly from other developed countries. Nearly half of emissions are methane and nitrous oxide from agriculture. Transport is the second biggest emissions source, and its emissions have risen more than other sources. Emissions from electricity generation are relatively small due to New Zealand's abundant sources of renewable energy.
- Forestry offsets cover about a third of New Zealand's gross emissions. This is a high proportion by international standards. However, due to a decline in planting since the forestry boom in the mid-1990s, carbon offsets from forestry have been falling and are likely to fall further without a significant increase in planting.
- Meeting New Zealand's first commitment under the Paris Agreement for the period between 2021 and 2030 will be highly challenging, even with immediate and strong action to reduce domestic emissions. New Zealand can invest in international offsets to help meet its commitment, although no formal mechanism is currently in place for acquiring these offsets. Further, any delay in making reductions in domestic emissions will make future commitments even more difficult to achieve.
- The Government plans to replace New Zealand's current long-term (2050) target of a 50% reduction in emissions (compared to 1990 levels) with a more ambitious target that is set in law. To achieve either the current 2050 target or a more ambitious one, New Zealand will need a substantial and sustained shift in the trajectory of its emissions compared to past trends.
- The Climate Change Response Act 2011 provides the main legal framework for New Zealand's climate change mitigation response. In particular, it provides the statutory basis for the New Zealand Emissions Trading Scheme (NZ ETS), the central policy tool for reducing emissions. It also recognises the right of Māori to be consulted on ministerial decisions related to climate change.
- In addition to the NZ ETS, a range of complementary measures led by central government are in place to encourage emissions reductions.

This chapter provides context for New Zealand's transition to a low-emissions economy. It:

- explains key concepts around climate change and greenhouse gas (GHG) emissions;
- describes the Paris Agreement – the global climate change treaty which New Zealand is party to;
- analyses New Zealand's contribution to global emissions, how its emissions have changed over recent decades and the key drivers of these changes;
- outlines New Zealand's current international emission reduction commitments, including the approach used to account for emissions, and New Zealand's progress towards achieving its mitigation targets;
- discusses New Zealand's long-term commitments for reducing emissions; and
- provides a brief overview of New Zealand's current climate change governance arrangements and mitigation policies.

2.1 The impact of greenhouse gas emissions on the climate

GHG emissions caused by human activity impact global temperatures (Box 2.1). The Intergovernmental Panel on Climate Change (IPCC) concludes:

Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever ... Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century. (IPCC, 2014a, p. 4)

Increases in global temperature are causing, and will continue to cause, widespread impacts on humans and natural systems. Due to the large volume of GHGs already released into the atmosphere, some amount of climate change is now unavoidable. However, allowing global average temperatures to rise much more than 1.5°C (compared to pre-industrial levels) risks more serious and irreversible impacts (IPCC, 2014a; Maslin, 2009). Such global impacts include an increase in heatwaves and extreme rainfalls, water scarcity, threats to food security, flooding caused by sea-level rise, and extinction of more species of flora and fauna. The magnitude of change expected from only a small rise in the global temperature is substantial.

New Zealand is not immune to these impacts. Since the early 1900s, New Zealand's average temperature has already increased by 1°C. While the detail of future climate change is uncertain and depends on global mitigation efforts, New Zealand can expect sea-level rise, a warmer climate, ocean acidification, and more frequent extreme weather events such as droughts and cyclones (Meduna, 2015; MfE & Stats NZ, 2017).

These impacts will likely have damaging and pervasive long-term consequences for New Zealand's people and the natural environment (MfE & Stats NZ, 2017). For instance, rising sea levels will increase the risk of erosion and inundation on New Zealand's coastlines. Warmer temperatures favour conditions for the spread of diseases and pests and affect the habitats of many species of New Zealand's flora and fauna, increasing the risk of their extinction. Ocean acidification also threatens many marine species, while more frequent droughts and cyclones will increase flooding and disruption for households and economic production.

Box 2.1 Greenhouse gas emissions

GHGs trap heat in the earth's atmosphere – a process known as the greenhouse effect. The different types of GHGs include, for example, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆). These gases form a blanket above the earth's surface and prevent the sun's infrared radiation from escaping into outer space. GHGs play an important role in keeping the temperature of the earth's surface sufficiently warm to support human life.

However, the rapid increase in the rate of human-induced GHG emissions is strengthening the greenhouse effect. Many different types of human activity result in GHG emissions, such as using fossil

fuels for transport and generating energy, deforestation, and farming. Well over half of global GHG emissions are CO₂ emissions.

While human activity increases the stock of CO₂ in the atmosphere, some natural processes remove CO₂ from the atmosphere. This process is known as carbon sequestration, and the reservoir where CO₂ is stored is called a carbon sink. Trees are excellent carbon sinks. They sequester CO₂ as they grow and store it through the process of photosynthesis. However, once a tree stops growing, it absorbs no more CO₂ than it releases.

The length of time that GHGs spend in the atmosphere and the warming impact of GHGs vary. Short-lived gases, such as CH₄, dissipate relatively soon after being released, but can have a large warming effect while present in the atmosphere. By comparison, long-lived gases, such as CO₂, persist in the atmosphere over much longer timescales. For these gases, what matters most for warming is the stock of cumulative emissions stored in the atmosphere over time (Chapter 9).

To enable adding up of emissions of different GHGs, emissions are typically measured in units of carbon dioxide equivalent (CO₂e). The standard metric used in international agreements is Global Warming Potential (GWP₁₀₀). This measures the amount of warming that a GHG causes over 100 years after being released, compared with the amount of warming caused by CO₂.

Source: Allen (2015); IPCC (2014a); Stips et al. (2016); Vivid Economics (2017b).

2.2 The global challenge of reducing emissions

Substantial and sustained reductions in global GHG emissions are required to limit rises in global temperatures and the harmful impacts of climate change. To have a likely chance of limiting the rise in global average temperatures to 2°C this century, scenarios modelled by the IPCC indicate that global anthropogenic GHG emissions need to reduce by between 40% and 70% by 2050, and to near zero or below by 2100. Few IPCC scenarios show a likely chance of limiting rise to 1.5°C, although results suggest a global reduction in emissions of between 70% and 95% by 2050 is needed to achieve this end (IPCC, 2014a).

Reducing CO₂ emissions to net-zero levels is crucial

Because CO₂ can stay in the atmosphere for hundreds of thousands of years, reducing CO₂ emissions to net zero levels – where removals of CO₂ by carbon sinks offset CO₂ emissions – is a crucial part of stabilising global temperatures (Allen, 2015). As long as the world continues to emit more CO₂ than is absorbed and the stock of CO₂ continues to rise, the climate will keep warming (World Bank, 2015).

Further, the world has a finite amount of CO₂ that it can emit to keep global temperature rise below 2°C (and 1.5°C), widely known as the global carbon budget. This budget is being used up rapidly. The IPCC (2014a) estimates the global carbon budget, as at 2011 for a 2°C threshold, is about 1 000 gigatonnes (Gt) of CO₂. If global CO₂ emissions continue to rise at current rates, this budget will be used up by around 2036 (Chapter 9). In the event that this budget is exceeded, technologies to remove GHGs from the atmosphere (in addition to forest sinks, described in Box 2.1) would be needed to sufficiently limit warming.

The Paris Agreement

Since 2015, 195 parties, including New Zealand, have signed the Paris Agreement, committing to the goal of net-zero emissions globally in the second half of this century (Box 2.2).

Box 2.2 The Paris Agreement

The central aim of the Paris Agreement is to keep global average temperature rise this century well below 2°C above pre-industrial levels, and to pursue efforts to limit temperature increase to 1.5°C. The Agreement entered into force in November 2016.⁴

To achieve these temperature outcomes, the Agreement aims to peak global emissions as soon as possible, and to later undertake rapid reductions to reach net-zero emissions in the second half of this century. Net-zero emissions means balancing the amount of GHGs emitted into the atmosphere with the amount of GHGs removed from the atmosphere by sinks (eg, forests).

Under the Agreement, each government must communicate their Nationally Determined Contribution (NDC) every five years. Each NDC outlines a country's chosen ambition for emissions reductions, taking into account its domestic circumstances and capability. These commitments are voluntary. However, failing to comply with these commitments puts a country at risk of being "named and shamed" by the international community, and suffering reputational damage.

Emissions reductions pledged so far in NDCs cover roughly only a third of reductions needed to achieve the 2°C target. Countries are expected to set increasingly ambitious emission reduction targets. Article 4 of the Agreement requires developed countries like New Zealand to take the lead in pursuing economy-wide emissions reductions. The Agreement also encourages countries to prepare a long-term development strategy by 2020, which sets out its policy approach to transitioning to a low-emissions economy.

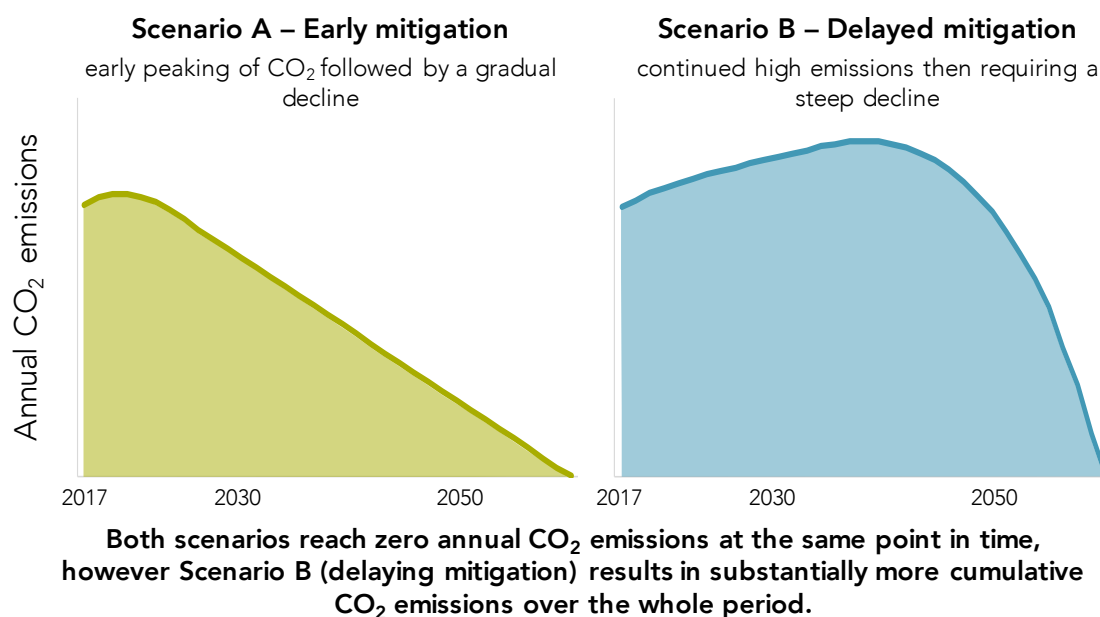
Source: UNEP (2017a); UNFCCC (2018b).

Delaying mitigation is costly

The Paris Agreement highlights the urgent need for countries to pursue a low-emissions transition. A low-emissions transition entails the decarbonisation of an economy, including a move away from the use of fossil fuels towards cleaner low-emissions technologies for generating energy. In many countries, significant changes in land use patterns are also needed, for example to remove CO₂ from the atmosphere through greater afforestation, and reduced rates of deforestation (UNEP, 2017).

The pace of this transition matters a lot. Because most GHGs emitted today will remain in the atmosphere for the rest of the century, delaying action and deferring mitigation to the future comes at the cost of greater long-term warming even when the future action is substantial (Figure 2-1). It also risks exacerbating the economic and social costs from a low-emissions transition, since future reductions would need to be much more dramatic and abrupt to compensate (OECD, 2017c; RSNZ, 2016; World Bank, 2015).

⁴ Negotiations regarding the implementation of the Agreement are ongoing. Details yet to be resolved include accounting rules and processes for assessing each country's progress towards their NDCs.

Figure 2-1 Simple illustration of CO₂ emissions under early and delayed mitigation strategies

Source: Based on RSNZ (2016).

2.3 New Zealand's emissions profile and recent trends

This section describes New Zealand's contribution to global emissions, its recent emissions trends, and the relative contribution of different sources and gases to New Zealand's overall emissions. The Ministry for the Environment (MfE) reports on New Zealand's emissions each year in the *New Zealand Greenhouse Gas Inventory*. Consistent with the reporting guidelines of the United Nations Framework Convention on Climate Change (UNFCCC), the inventory separates sources of emissions into five broad categories (Table 2.1).

Table 2.1 Categories of emissions sources in New Zealand under UNFCCC reporting

Emissions categories	Dominant examples of emissions sources in New Zealand
Agriculture	<ul style="list-style-type: none"> Livestock produce CH₄ as they digest their food, through the process of enteric fermentation A small portion of the nitrogen content in animal urine oxidises into N₂O after interacting with microbes in the soil
Energy	<ul style="list-style-type: none"> Fossil fuels consumed to power road vehicles emit CO₂ Process heat generated for manufacturing plants by burning coal or natural gas emits CO₂
Industrial processes and product use	<ul style="list-style-type: none"> Steel production requires the chemical reduction of iron sand using coal, thereby emitting CO₂ Refrigeration and air conditioning use HFCs.
Waste	<ul style="list-style-type: none"> Waste decaying in unmanaged landfills produces CH₄
Land use, land-use change and forestry	<ul style="list-style-type: none"> As forests grow, they sequester CO₂ from the atmosphere through photosynthesis (an example of emissions removal) Conversion of forests to pastoral agriculture reduces the stock of carbon held in the land and results in CO₂ being released into the atmosphere.

Source: MfE (2018d).

The inventory also reports on two different measures of New Zealand's total emissions:

- gross emissions includes all sources of emissions except forestry and other land uses (these come under the category "land use, land-use change and forestry" (LULUCF)); and
- net emissions includes all sources (and removals) of emissions.

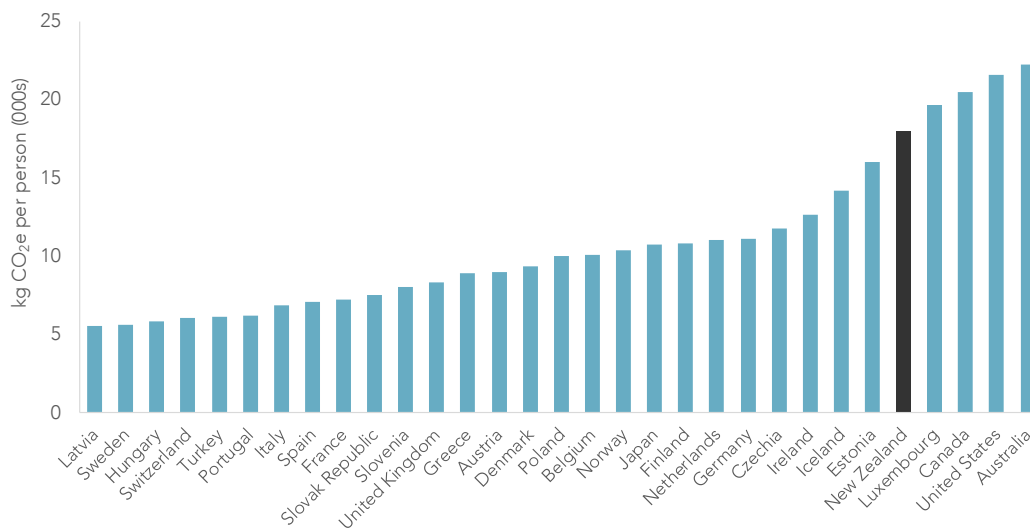
The difference between New Zealand's gross and net emissions is the emissions from forestry and other land uses. This amount can be positive or negative. It is roughly the difference between the amount of CO₂ emitted after forests are harvested or deforested and the amount of CO₂ that growing forests sequester.⁵

This chapter includes estimates of emissions based on New Zealand's GHG Inventory. Therefore, emissions are estimated using the standard GWP₁₀₀ framework. However, different metrics can be used to compare the warming effect of GHGs, for calculating emissions. The choice of metric has a substantial bearing on estimates of emissions (Chapter 9).

New Zealand's emissions per person are relatively high

New Zealand is a small country and its emissions make up only about 0.2% of the world's total GHG emissions. However, New Zealand's emissions per person are high. Its gross emissions per capita are the fifth highest among developed countries (Figure 2.2).

Figure 2-2 Gross GHG emissions per capita for OECD countries, 2014



Source: OECD (2018a).

F2.1

As a small country, New Zealand's absolute contribution to global emissions is small. However New Zealand's per person gross emissions are one of the highest among developed countries.

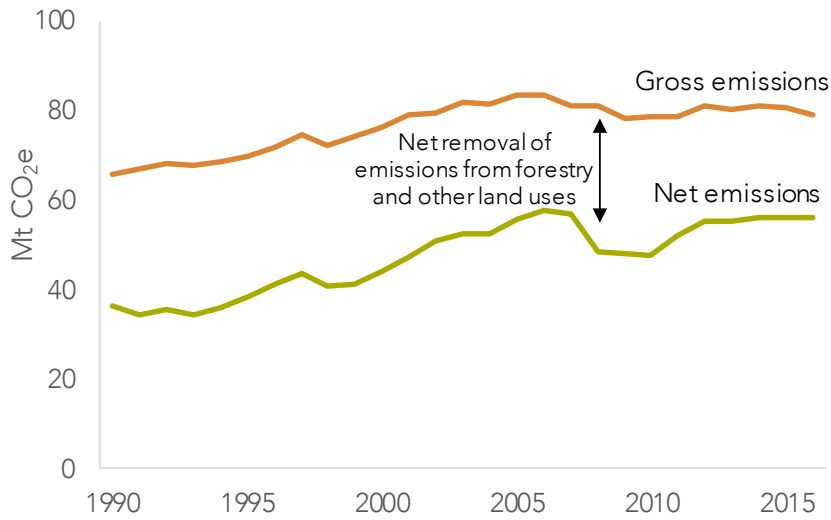
New Zealand is yet to see a sustained decline in its emissions

New Zealand's gross and net emissions have flattened over the last decade after steadily rising before the mid-2000s (Figure 2-1). Between 1990 and 2016, gross emissions rose by about 13 megatonnes (Mt) of CO₂e, or in percentage terms by about 20%. Net emissions increased by about 20 Mt CO₂e or 54%, reflecting the rise in gross emissions as well as a fall in the net amount of CO₂ removed by New Zealand's forests. Factors causing emissions to fluctuate include the Global Financial Crisis, lower livestock numbers during droughts, tree harvesting cycles, cold winters, and dry years (PCE, 2017).

⁵ Emissions for LULUCF can also come from non-forestry sources such as the change in the stock of carbon held in cropland. However, nearly all New Zealand's LULUCF emissions are due to carbon sequestration by forests and harvested wood products, forest harvesting and deforestation.

New Zealand’s gross emissions are currently greater than its net emissions. This is because New Zealand’s forests are a net carbon sink – they absorb more CO₂ than they release each year. Currently, forestry offsets just under one third of New Zealand’s gross emissions (Figure 2-3).

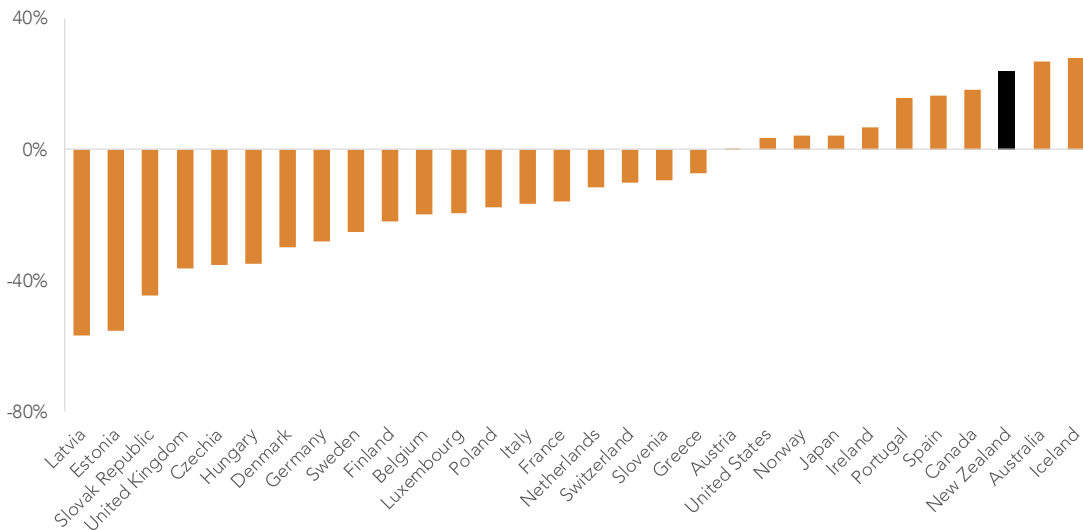
Figure 2-3 New Zealand's gross and net emissions, 1990–2016



Source: MfE (2018d).

Over the last 25 years, New Zealand’s emissions have increased faster than most other developed countries. Further, more than half of developed countries have reduced their emissions since 1990 (Figure 2-4). These trends not only reflect the relative stringency of each country’s mitigation efforts (including decarbonising their energy supply), but also a multitude of other country-specific factors such as economic and population growth, and the composition of each country’s emissions. For example, strong population growth was a factor that contributed to New Zealand’s rising emissions (see discussion later in this section).

Figure 2-4 Percentage change in gross emissions across OECD countries, 1990–2015



Source: OECD (2018a).

Notes:

1. Turkey is excluded from Figure 2.4, as its rate of emissions growth is a significant outlier.

F2.2

New Zealand is yet to see a sustained decline in its emissions. Gross and net emissions have flattened over the last decade after steadily increasing before the mid-2000s.

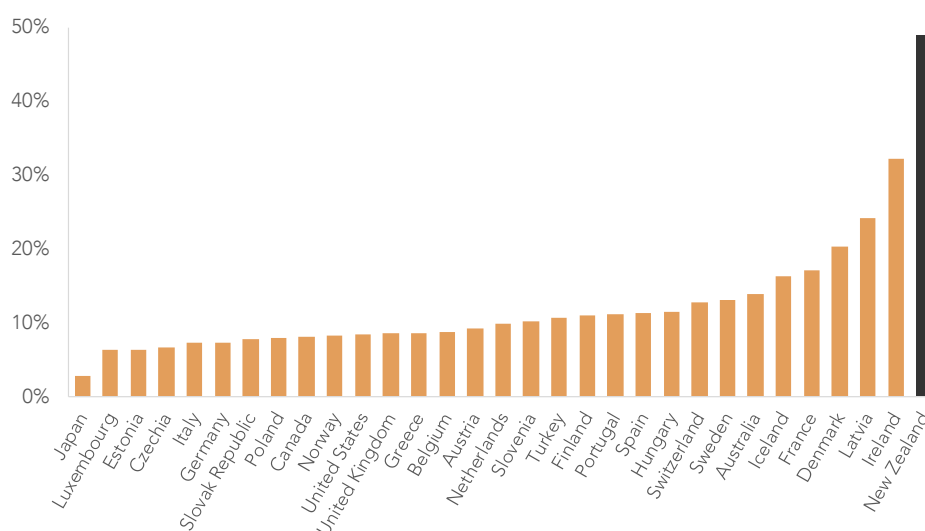
New Zealand's emissions profile is distinctive

The challenge New Zealand faces in mitigating its emissions differs from most other developed countries, because of its distinctive emissions profile. New Zealand's emissions profile largely reflects its prominent agricultural and forestry sectors, and its abundant sources of low-carbon energy.

Agriculture and transport make up a large share of New Zealand's emissions

Nearly half of New Zealand's emissions come from agriculture (Figure 2-6) – considerably more than any other developed country (Figure 2-5). Sheep and cattle are responsible for nearly all New Zealand's agricultural emissions. Over a third of New Zealand's total emissions are CH₄ produced by livestock. About 11% of emissions are N₂O that arise from the oxidisation of the nitrogen in animal urine and dung and in chemical fertilisers.

Figure 2-5 Agricultural emissions as a percentage of gross emissions across OECD countries, 2014



Source: OECD (2018a).

After agriculture, the largest source of emissions is transport – particularly road transport. Together, transport and agriculture account for over two-thirds of emissions. Generating energy for manufacturing is also a significant emissions source, accounting for just under 9% of emissions. This includes emissions from industrial heat for drying milk and producing chemicals.

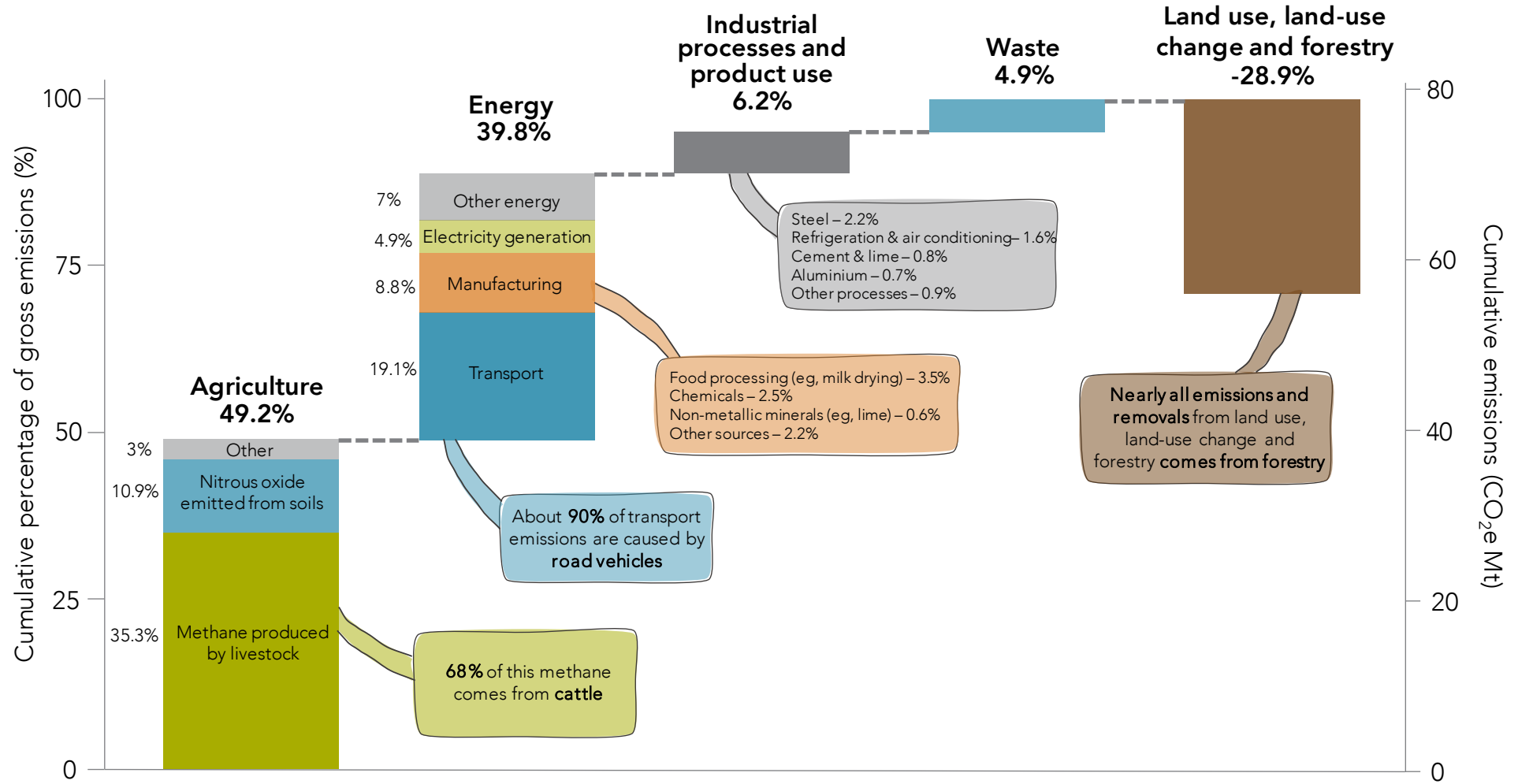
Electricity generation accounted for about 5% of emissions in 2016. The percentage is low by international standards, due to New Zealand's heavy use of low-carbon renewable energy. Around 85% of New Zealand's electricity is generated using renewable sources, particularly hydro and geothermal power. This compares to 17% in Australia, 25% in the United Kingdom, and 65% in Canada (Clean Energy Council, 2016; Natural Resources Canada, 2018; UK Government, 2017a). Overall, roughly 40% of New Zealand's energy (including for transport, electricity and industrial heat) is generated using renewable sources.

Industrial processes such as those used to manufacture steel, cement and aluminium contribute 4.5% of emissions, with a large proportion of these produced by a relatively small number of large emitters. Emissions from the waste sector also make up about 5% of emissions. The use of fossil fuels for space heating and other purposes in commercial and residential buildings, and the use of refrigeration and air conditioning systems, both account for close to 2% of emissions.

F2.3

Agriculture makes up nearly half of New Zealand's emissions – more than any other developed country. Transport is the next largest source, contributing about a fifth of emissions. Electricity emissions are relatively low in New Zealand due to the country's heavy use of low-carbon, renewable energy.

Figure 2-6 New Zealand’s GHG emissions and removals by source, 2016



Source: MfE (2018e).

Notes:

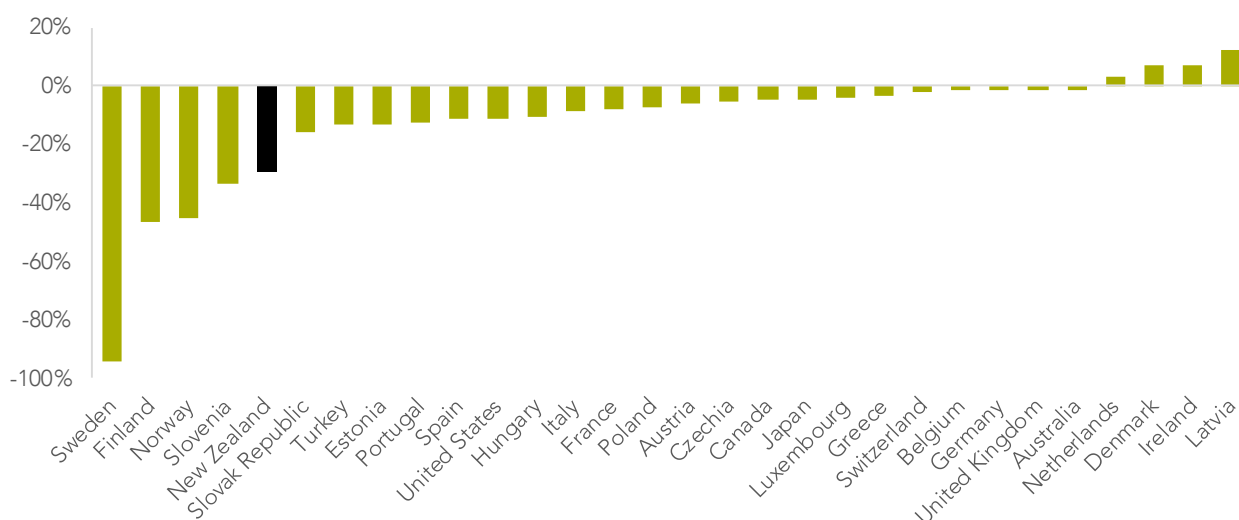
1. Emissions are measured using a GWP₁₀₀ framework.
2. Emissions from industrial processes exclude emissions from the generation of energy to power those processes.
3. Emissions from electricity generation include fugitive emissions from producing geothermal energy.
4. Methane emissions produced by livestock only includes emissions produced as a result of enteric fermentation.

Forestry plays a significant role in offsetting New Zealand's gross emissions

Sequestering carbon in forests currently offers the only viable way of meaningfully removing CO₂ already emitted into the atmosphere (Evison, 2016). On the other hand harvesting forests and changing land uses, for example from forestry to pastoral farming, emits CO₂.

New Zealand's forests offset just under one-third of gross emissions each year – a significant proportion by international standards (Figure 2-6 and Figure 2-7). Plantation forests cover about 1.7 million hectares of New Zealand's land. Those forests and strong historic planting (especially in the mid-1990s) have benefited New Zealand by lowering the country's net emissions.

Figure 2-7 Forestry and other land-use emissions as a percentage of gross emissions across OECD countries, 2015



Source: OECD (2018a).

Notes:

1. Israel, Chile, Mexico and Korea are excluded due to absence of up-to-date data. Iceland is also excluded as it is an extreme outlier – above 200%.

Yet the yearly amount of CO₂ sequestered by New Zealand's forests fell by nearly a quarter between 1990 and 2016. Since the planting boom in the mid-1990s, planting rates have fallen dramatically while rates of deforestation have increased (MfE, 2018d).

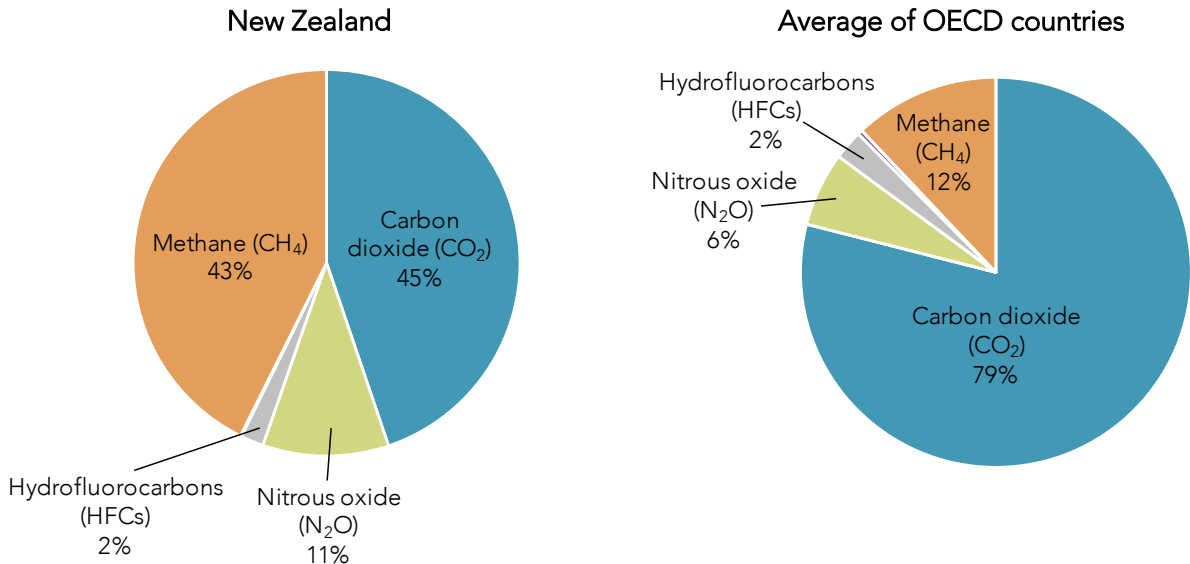
In addition, forest CO₂ sequestration is likely to fall further if there is not a significant increase in planting, as many of those forests planted in the 1990s are due for harvest between now and 2030 (MfE, 2017d).

F2.4

Forestry offsets just under one-third of New Zealand's gross emissions. Yet, because planting rates have dropped sharply since the planting boom in the 1990s, and many of these forests are shortly due for harvest, carbon offsets from forestry are likely to decline if there is not a significant increase in planting.

Carbon dioxide, methane and nitrous oxide emissions are all important for New Zealand

For other developed countries, limiting the impacts of climate change primarily means focusing on mitigating CO₂ emissions. Yet, because such a large proportion of New Zealand's emissions comes from agriculture (and such a small proportion comes from generating electricity), over half of its emissions are made up of non-CO₂ gases – CH₄ and N₂O (Figure 2-8).

Figure 2-8 GHG gross emissions by gas, for New Zealand and OECD countries, 2015

Source: OECD (2018a).

Notes:

1. Perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆) together accounted for approximately 0.1% of New Zealand's emissions and 0.4% of the average OECD country's emissions.
2. OECD countries exclude Israel, Korea, Chile for which no data was available.

This is not to say that CO₂ is not important in the New Zealand context. CO₂ is still the most prominent GHG in New Zealand, making up around 45% of emissions. Further, New Zealand's CO₂ emissions have increased much more than other gases over the last 25 years (see next subsection). Transport contributes roughly 40% of New Zealand's CO₂ emissions, while generating energy for manufacturing contributes just under 20%.

F2.5

New Zealand's emissions profile differs markedly to other developed countries, because of its high agricultural emissions and low electricity emissions. While carbon dioxide is New Zealand's most prominent greenhouse gas, over half of emissions are methane and nitrous oxide.

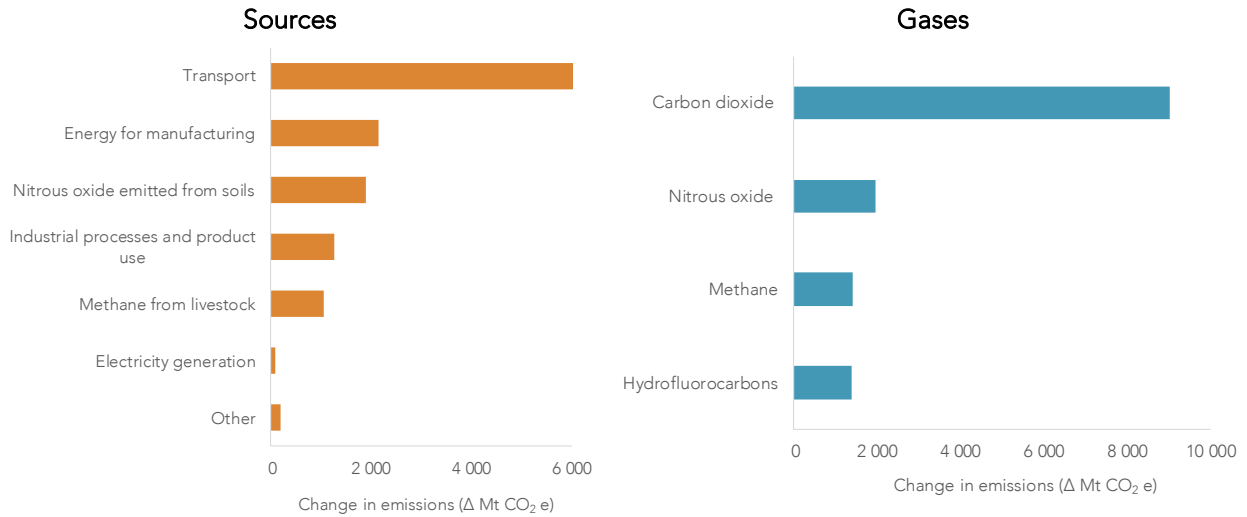
Transport has dominated the increase in New Zealand's emissions

Transport has been by far the biggest contributor to the rise in New Zealand's gross emissions since 1990. As result, CO₂ emissions have risen much more than other gases (Figure 2-9). Between 1990 and 2016, transport emissions increased by about 70%. Over this period, New Zealand's vehicle fleet increased in size by 1.5 million vehicles. New Zealand's vehicle fleet is among the oldest (and lowest in terms of fuel efficiency) in the developed world, therefore exacerbating the emissions impact of having additional vehicles on the road (Chapter 12).

Growth in agricultural emissions accounted for about a third of the increase in gross emissions, mostly from N₂O. The growth in emissions from dairy farming was partially offset by a fall in emissions from sheep and beef farming. Between 1990 and 2016, New Zealand's sheep numbers halved and beef cattle numbers fell by nearly a quarter, while its dairy herd nearly doubled. The intensification of the dairy industry, and greater use of synthetic nitrogen fertilisers led to nearly a 30% rise in agricultural N₂O emissions (Chapter 11).

The rise in industrial emissions mostly came from HFCs used to replace ozone-depleting substances in refrigeration and air conditioning. Waste emissions decreased slightly, mainly due to better landfill management practices, such as CH₄ recovery.

Figure 2-9 Absolute change in gross emissions across sources and gases, 1990–2016



Source: MfE (2018e).

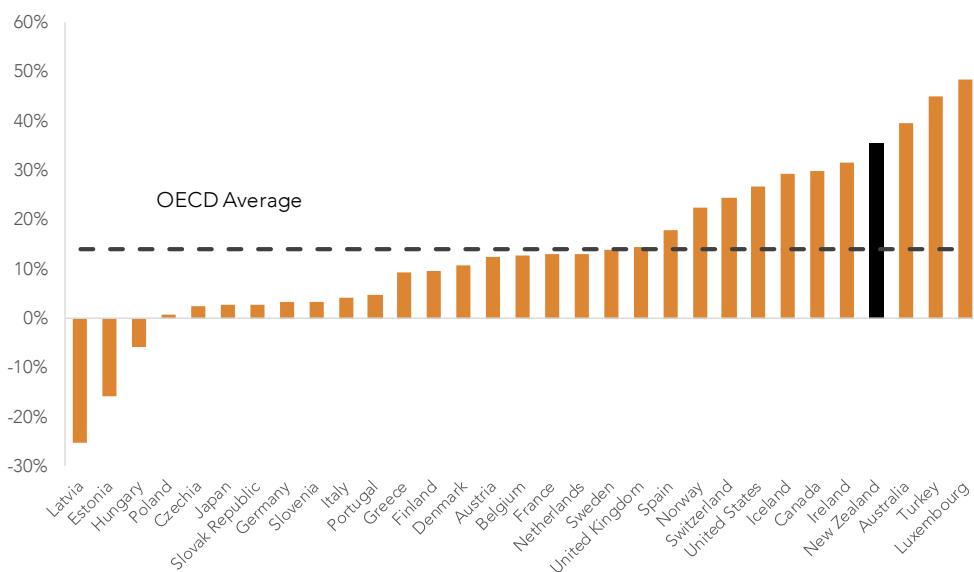
F2.6

Transport has been the biggest contributor to the rise in New Zealand’s gross emissions since 1990. The growth in emissions from dairy farming was partially offset by a fall in emissions from sheep and beef farming. Because of the growth in transport emissions, carbon dioxide emissions have risen much more than methane and nitrous oxide.

Population and economic growth have been underlying drivers of emissions

Strong population growth and economic growth have been key underlying drivers of New Zealand’s rising emissions since 1990. Between 1990 and 2016, New Zealand’s real GDP doubled. During the same period, population growth was higher than most other developed countries (Figure 2-10). More people has led to greater consumption of goods and services that contain emissions (eg, more vehicle use, and greater demand for electricity). Economic growth (and indirectly, population growth) has led to more emissions-intensive goods and services being produced.

Figure 2-10 Population growth across OECD countries, 1990–2015

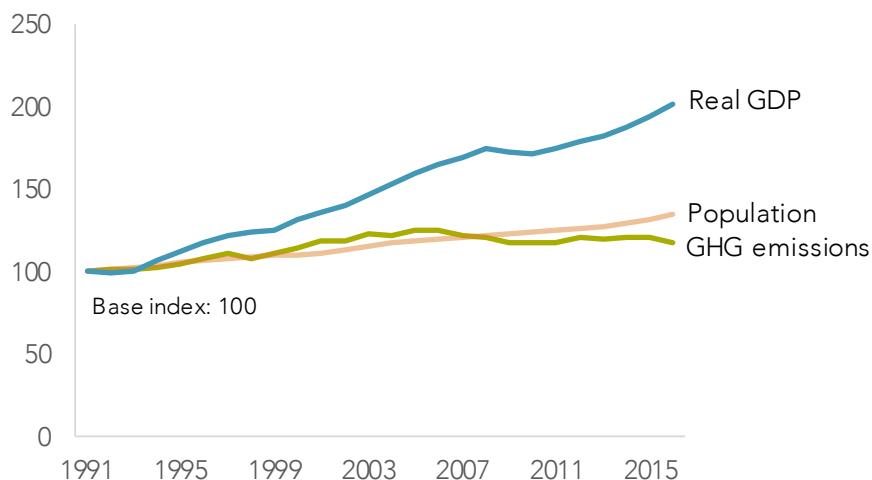


Source: UN DESA (2018).

Yet, emissions have been growing slower than economic and population growth (Figure 2-11). The average New Zealander was responsible for about 12% fewer emissions in 2016 than in 1990, while New Zealand emitted about 40% fewer GHGs per unit of goods and services produced (also known as emissions intensity)

over the same period. Technological advancements in areas such as energy and fuel efficiency, and agriculture, and greater use of low-emissions sources of electricity help to explain these trends.

Figure 2-11 Relative growth in New Zealand’s gross emissions, population and real GDP, 1991–2016



Source: MfE (2018e); Stats NZ (2018d, 2018e).

While a rising population and growing economy could provide a future headwind for mitigation efforts, the relationship between population growth and economic growth, and emissions is likely to diminish over time as households and businesses adopt more low-emission practices. For instance, currently population growth is strongly linked to higher transport emissions, but the adoption of electric vehicles would significantly reduce the emissions that an additional person generates.

F2.7

Economic and population growth have been important underlying factors in New Zealand’s rising emissions. Over the last 25 years, New Zealand’s emissions per person and emissions per unit of output have decreased, but the increase in population and output has caused overall emissions to increase.

2.4 New Zealand’s international mitigation commitments

As a party to the Paris Agreement, New Zealand has committed to reducing GHG emissions to limit global temperature rise to well below 2°C, and to pursue efforts to limit temperature rise to 1.5 °C. New Zealand recently submitted its first NDC under the Paris Agreement. This has a target of reducing emissions to 30% below 2005 levels by 2030. New Zealand is required to submit a new or updated NDC by 2020 and every five years after that. Commitments must become increasingly ambitious.

In addition, New Zealand has a 2020 target, set through the UNFCCC, to reduce emissions to 5% below 1990 levels.

Both New Zealand’s 2020 and 2030 targets are international responsibility targets. This means that investing in emissions reductions in other countries can assist New Zealand in meeting these targets, along with domestic emissions reductions (Box 2.3). However, the use of these offsets would likely only be temporary – ie, they would only count towards one commitment period.

Box 2.3 The contribution of international credits to emission reduction targets

New Zealand can make progress towards meeting its international commitments by investing in emissions reductions in other countries. The Paris Agreement explicitly allows for “cooperative approaches that involve the use of internationally transferred mitigation outcomes towards nationally determined contributions” (UNFCCC, 2015b, p. 6). For New Zealand’s first NDC, the previous Government expressed its intention to use these reductions to meet its 2030 target.

The use of international offsets played an integral part for New Zealand in meeting its first emissions reduction commitment between 2008 and 2012 under the Kyoto Protocol. At the time, New Zealand's Emissions Trading Scheme (NZ ETS, see section 2.6) was linked to the global carbon trading market set out in the Kyoto Protocol, which allowed emitters to purchase overseas credits to "pay" for their emissions. New Zealand accumulated a large surplus of overseas credits, after a huge oversupply on that market led to a dramatic drop in the global price of emissions credits. It is widely accepted that a significant number of credits traded in the global market did not constitute credible emissions reductions (E. Mason, 2013; OECD, 2017e). New Zealand was the top buyer of units from this market, as a proportion of its domestic emissions (Simmons & Young, 2016).

At present, no formal mechanism is in place for trading international emissions reductions, since the NZ ETS is no longer linked to global markets. The Government is currently working with other countries on developing new arrangements for trading credits under the Paris Agreement (Chapter 5). Ensuring that any future purchases of emissions reductions are of a high environmental integrity will be essential for maintaining the credibility of New Zealand's mitigation efforts.

Accounting for New Zealand's emission reduction commitments

Accounting for New Zealand's emission reduction targets is not as simple as comparing New Zealand's net emissions (as reported in the national inventory) in the specified target year with its net emissions in a baseline year. The three reasons for this are:

- New Zealand uses a gross/net accounting approach for its targets;
- only certain types of forests can contribute towards New Zealand targets; and
- progress toward New Zealand's targets is based on emissions across a multi-year period.

A gross/net accounting approach means that New Zealand's targets are expressed as reductions in net emissions compared to a historic gross emissions baseline. For example, New Zealand's 2030 target of reducing emissions to 30% below 2005 levels translates to a 30% reduction in net emissions compared to 2005 gross emissions levels.

However, net emissions reported in the GHG inventory are **not** the same as net emissions for the purposes of New Zealand's targets. This is because special accounting rules limit the types of forestry and other land-use emissions that can count towards targets. Box 2.4 explains these rules.

Further, New Zealand manages its emission reduction commitments using a multi-year budget approach. Rather than just looking at emissions in the target year, New Zealand looks at emissions in each year across a target period. New Zealand's commitments require it to keep total emissions over this target period within a budget calculated in accordance with the emissions target. For instance, New Zealand's 2030 NDC target has a target period from 2021 to 2030. Over this period, New Zealand must keep its total net emissions (minus any international credits) below roughly 600 Mt CO₂e (or 60Mt a year).

Box 2.4 Accounting for forestry emissions: inventory versus emissions-reduction targets

The amount of forestry and land-use emissions reported in New Zealand's inventory is not the amount that counts towards its targets. This is an important yet often misunderstood fact. The inventory includes emissions for all land across New Zealand. However, special accounting rules determine the subset of these emissions that can contribute to targets. These rules are intended partly to ensure that countries are only rewarded for newly planted forests.

One of the most consequential rules concerns the treatment of forests established before 1990. Essentially, the removal of CO₂ by these pre-1990 forests does not count towards New Zealand's targets, but is included in estimating net emissions for the inventory. This distinction may seem minor,

but it is important. Of the 24 Mt of CO₂ sequestered in 2015, only about 12 Mt counts towards New Zealand's 2020 target.

Accounting rules can also differ between specific targets. Under the Paris Agreement, countries have greater flexibility to choose their own accounting rules, compared to the Kyoto Protocol. In its first NDC, the Government has indicated that it will modify the Kyoto Protocol rules to adopt an averaging approach,⁶ though the full details of the rule changes are not yet confirmed.

Source: MfE (2017b, 2018d); New Zealand Government (2017c).

Progress towards New Zealand's current international commitments

New Zealand is on track to meet its 2020 emission reduction commitment. The target period for this commitment is between 2013 and 2020. MfE (2018g) projects that net emissions over this period will be around 6% (31 Mt CO₂e) above the emissions budget. However, New Zealand plans to meet the budget by carrying over surplus credits from its first commitment under the Kyoto Protocol (this surplus was achieved only after counting international credits).

However, New Zealand's first NDC under the Paris Agreement will be far more challenging to meet. To recap, because the commitment is in the form of a ten-year emissions budget, the annual emissions for each year between 2021 and 2030 matter for achieving the commitment. Based on current policies, MfE projects that New Zealand's emissions over this ten-year period will be roughly 200 Mt CO₂e higher than the budget of roughly 600 Mt (Figure 2-12). Even if New Zealand successfully reduces emissions to meet the point-in-time target for 2030 (30% below 2005 emissions), total emissions over the period will still significantly exceed the budget.⁷

The key reason for this is that New Zealand has so far relied heavily on temporary means of meeting its emission reduction commitments: first, offsets from pine forests which were planted in the 1990s and will soon cease to sequester further carbon;⁸ and second, the purchase of international credits. Unlike reducing gross emissions or continuing to plant new forests, these do not assist in meeting future commitments.

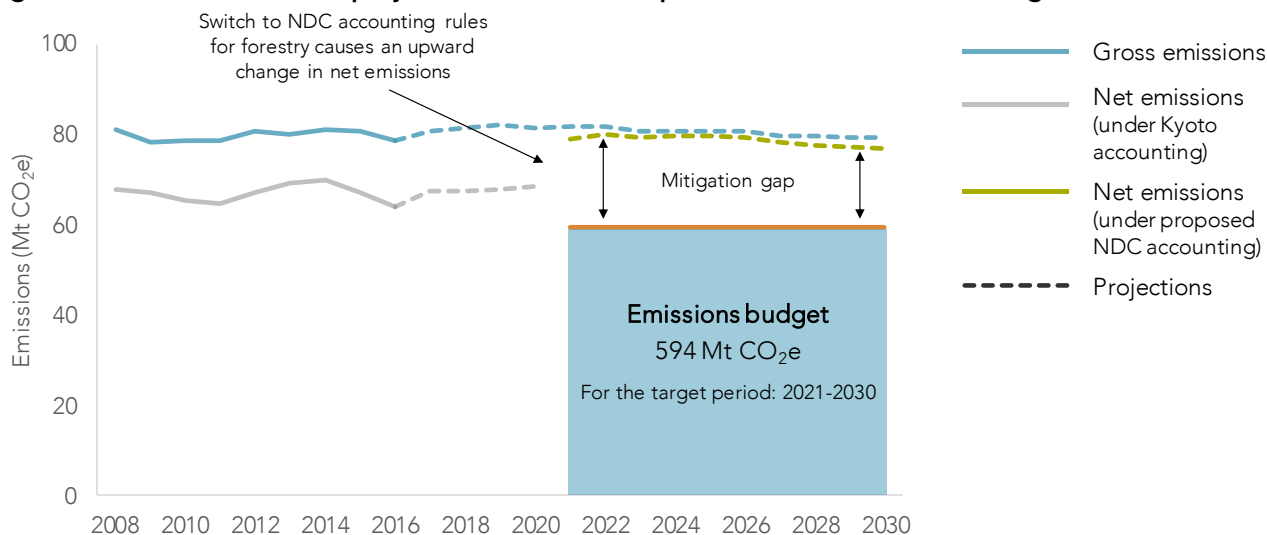
To achieve the NDC budget using only domestic emissions reductions, New Zealand's net emissions over the period would need to average about 60 Mt per year – about 20 Mt lower than projected (using the NDC accounting rules for forestry). To put this into perspective, eliminating New Zealand's total yearly emissions from transport would only remove 15 Mt of emissions. High emissions early in the period would also necessitate even greater annual reductions later in the period to meet the budget.

As noted, NDCs under the Paris Agreement are not strictly domestic commitments – New Zealand can meet its commitment (and thus eliminate this mitigation gap) through a combination of domestic emissions reductions and investment in reductions in other countries. How New Zealand could get credit for international reductions and how much these credits will cost is uncertain (Box 2.3). Even with access to international offsets, meeting the NDC will still require immediate and strong action to reduce New Zealand's domestic emissions, especially given the temporary nature of international offsets. Substituting efforts to reduce domestic emissions for purchases of international offsets will make future NDC commitments even more difficult to achieve.

⁶ New Zealand communicated in its NDC that it will adopt an averaging approach for accounting for forest sequestration. Under this approach, New Zealand will receive credit for sequestering CO₂ in a forest up to the long-term average stock of carbon stored in the forest. After this point, a forest is assumed to be carbon neutral. So, New Zealand's emissions, with respect to targets, are not affected when a forest is harvested, as long as the forest is replanted.

⁷ The NDC budget is effectively calculated by plotting a trajectory from New Zealand's most recent emissions budget (the 2013-2020 budget) to the target for 2030. Yet, New Zealand will only meet its 2013-2020 budget by carrying over previous surplus credits, and New Zealand's forest offsets are projected to fall. Consequently, New Zealand's overall domestic emissions are projected to be much higher than the level needed to meet its NDC budget.

⁸ After switching from the Kyoto rules for accounting for forestry sequestration to the pledged NDC rules in 2021, New Zealand's net emissions are projected to jump up. But, without the rule change, net emissions were projected to increase by even more because of the significant harvesting expected in the 2020s (Young & Simmons, 2016; see footnote 6).

Figure 2-12 New Zealand's projected emissions compared with its 2030 NDC budget

Source: MfE (2018a).

Notes:

1. Net emissions are based on target accounting rules for forestry. Rules are specific to each target period.
2. Emissions projections are for the period 2017-2030. Projections are based on current mitigation policies.

F2.8

Meeting New Zealand's first commitment under the Paris Agreement will be highly challenging, even with immediate and strong action to reduce domestic emissions. International offsets can play a part in meeting this commitment, but any delay in domestic reductions will make future commitments even more difficult to achieve.

2.5 A long-term emissions reduction target for New Zealand

Currently, New Zealand has an emissions reduction target for 2050 to reduce net emissions to 50% below 1990 gross emissions levels. The Government set the target in 2011 and gazetted it under section 224 of the Climate Change Response Act 2002. The rules for accounting for forestry and other land use emissions for the target are based on the Kyoto Protocol rules (MfE, 2016b).

The current Government is currently consulting on setting a more ambitious long-term target that would be set in legislation. In its consultation document released in June 2018, the Government seeks feedback on three target options for 2050:

- Option 1: achieving net zero CO₂ emissions (so excluding CH₄ and N₂O emissions)
- Option 2: achieving net zero emissions for long-lived GHGs (ie, CO₂ and N₂O) and stabilised emissions for short-lived GHGs (ie, CH₄)
- Option 3: achieving net zero emissions across all GHGs

Achieving any of these target options would require a substantial and sustained shift in the trajectory of New Zealand's domestic emissions compared to past trends. The Government has not yet confirmed the role that international offsets will be able to play in meeting a long-term target, although it has agreed in principle that mitigation efforts should not unduly rely on international emissions reductions (Office of the Minister for Climate Change, 2017).

2.6 Governance arrangements, and mitigation policies

This section provides a brief overview of New Zealand's governance arrangements and policies to reducing its emissions. It covers New Zealand's Climate Change Response Act and how the Treaty is reflected in

current governance arrangements. It also describes New Zealand’s main tool for reducing domestic emissions – the New Zealand Emissions Trading Scheme (NZ ETS).

Governance arrangements

The Climate Change Response Act 2002 (CCRA) is New Zealand’s principal statute for mitigating climate change. The Act has two central purposes:

- providing a legal framework for New Zealand to meet its commitments under the Kyoto Protocol and the UNFCCC; and
- implementing, operating and administering the NZ ETS to reduce emissions beyond business as usual (see discussion of the Scheme below).

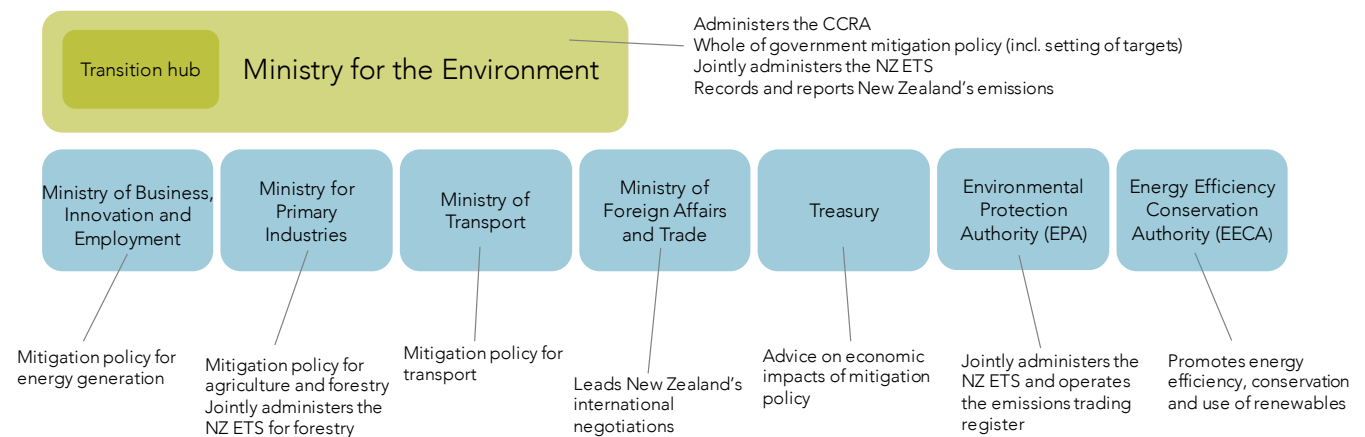
The CCRA was established in the context of New Zealand’s participation in the Kyoto Protocol. After 2020, the Paris Agreement will supersede the Protocol as the global framework for mitigating emissions.

The CCRA requires the Minister or the Chief Executive of the administering agency to consult with Māori before making specified decisions under the Act (Chapter 8). This is intended to recognise the Crown’s responsibilities under the Treaty of Waitangi. The specified decisions particularly (but not only) recognise that actions to mitigate climate change may affect or involve Māori interests in the natural environment and their ancestral relationship with the land (Chapter 11). This dovetails well with the Paris Agreement, which specifically recognises the rights of indigenous peoples in the context of climate change mitigation (CCILG, 2016a).

Currently, MfE is the lead department on climate change mitigation, being the administrator of the CCRA. In early 2017, the Government created a Transition Hub to provide advice on New Zealand’s transition to a low-emissions economy. The Hub sits within MfE. The advice it delivers in late 2018 will inform the Government’s strategy for meeting New Zealand’s 2030 target. In late 2017, Cabinet also agreed to establish an interim climate change committee to provide further advice on key policy issues (Chapter 8).

In addition, because climate change mitigation is far-reaching, several other departments across government play a role in providing advice on mitigation, administering mitigation policy and supporting New Zealand in climate change negotiations (Figure 2-13). The Ministry for Primary Industries, for example, not only provides advice on mitigation policy for agriculture and forestry; it also helps to administer the NZ ETS for forestry.

Figure 2-13 Government’s current roles in mitigating New Zealand's emissions



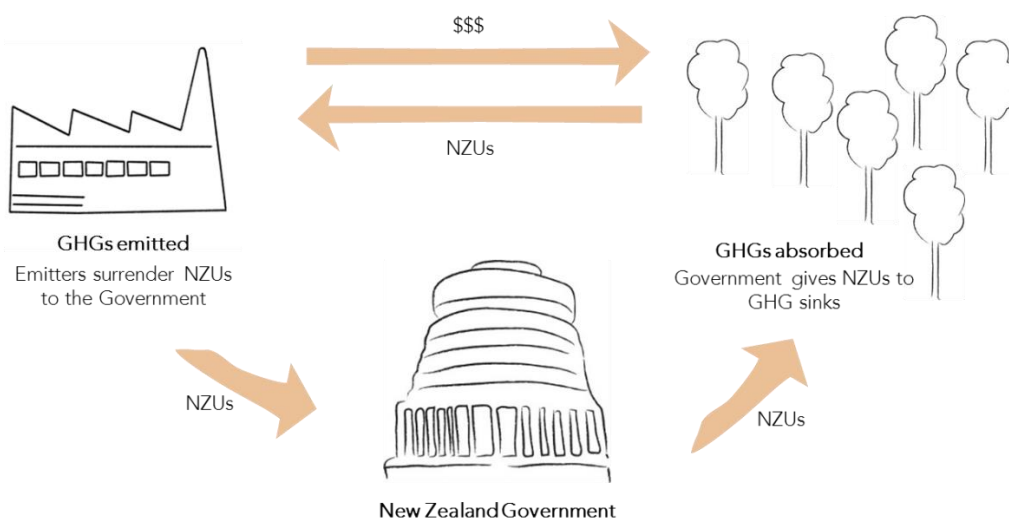
The New Zealand Emissions Trading Scheme

The NZ ETS is the Government’s principal response to climate change. Established under the framework of the CCRA, the NZ ETS commenced in 2008. The NZ ETS currently requires the energy, fishing, forestry, industrial processes, liquid fossil fuels (ie, transport fuels), synthetic gases,⁹ and waste sectors to report on,

⁹ Synthetic gases emitted in New Zealand include HFCs, PFCs, and SF₆.

purchase and surrender emissions units to the Government so as to emit GHGs. Agriculture is the only sector exempted from having to surrender units for their emissions.

Figure 2-14 The basic structure of the NZ ETS



Source: MfE (2015b).

Under the NZ ETS, New Zealand Units (NZUs) each represent one tonne of CO₂e. The scheme covers CO₂, CH₄, N₂O, SF₆, PFCs, and HFCs. Participants must surrender one NZU for a certain amount of CO₂e emitted (eg, one NZU for each tonne of CO₂e emitted). The Government provides credits in the form of NZUs to eligible forestry activities that sequester CO₂. Participants can purchase these credits (Figure 2-14). Currently, they can also purchase NZUs from the Government at \$25 a unit.

Allocations of NZUs differ depending on activities of each participant firm and are determined under the Climate Change Response (Moderated Emissions Trading) Amendment Act 2009. Emissions-intensive, trade-exposed (EITE) industries receive free allocations of either 60% or 90% of their requirements as determined by the Climate Change (Eligible Industrial Activities) Regulations 2010. Requirements are determined by multiplying the output of each EITE firm by the average emissions intensity of its industry based on data collected between 2006 and 2009. This system is designed to maintain the international competitiveness of New Zealand production and to prevent emissions leakage.¹⁰

The point of obligation – the point at which the scheme participant is required to monitor and surrender NZUs – differs for each participant sector but, in general, is upstream (eg, fossil fuel producers or importers) rather than downstream (eg, consumer-level).¹¹ For example, in the industrial processes sector the point of obligation is the point of production of the good in question (eg, aluminium), and in the waste sector it is with landfill operators.

Complementary policies for achieving domestic emissions reductions

Outside the NZ ETS, a range of policies affect New Zealand's domestic emissions, although only a handful was implemented purely for addressing climate change. This demonstrates that emissions reduction policies can have a range of benefits. For example, the Afforestation Grant Scheme was put in place to help reduce soil erosion, improve land-use productivity, boost regional development, improve water quality and store CO₂. Other policies, such as the Warm Up New Zealand: Healthy Homes Programme, were implemented primarily for reasons unrelated to climate change. The Programme subsidises insulation for homeowners to make homes warmer, drier and healthier. Yet improved insulation has the indirect benefit of reducing the need to heat homes, which in turn helps to reduce emissions.

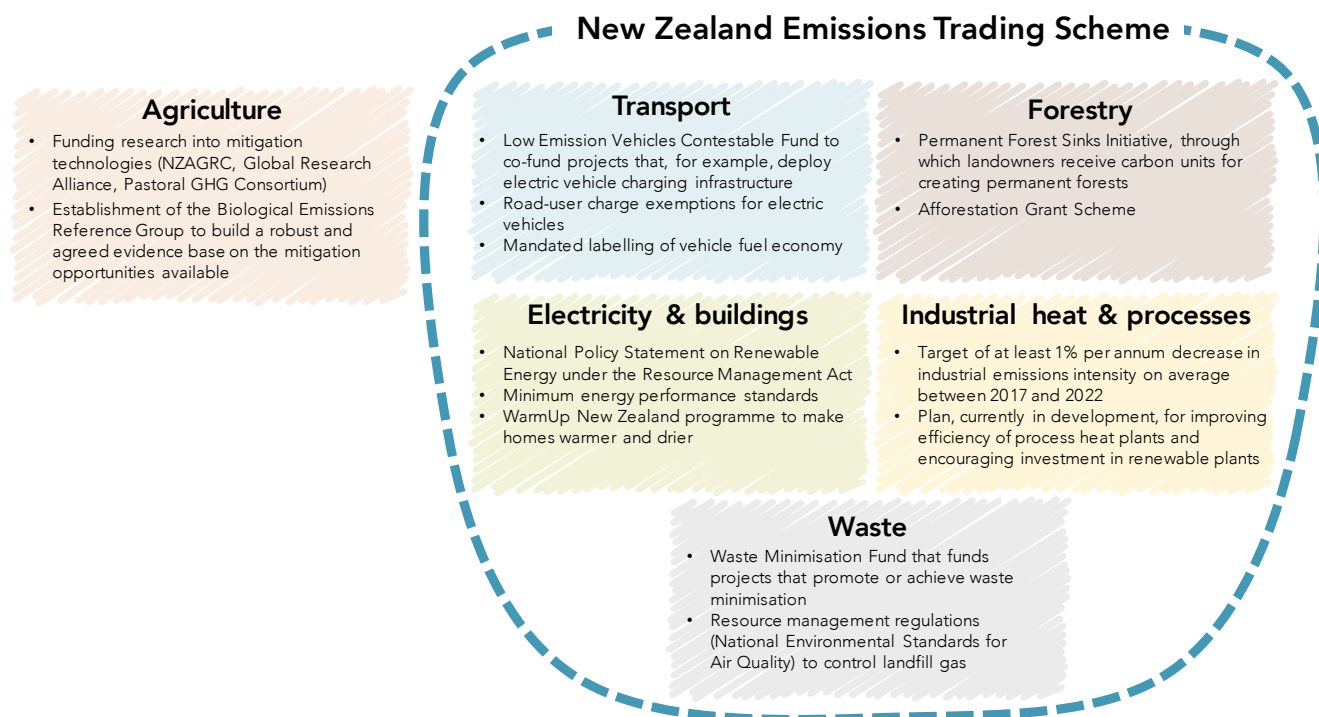
Figure 2-15 provides examples of New Zealand's mitigation policies currently in place. New Zealand's unique emissions profile has also provided impetus for investment into researching low-cost ways of

¹⁰ Emissions leakage refers to the situation whereby reducing emissions in location A through a reduction in output leads to an increase in output in location B and an increase in its emissions. Where location B is a higher-emitting producer than location A, total emissions may rise.

¹¹ See Section 4.4 of MfE and The Treasury (2007) for a more detailed discussion of potential points of obligation in the NZ ETS.

reducing on-farm emissions, such as through the New Zealand Greenhouse Gas Agricultural Research Centre (see Chapter 11).

Figure 2-15 Examples of New Zealand's current mitigation policies



2.7 Conclusion

Globally, countries face the serious challenge of dramatically reducing their GHG emissions to net-zero levels this century to limit temperature rise and the impacts of climate change. The Paris Agreement sets out a global goal of limiting temperature rise to well below 2°C with an ambitious goal of reducing it further to 1.5°C.

New Zealand is yet to see a sustained decline in its emissions. Nearly half of New Zealand's total emissions come from agriculture, most of which are methane. This makes New Zealand's emissions-reduction challenge distinctive compared to many other developed countries. Transport is another significant source, and its emissions have been growing rapidly. On the other hand, New Zealand benefits from its large forestry sector as an emissions offset, and from the low-emissions footprint of its electricity grid.

New Zealand's first commitment under the Paris Agreement will be highly challenging to meet. New Zealand has committed to keeping emissions between 2021 and 2030 below roughly 600 Mt of CO₂e. This represents a mitigation task of roughly 20 Mt a year over this period, compared to what is projected. To put this into perspective, reducing New Zealand's annual transport emissions would only achieve a 15 Mt reduction. New Zealand can also invest in emissions reductions in other countries to help meet its commitment, though any delay in reducing domestic emissions will make future NDC commitments more difficult to achieve.

The Government also plans to increase the ambition of New Zealand's present long-term emissions-reduction target from a 50% reduction (compared to 1990 levels). To achieve either the current target or a more ambitious one, a substantial and sustained shift in the trajectory of New Zealand's emissions is needed. A range of government policies are in place to reduce emissions, the main one being an Emissions Trading Scheme. Emissions trends clearly show that additional policies and the reform of existing policies are necessary.

Part Two:

Low-emissions pathways

Part One looked back at New Zealand's historic emissions over the last 30 years. Part Two now looks into the future at possible pathways for New Zealand's transition to a low-emissions economy. It presents the results of modelling undertaken for the inquiry and examines the nature of major economic and social transitions.

Crucial to fulfilling the inquiry Terms of Reference, the modelling in Chapter 3 throws light on important questions such as:

- Is an ambitious low-emissions target feasible for New Zealand?
- What are likely to be the key opportunities, as well as the biggest risks and uncertainties for New Zealand in reducing its emissions?
- What measures are likely to be needed to achieve a low-emissions economy? What role will an emissions price play?

What might a major transition involve? By drawing on lessons from the past and expectations about the future, Chapter 4 illustrates the potential nature of a 30-year transition to a low-emissions economy.

Examining possible pathways to a low-emissions future and the nature of major economic and social transitions lays the ground for later chapters of this report. Part Three examines policies and institutions, such as emissions pricing and setting targets in law, that will be important for keeping New Zealand's emissions headed in the right direction at the right pace. Part Four then digs into specific emitting sources that contain the key opportunities and challenges to reduce emissions.

3 Mitigation pathways

Key points

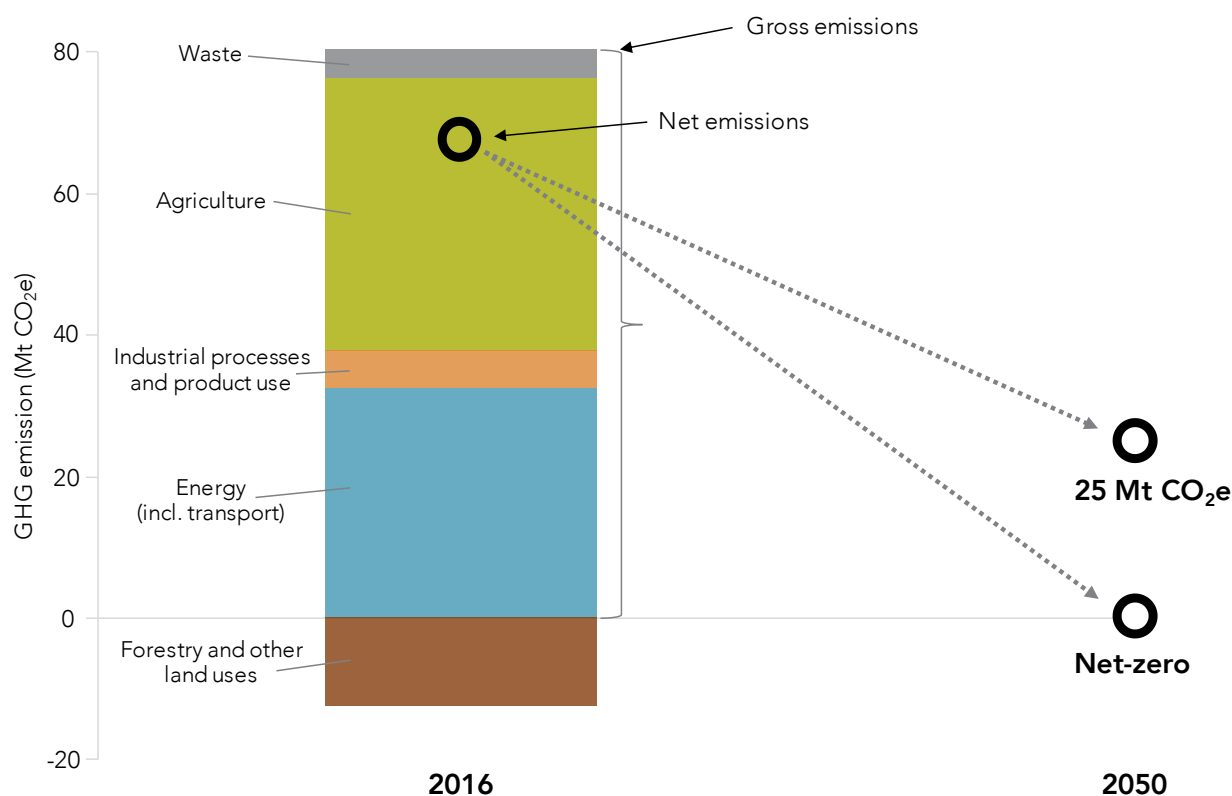
- The Commission has undertaken modelling to examine pathways that lower New Zealand's emissions of greenhouse gases (GHG) from current levels to two alternative long-term targets of 25 megatonnes (Mt) of carbon dioxide equivalent (CO₂e) by 2050 (around a 60% reduction from 1990 levels) and a more ambitious target of net-zero emissions by 2050.
- Modelling can throw light on important aspects of the transition to a low-emissions economy including whether a target is feasible, the measures needed to achieve a target, the existence and character of alternative pathways, and a quantitative picture of what needs to happen by when to reach a target.
- Yet modelling has well-known limitations and is not prediction. The transition to a low-emissions economy for any country will be a long journey to a known and desired destination, but through very uncertain terrain. The modelling captures some important aspects of the uncertainty by examining three scenarios about how future technology could evolve.
- The three scenarios vary in the extent and type of technology changes that reduce emissions, and the impact of those changes on the structure of the economy. The 'Policy Driven' scenario assumes that technologies are slow to develop and reductions in emissions must rely on strong policy such as high emissions prices. The 'Disruptive Decarbonisation' scenario assumes that technological change is fast, and it disrupts existing industries. The 'Stabilising Decarbonisation' scenario assumes that technological change is also fast, but it reduces emissions in existing industries.
- A second stage of modelling included the possibility that decision makers can adjust their strategies at a point in the future when they have additional information about technological progress and other factors such as the pace of climate action internationally.
- The modelling indicates that reducing New Zealand's emissions at least cost will require three key drivers: a large expansion of forestry (mainly from sheep and beef farming), changes to the structure and methods of agricultural production, and switching from fossil fuels to clean electricity and other low-emissions energy sources in transport and process heat. An emissions price rising from current levels to between \$75 and \$150 a tonne (t) of CO₂e by 2050 could lower New Zealand's emissions to 25 Mt CO₂e in 2050.
- New Zealand could reach net-zero GHG emissions by 2050, with emissions prices rising more strongly to between \$150 and \$250 a tonne of CO₂e by 2050. These prices are within the range of emissions prices that will likely be needed in other developed countries to deliver the objectives of the Paris Agreement. Key to enabling New Zealand's reductions are its low-emissions electricity system and large land area (relative to population) that is suitable for forest expansion.
- Yet, the heavy reliance on forestry could create longer-term challenges – with continued emissions reductions required after 2050 to maintain net-zero emissions. New Zealand will need to find other ways to reduce emissions or continually plant more and more land in forests. New Zealand has time to consider its options, and develop or deploy technologies that offer new, cost-effective ways to mitigate GHGs.
- A powerful insight from uncertainty analysis is the potential value of early, strong action in the form of higher emissions prices in the period from now to 2030. This action can provide insurance against slow technological progress and high international carbon prices, lower the likelihood of high-carbon investments that lock in emissions for many years into the future, and stimulate valuable afforestation and low-emissions innovation.

This chapter presents the results of modelling undertaken for the inquiry. This modelling is crucial to fulfilling the inquiry Terms of Reference, which call upon the Commission “to consider the different pathways along which the New Zealand economy could grow and develop to achieve New Zealand’s emissions targets”. As noted in Chapter 2, New Zealand currently has a long-term target of reducing net emissions to 50% of 1990 levels by 2050,¹² but the Government is considering more ambitious targets including net-zero emissions by 2050. Without judging the merits of the targets, the Commission has examined pathways from current greenhouse gas (GHG) emissions levels to two alternative low-emissions targets:

- net emissions in 2050 of 25 megatonnes (Mt) of carbon dioxide equivalent (CO₂e) of GHGs; and
- net-zero emissions of GHGs by 2050 (Figure 3-1).

This first target is around 60% below 1990 levels, so would achieve a greater reduction of 10 percentage points in emissions than New Zealand’s current long-term target. This target turns out to be broadly consistent with achieving net-zero *long-lived* GHG emissions by 2050 and, with further progress, would put the country on track to achieve net-zero emissions in the second half of this century.

Figure 3-1 The two emissions targets for the modelled pathways



Source: MfE (2017b).

Notes:

1. The forestry emissions shown for 2016 use the Kyoto Protocol accounting rules which apply to New Zealand’s 2020 target. The Government has signalled a change to a revised accounting approach for future targets (Chapter 2).

Modelling pathways to these low-emissions targets provides insights into how and where New Zealand can achieve reductions in its GHG emissions to fulfil its international commitments. Modelling can throw light on:

- the feasibility of achieving a target reduction in emissions through domestic decarbonisation;
- the measures needed to achieve a target such as emissions pricing and other regulatory policies;
- the role and importance of different sorts of technological change;

¹² New Zealand’s gross and net emissions in 1990, as measured under emissions-accounting rules applied to its targets, were essentially the same. Sequestration from pre-1990 forests does not generally count as offsetting gross emissions (Chapter 2).

- the alternative pathways that exist and the challenges, opportunities, benefits and costs of each pathway; and
- what likely needs to happen by when in quantitative terms – the hard numbers that can reveal where the tough choices and risks lie, as well as the opportunities.

Modelling has limitations and it does not constitute prediction of the future. Models are a simplified representation of reality focused on the essential elements and relationships to make complex problems more tractable. By necessity, a model will always lack a certain level of detail and complexity. Even so, models can provide insight and help build a stronger evidence base to inform decision making.

It is wise to remember that New Zealand's journey to a low-emissions economy faces deep uncertainties. While the destination is known, it would be foolhardy to try to pin down in advance the best route for this 32-year journey to 2050. Rather, the situation calls for careful preparation and a capability for adaptation that equips the country to deal well with whatever terrain emerges, and enables a wise choice of route for the first stage of the journey.

The chapter is structured as follows:

- an overview of key modelling results and insights;
- the modelling approach – framework, assumptions and workings;
- results for three modelled pathways that achieve the 25 MtCO₂e target under different scenarios about technology and structural change in the economy, and another three that apply the same scenarios but achieve the more ambitious net-zero target;
- an analysis of future uncertainties about technology and commodity prices;
- a reflection on what models can really tell us about New Zealand's transition to a low-emissions economy;
- conclusions on modelling insights, and how they relate to the rest of the report.

3.1 Overview of key modelling results and insights

In the coming years, New Zealand's government, businesses and society will make choices that will influence the structure of the economy and the cost of reducing GHG emissions. The broad purpose of the Commission's inquiry is to recommend the actions the government might take to reduce New Zealand's emissions given the range of choices within the government's control, yet recognising that some factors that will influence the desirability of those choices are outside its control. The modelling seeks to throw light on the impacts of these actions on outcomes of interest, such as economic activity and GHG emissions across sectors.

The modelling investigates three scenarios about possible technological developments that reduce GHG emissions. Each scenario is associated with matching policy and investment strategies adopted by the government and private actors. These policies and strategies will also vary according to which target is chosen. Combining each scenario with each target creates six pathways that the modelling investigates. Along each pathway will be major long-term impacts on investment in capital assets in the energy and industrial sectors, and on the use of land for agriculture and forestry. Sections 3.3 and 3.4 describe and assess these impacts.

In the modelling, the central policy lever for the government is its influence over the emissions price. As detailed in Chapter 5, this influence comes through setting the total number of emission permits in the New Zealand Emissions Trading Scheme (NZ ETS).

The modelling results suggest that New Zealand could move onto a low-emissions pathway at emissions prices that are moderate by international standards. This pathway to decarbonisation would rely on three key drivers: the expansion of forestry, changes to the structure and methods of agricultural production, and

switching from fossil fuels to clean electricity and other low-emissions energy sources in transport and process heat. By combining these drivers, New Zealand could move to a pathway consistent with 25 Mt CO₂e in 2050 at emissions prices that rise to between \$75/t of CO₂e and \$150/t of CO₂e by 2050 (where prices are in 2017 New Zealand dollars).

Further, the results suggest that New Zealand could reach net-zero emissions by 2050, with emissions prices rising to between \$150/t of CO₂e to \$250/t of CO₂e. These are within the estimated range of the emissions prices likely to be required in other developed countries to deliver on the objectives of the Paris Agreement.

Across all modelled pathways, the expansion of forestry is central to achieving large reductions in net emissions. This is particularly the case to achieve net-zero emissions by 2050. Yet this reliance on forestry could create challenges in the longer term – with continued emissions reductions required after 2050 to maintain emissions at (or below) net-zero. New Zealand would need to find other ways to reduce emissions or continue to sequester emissions by further expansion of permanent forestry or forestry for harvest. But New Zealand has time to consider these options and pursue technological developments with the potential for further cost-effective mitigation.

The modelling shows that switching from fossil fuels to clean electricity and other low-emissions energy sources in transport and process heat has the potential to play a large role in supporting New Zealand's emissions-reduction objectives. With the country's current comparatively emissions-intensive vehicle fleet and its low-emissions electricity system, a move to electric vehicles (EVs) could deliver significant and rapid reductions in emissions. The tendency of New Zealanders to keep their vehicles on the road for up to 20 years or more works against this if no additional measures are put in place.

Emissions reductions in the agricultural sector can be delivered through a mix of technological and structural change. With reductions in emissions intensity, the dairy industry may be able to expand – although this will be limited by water-quality concerns. Sheep and beef farming are likely to contract, in a continuation of recent trends. The scale of this shift will be driven by demand for land from an expanding forest sector, whose high value will mean it will become more profitable for some farmers to plant trees rather than retain livestock on this land.

The results indicate that greater technological change and early action to raise emissions prices will help to constrain long-term costs. Given technological change is uncertain, this suggests that early action provides future options. Those options would allow New Zealand to benefit from low costs should technological breakthroughs occur. And New Zealand would be able to continue to meet its commitments with lower risk of high emissions prices in the future, should technological progress be slower than hoped.

Choices made now will have long-term consequences. For instance, assets such as road vehicles and industrial boilers may remain in operation for several decades. Likewise, a landowner's decision to convert land may have implications for land use over an extended period. Given these dynamics, it is important to influence these decisions sooner rather than later, to avoid locking in higher emissions for decades. Yet taking stronger early action would need to be balanced against a concern that moving more quickly than international partners could, without protective measures, lead to problems such as some economic activities moving offshore and even an increase in global emissions.

Decision makers can and should update their strategies over time as uncertainties resolve and evidence accumulates. In other words, it is both reasonable and appropriate for New Zealand to adapt its policies in response to changed circumstances and a changing evidence base, and take steps to anticipate and avoid adverse outcomes.

3.2 Modelling approach: framework, methods and assumptions

Early in the inquiry the Commission and the Ministry for the Environment (MfE) contracted a consortium of organisations with experience in modelling and the economics of climate change mitigation to undertake modelling of New Zealand's transition to a low-emissions economy. The three organisations and their specialisms are noted below.

- **Concept Consulting Group** is a specialist energy and economics consultancy based in Wellington. It has done recent work for the Parliamentary Commissioner for the Environment, and several energy distribution companies (Concept Consulting, 2016b, 2017a, 2018a).
- **Motu Economic and Public Policy Research (Motu)** is a leading economic and public-policy research institute with an extensive, distinguished record of work focused on the environment and agriculture. Recent work on climate mitigation policy includes Motu (2017), Kerr (2016), and Kerr et al. (2017).
- **Vivid Economics** is a London-based consultancy whose practice areas include carbon pricing, energy and industry, growth and development, and natural resources. Vivid Economics produced the report *Net Zero in New Zealand* for GLOBE-NZ, a cross-party group of 35 members in the last Parliament (Vivid Economics, 2017a).

Vivid Economics headed the consortium and led the interpretation and reporting of modelling results. Motu used its Land Use in Rural New Zealand (LURNZ) model to simulate the effects of the emissions price and other factors on owners' land-use decisions between forestry, dairy, sheep/beef, scrub and horticulture. Concept Consulting used its Energy and Industry (ENZ) model to simulate the effects of the emissions price and other factors on decisions in the transport, energy, process heat and industrial processes parts of the economy, as well as on household decisions such as whether to buy an EV or install heat pumps for home heating. Concept Consulting also integrated the LURNZ and ENZ models into what became, in effect, a model of the whole New Zealand economy as it transitions to progressively lower emissions. Two reports (Concept Consulting, Motu Economic and Public Policy Research, and Vivid Economics (2018a, 2018b)) together contain full descriptions of the modelling and results.

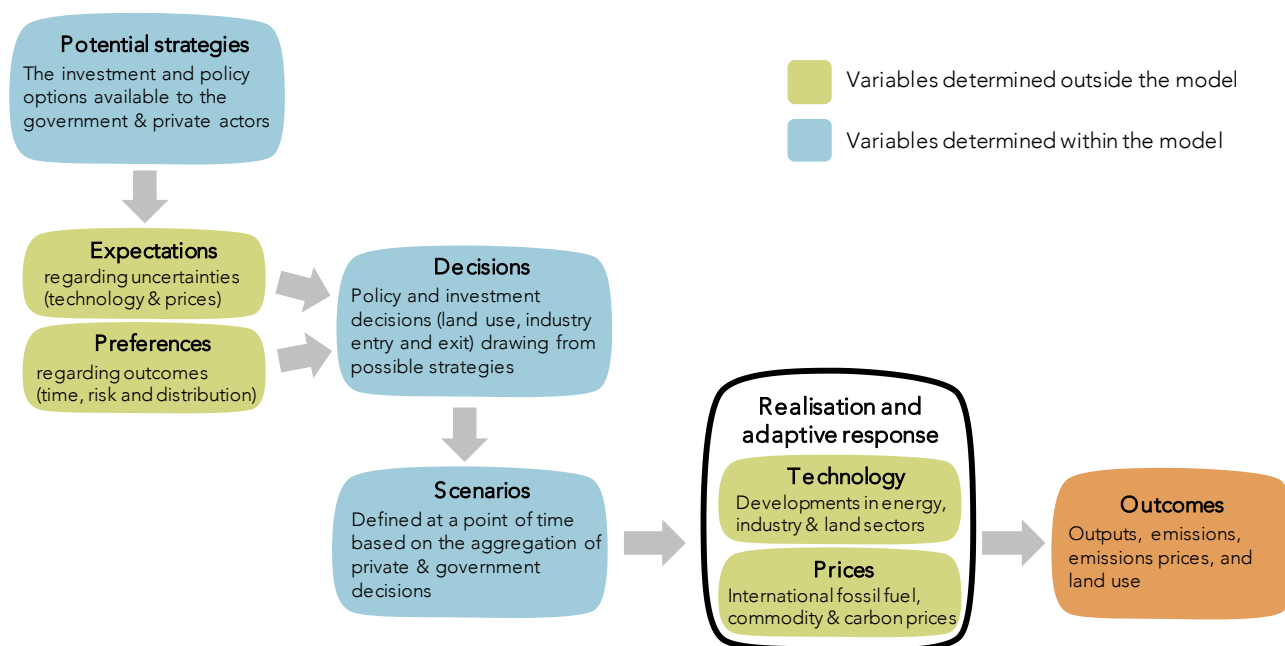
In addition to the modelling for this inquiry, MfE commissioned the New Zealand Institute of Economic Research (NZIER) to undertake other modelling to inform its climate policy advice. This modelling used a different type of economic model to examine New Zealand's transition to a low-emissions economy (NZIER, 2018). A subsection of section 3.3 below compares and discusses some of the results from the two modelling exercises. MfE has commissioned NZIER to extend and refine its modelling but the results of this work were unavailable at the time of publication of this report. MfE also commissioned a wider set of studies to inform its climate policy advice. These studies are available on MfE's website.

The conceptual framework

The Concept Consulting, Motu, Vivid Economics (CMV) model framework is illustrated in Figure 3-2. The starting point is a set of actors comprising the government on the one hand and private actors (businesses and households) on the other. Each actor has a set of potential strategies from which to choose (eg, how high to price emissions, or whether and when to replace high-carbon assets with low-carbon assets). Each actor decides their best strategy based on their preferences and their expectations about how the future will evolve (in terms of features such as technology and prices). The government is concerned to achieve an emissions target for the whole country at least economic cost. Businesses want to be commercially successful, and households want a high standard of living (including good environmental quality).

Scenarios

When the government decides a strategy, and acts on it by setting a clear, long-term emissions target and implementing policies that reward some behaviours and discourage others, businesses and households respond to these signals and incentives. The government's actions and the private sector's responses add up to a pattern of decisions across society. The pattern reflects the preferences and expectations of the actors. This pattern of decisions is called a *scenario*.

Figure 3-2 Conceptual structure of the CMV modelling

Source: Concept Consulting et al. (2018a).

The government has many policy levers and institutional arrangements that it can use to deliver on the emissions target. Among them, emissions pricing is central because it provides economy-wide incentives that encourage business and individuals to consider the costs of emissions when making investment and consumption decisions. The government may also adopt other policies alongside or instead of emissions pricing. The government's policy stance and mix will reflect:

- the ambition of its emissions target;
- its expectations about future technology developments and shifts in demand;
- the preferences and the trade-offs it will have to make to achieve emissions reductions and other goals that are important. For example, different emissions reduction policies will have different impacts on the various groups and sectors that make up New Zealand's economy and society. The government will have preferences about how the impact should be distributed across these groups (Chapter 10); and
- intertemporal trade-offs – because GHGs vary in their impact on the climate over time. This could lead to the government choosing to take different approaches to short- and long-lived GHGs (Chapter 9), for example.

Taking some examples of business decisions, the choice by a landowner about whether to convert land from dairy production to forestry will be a function of not only current policies and prices (eg, commodity prices and the emissions price) but also expectations regarding how such policies and prices will evolve in the future. Similarly, investors making decisions about the composition of new electricity-generation assets, or about the future of emissions-intensive manufacturing, will factor in their expectations about future demand, prices (commodity and emissions), and technological developments.

Technology development is part of every scenario

A fundamental part of every scenario noted above is the actors' expectations about future technological developments. Technology has the potential to lower the cost of reducing emissions. While reality is bound to be complex, the modelling assumes that technology in decarbonisation will develop in one of three distinct ways: policy-driven, disruptive, or stabilising. These ways differ in two dimensions – the extent of technology development, and the type of technology development. In turn, the technology will have varying impacts on demand, production patterns, and prices throughout the New Zealand economy. The three scenarios, which incorporate different forms of technology development, are noted below. As well as the technology itself, each includes associated policy choices.

- **Policy Driven** – this scenario features slow technological change that is evenly spread across sectors. This means that efforts to reduce emissions can expect only modest help from new technologies. Rather, they will need to rely on strong policy action, particularly a greater rise in emissions prices, to achieve the emissions targets. As seen in the modelling results, the high emissions prices stimulate a rapid expansion of the forestry sector (including policy to support native afforestation) and contraction of emissions-intensive animal agriculture. In the transport sector, the government provides further incentives to support public and active transport, and EVs enter the fleet at only a moderate pace since EV prices fall relatively slowly.
- **Disruptive Decarbonisation** – this scenario features rapid technological change that disrupts current economic structures, with new technologies and products creating new markets, destroying demand in traditional industries and accelerating turnover in capital assets. A shift in global demand patterns supports the expansion of horticulture and reductions in dairy. EVs spread rapidly due to low costs, supportive policies and consumer preferences. The reduction in the cost of renewable generation is reflected in the closure of coal-fired generation capacity, and a reduction in baseload gas-fired generation capacity. It is assumed that aluminium and steel plants choose to close in response to expectations that global technological developments and market shifts will reduce demand for these products.¹³
- **Stabilising Decarbonisation**¹⁴ – this scenario features rapid technological change that stabilises existing industry structures through the emergence of new mitigation options (such as methane vaccines and nitrogen inhibitors) that reduce the need for large shifts in economic activity. Recent trends to convert land for dairy farming continue at a modest rate. In transport, efficiency improvements in internal combustion engine vehicles and slow reductions in battery costs result in much slower uptake of EVs.

These three scenarios are illustrated in Figure 3-3 by locating them against the two dimensions of expectations that drive decision making: the pace of technological change, and the extent that industry composition changes. The differences between these scenarios are profound and fundamental to New Zealand's future as it seeks to transition to a low-emissions economy. For instance, as a major exporter of agricultural products, New Zealand's pastoral agriculture faces a significant risk that hi-tech firms could develop synthetic meat and dairy products to the point they become extremely cost-competitive with traditional products, with a fraction of the environmental footprint.¹⁵

Pathways to 2050

The modelling examines pathways from the present to the two 2050 emissions reduction targets. The number of pathways modelled is six because each of the three technology scenarios is linked with each of the two emissions targets as shown in Table 3.1. The right column shows the abbreviations for each pathway.

Table 3.1 The six modelled pathways

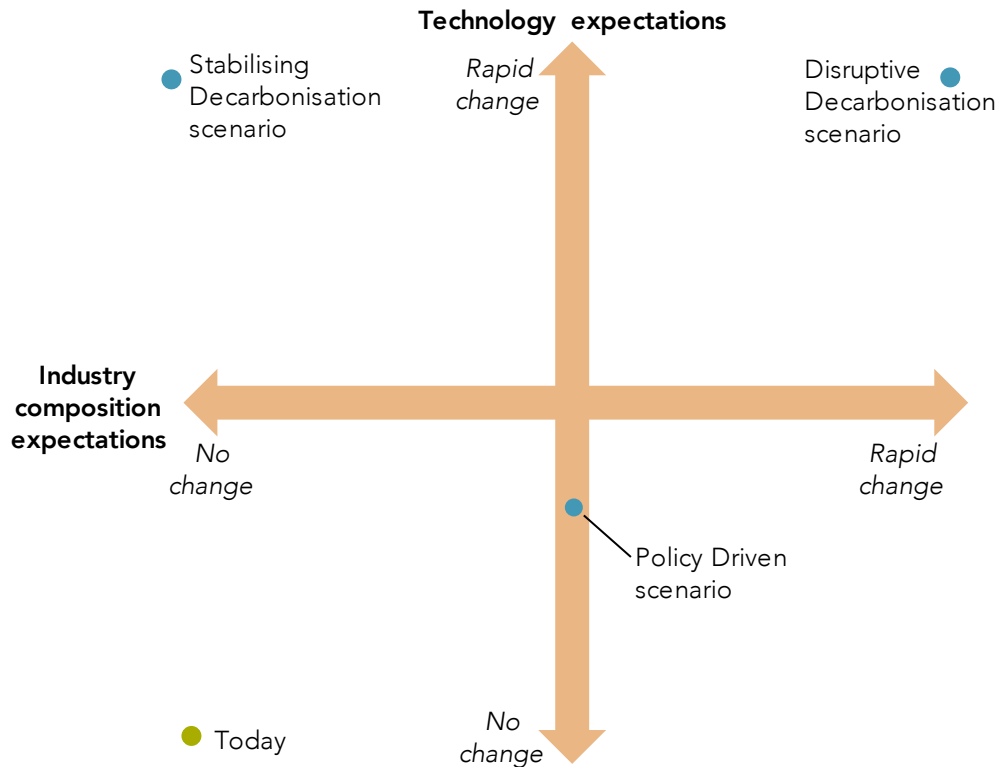
Scenario	Net emissions target in 2050	Pathway name
1. Policy Driven Decarbonisation	25 Mt CO ₂ e	PD-25
2. Policy Driven Decarbonisation	Net zero	PD-0
3. Disruptive Decarbonisation	25 Mt CO ₂ e	DD-25
4. Disruptive Decarbonisation	Net zero	DD-0
5. Stabilising Decarbonisation	25 Mt CO ₂ e	SD-25
6. Stabilising Decarbonisation	Net zero	SD-0

¹³ Making aluminium and steel is an emissions-intensive manufacturing process. New substitute materials may emerge that use a manufacturing process that is less emissions-intensive.

¹⁴ In Concept Consulting et al. (2018a), the Stabilising Decarbonisation scenario is called "Techno-optimist".

¹⁵ The low environmental footprint is likely to manifest in outcomes such as better water quality and low GHG emissions. Factoring in emissions prices for farm-produced meat and dairy products would make the synthetic versions even more cost-competitive.

Figure 3-3 Illustrative mapping of technology scenarios against expectations that drive decision making



Source: Concept Consulting et al. (2018a).

The three sets of pathways also represent differences between demand-side and supply-side mitigation. The Policy Driven pathways are characterised by policy that pushes up the price of emissions-intensive products and processes and causes the demand for them by households and businesses to drop and switch to lower-emissions alternatives. By contrast, the Disruptive and Stabilising Decarbonisation pathways are characterised by supply-side response to new technology opportunities: the Disruptive Decarbonisation pathway is associated with new products and services and rapid industrial change; while the Stabilising Decarbonisation pathway is based on the emergence of new technologies that reduce emissions intensity of existing industries and enables them to continue.

F3.1

The Commission's modelling depicts, in a stylised manner, three possible ways that low-emissions technologies could develop. First, they could fail to develop or develop only slowly. Second, they could develop faster in ways that disrupt existing industries. Third, they could also develop faster, but lower the emissions intensity of existing industries. The differences between these ways in which technology could develop are profound and fundamental to New Zealand's future as it seeks to transition to a low-emissions economy.

Of course, sharply differentiating between three broadly different technology patterns is a crude way to capture the critical effects of technological change on emissions pathways. Ideally a model would simulate the dynamics of technological change, including the way that an emissions price incentivises innovation. But this is extremely difficult to do. The Parliamentary Commissioner for the Environment commented on these points:

Innovation and technological change are what matter most for long term emissions reductions. Yet assumptions about innovation are inputs into the modelling and prices are the headline result. There is no explicit feedback loop, in the modelling, between emissions prices, or expectations about emissions prices, and investment in new technologies or new knowledge. Modelling innovation is of course extremely difficult, and it is inevitably assumption driven. But the mitigation pathways and prices

presented in the report are also driven by assumptions about innovation. So more attention to those assumptions and to innovation dynamics would be useful. (DR387, p. 2).

Uncertainty analysis

Decision makers know that the world is uncertain and the future may not turn out as expected. But they also know they will have opportunities to revise their strategies as they observe how conditions are evolving. To capture this important reality, CMV undertook a second stage of modelling for the Commission that explored the implications of future external factors (eg, technology and international emissions prices) turning out differently than expected. It considered the ability of decision makers to “re-optimize” as more information about key uncertainties is revealed. Concept Consulting et al. (2018b) contains detailed results of this modelling.

The modelling provides insights about which starting strategies for achieving a low-emissions economy will not only be sensible in the short run, but also resilient to future information “shocks”. Resilient strategies take uncertainty into account by preserving rather than closing off future options. Resilient strategies also enable adjustments to be made as needed along the way without causing excessive costs or regrets about earlier decisions.

The key reasons for extending the modelling to include uncertainty and the ability of decision makers to adapt their strategies in the light of new information are captured in the National Energy Research Institute’s submission.

[W]hat will be required is an adaptive approach, i.e. starting with our current situation and selecting what look like the best options for action towards the 2050 goal in light of the current state of knowledge and the uncertainty. As more information flows in, the process is adapted in light of this. This requires not only an understanding of potential benefits but also a high level of awareness of the potential for lock-in to undesirable long-term outcomes, especially as infrastructure investments may have lifetimes of 50-80 years. Any mitigation pathways will evolve from this process.

A consequence is that the optimum policy responses at any time (e.g. institutional change, pricing, regulation, investment etc.) will be state dependent. (DR337, p. 6)

Key uncertainties

The key future uncertainties facing New Zealand’s low-emissions transition are:

- technological change;
- fossil-fuel prices and commodity prices; and
- international carbon prices.

In general, rapid emissions-reducing technological change will decrease global mitigation costs. However, the specific nature of this change can result in different impacts across industries. As noted, in the agricultural sector, advancements in the development of plant-based meat substitutes and cellular agriculture would result in accelerated movement away from animal-based agriculture and growth in the production of crops or horticulture. By contrast, development of vaccines to reduce the production of methane by livestock would increase the competitiveness of pastoral agriculture relative to alternative land uses (assuming that agricultural emissions are priced). In the transport sector, increased internal combustion engine (ICE) fuel efficiency could prolong the use of ICE vehicles, while rapid improvements in EVs and reductions in their cost could accelerate the transition away from ICE vehicles.

The prices of fossil fuels and commodities are key uncertainties that will determine changes in the level of production, especially in trade-exposed industries such as agriculture, forestry and manufacturing. New Zealand acts as a price taker in most tradeable goods markets, making its economic performance closely linked to commodity prices. Fossil-fuel prices also play an important role in helping to determine the competitiveness of different electricity-generation assets and transport technologies.

International carbon prices, or equivalent policies,¹⁶ are a key determinant of the relative costs of emissions between jurisdictions. Differences in carbon prices across countries can be a driver of carbon leakage where production transfers from a jurisdiction with a higher carbon price to one with a lower carbon price, even though the latter may have a higher emissions intensity. The modelling includes simulation of the international competitiveness of trade-exposed industries in New Zealand.

Outcomes of interest will emerge as uncertainties resolve themselves

The outcomes that flow from embarking on a pathway are uncertain at the time the decisions that underpin it are made (and when the expectations that influence those decisions are formed).¹⁷ These outcomes relate to matters of daily economic life such as prices, products, jobs, business outcomes and economic costs. The six pathways modelled in the first stage assume that the decisions government and private actors make are based on expectations that turn out to be correct. Yet how a pathway turns out *in reality* will depend on the resolution of the uncertainties about technology and other factors as New Zealand pursues its low-emissions strategy. If expectations turn out to be correct, then expected outcomes will eventuate. If not, then the realised outcomes will be different.

Revising strategies as new information becomes available

No clear future point exists at which uncertainties resolve themselves and decision makers can revise their strategies. New information about such matters as technological advances and commodity prices arrives in a fairly continuous stream. But this information comes with further questions, such as is the new information a blip or is it a trend, and how much will the new technology cost? Further, it would be undesirable to adjust policy settings with every new piece of information. That would lead to great policy uncertainty. Rather, businesses and households require clear direction and policy stability if they are to be confident about making investments that reduce emissions. Later chapters describe policy frameworks that seek to strike a balance between responsiveness to new information and policy stability.

The second stage of CMV modelling takes 2030 as the point at which the government and private actors re-set their climate strategies after considering new information.

How uncertainty variants were modelled

The uncertainty modelling provides a simplified representation of the future by differentiating between two periods. It presents three scenarios for how the world may develop to 2030, at which point circumstances could change dramatically. The New Zealand government, businesses and individuals then adjust to these new conditions. The modelling setup is illustrated in Figure 3-4.

The modelling assumes that in the first period, between 2015 and 2030, governments and other actors make policy and investment choices based on a known economic environment. The choices and associated outcomes in this period define the 'scenarios'. This modelling employs the same three scenarios developed in the first stage and described above: Policy Driven, Disruptive Decarbonisation, and Stabilising Decarbonisation. Box 3.1 explains some differences in how these scenarios were specified.

In the second period, between 2030 and 2050, the economic environment may change – specifically regarding fossil-fuel prices, international emissions prices, and the pace and nature of technological change. Actors respond to these changed circumstances, but the way in which they can do so is affected by the combinations of choices and technological and price outcomes realised in the 2015–2030 period. The different states of the world that could emerge in the 2030–2050 period are called *uncertainty variants*. The modelling considers three uncertainty variants that differ in the pace and nature of technology development and in associated commodity prices. These each align with one of the earlier-defined scenarios:

- Moderate technological change (which aligns with the Policy Driven scenario);
- Innovation disrupting existing industries (which aligns with the Disruptive Decarbonisation scenario); and

¹⁶ Other pricing mechanisms such as energy and fuel taxes can have an "effective carbon rate", while different measures such as regulations can indirectly impose costs on emissions-causing activities (OECD, 2016d).

¹⁷ A decision can also be to do nothing except wait for the uncertainty to be resolved, and then decide. Yet, a strategy of wait and decide can be risky if, by failing to act now, an adverse and irreversible change in the environment occurs down the track that could have been prevented by acting sooner.

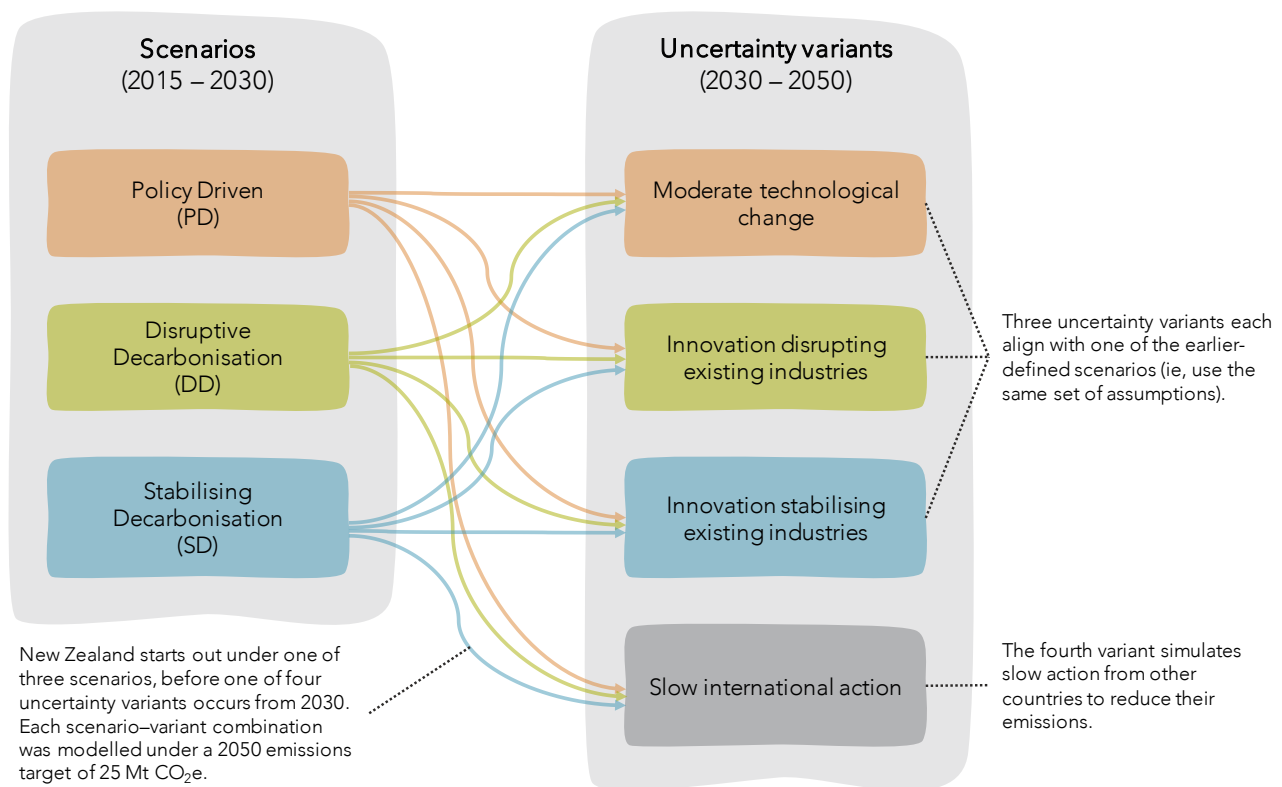
- Innovation stabilising existing industries (which aligns with the Stabilising Decarbonisation scenario).

The modelling also includes a fourth uncertainty variant to simulate slow action by other countries to reduce their emissions. It is defined by a low international emissions price and other associated assumptions. These include high prices for oil, metals and animal products, and slow improvements in the cost of EVs and renewable electricity sources.¹⁸ Government is assumed to respond by slowing the rate of withdrawal of free allocations in the ETS to protect trade-exposed producers.

The three scenarios (from 2015–2030) are each combined with the four uncertainty variants (from 2030–2050), giving a total of 12 scenario–variant combinations. Each combination was modelled under a 2050 emissions target of 25 Mt CO_{2e}. The net-zero emissions target was not used in the uncertainty analysis.

Separately, additional modelling also tested the sensitivity of the results to assumptions about population growth rates and rates of withdrawal of free allocation in the NZ ETS.

Figure 3-4 Illustration of the second stage of the modelling



Source: Commission analysis of Concept Consulting et al. (2018a, 2018b).

Box 3.1 Differences between the first and second stages of the modelling

Both stages of modelling undertaken by CMV were based on the same three core scenarios. However, the second stage (uncertainty analysis) involved some changes to how these scenarios were specified.

The most important difference is in the treatment of fossil-fuel prices, commodity prices and international emissions prices. In the first stage of modelling, all pathways were assessed using a single set of assumptions about these price variables. In the second stage, CMV varied these assumptions across scenarios and uncertainty variants. This leads to some differences between the first-stage and second-stage results.

The price assumptions in the second stage reflect plausible effects on global demand in line with the scenario expectations. For example, the Disruptive Decarbonisation scenario (and aligned uncertainty variant) assumed lower pastoral agricultural commodity prices and higher forestry commodity prices

¹⁸ For more information, see Tables 2 and 3 in Concept Consulting et al. (2018b).

compared to the baseline. This plausibly reflects lower demand for traditional meat and dairy products due to synthetic alternatives, and higher demand for timber as a substitute for emissions-intensive building materials. The Stabilising Decarbonisation scenario (and aligned uncertainty variant) featured the inverse assumption, with higher agriculture product prices and lower forest product prices.

The second stage of modelling also involved revised scenario assumptions on ETS free allocations and vehicle scrappage rates across the scenarios, and updates and refinements to the electricity module of the model.

The reports by CMV provide a full description of both stages of modelling and the assumptions used (Concept Consulting et al., 2018a; 2018b). Table 3.2 below also lists some key assumptions.

Source: Concept Consulting et al. (2018a, 2018b).

Like all modelling, the uncertainty analysis has limitations. Its ability to capture the impact of uncertainty to 2030 is limited as it assumes policy and investment decisions align with reality, while after 2030 the relative performance of different scenarios is tested against only a limited range of outcomes. As such, this modelling should be seen as the first stage of an ongoing process of analysing adaptive policymaking that responds to and integrates new information as it arises.

As noted, decision makers can continuously observe how conditions are evolving compared with expectations and can adjust their decisions from time to time. A large one-off adjustment in 2030 is not realistic. But neither would continuous adjustment be realistic or desirable. Allowing only a one-off adjustment at 2030 in the modelling simulates in a crude way this constrained flexibility. The year 2030 also coincides with the end of the period for New Zealand's first Nationally Determined Contribution under the Paris Agreement.

How does the modelling work?

As noted, the modelling draws on two models: Concept Consulting's ENZ model, and Motu's LURNZ model. The two models together cover almost all New Zealand's GHG emissions and provide a robust base for testing the implications of policy and investment strategies across the economy.

The models are "structural" models in that they break down the New Zealand economy into individual sectors (eg, transport), and then explicitly model the effects of key drivers of outcomes in those sectors. Box 3.2 and Figure 3-5 provide short descriptions of the models. The technical appendix of Concept Consulting et al. (2018a) provides much fuller descriptions.

The emissions price plays a key role in the models. It is the major driver of the actions that actors take to lower their emissions such as land-use change and fuel switching. In reality, other policies will also influence these actions. The emissions price in the model can be thought of as, in part, reflecting this wider set of policies.

Box 3.2 Short descriptions of the models used

Concept Consulting's ENZ model

ENZ is a series of inter-dependent modules or sub-models. The sub-models seek to identify the least-cost means of meeting demand for a service (for instance transport, process heat or electricity) given the underlying market drivers (such as population growth, emissions prices, fossil-fuel prices and technology costs) and policy actions that are exogenous (have an external cause or origin). Two such examples are support for shifting travel modes to public transport/cycling, and the forced closure of a fossil-fuelled power station. Some sub-models are highly dynamic and model the key drivers of outcomes in detail. For example: the electricity-sector modelling considers the intermittency in renewable generation (particularly in hydro and wind generation) and the transport-sector modelling considers differences between light- and heavy-fleet road transport. Conversely, some sub-models are

relatively simple, reflecting their relatively small share of emissions, the existence of significant uncertainty, or both.

The basic premise is that the business actors in the scenarios are driven by profit motives and will choose the lowest-cost investments to meet demand. Costs include the prices for GHG emissions. Effectively, supply-side investment decisions are targeted at meeting demand in the future at least cost. Household decisions focus on fuel and energy choices, including household investments in the expensive, long-lived assets associated with these (eg, vehicles and home heating). The model also simulates some of the non-price drivers of consumer decisions.

Motu's LURNZ model

LURNZ is a dynamic and spatially explicit, partial-equilibrium model of rural land use. It can simulate changes in dairy, sheep, beef, forestry and scrub in response to changes in economic incentives. In addition, it can spatially allocate exogenously determined changes in horticulture according to land suitability. LURNZ also simulates land-use intensity and emissions (or sequestration) associated with these land uses.

At the core of LURNZ are two econometrically estimated models that establish the relationship between observed drivers of land use and land-use outcomes:

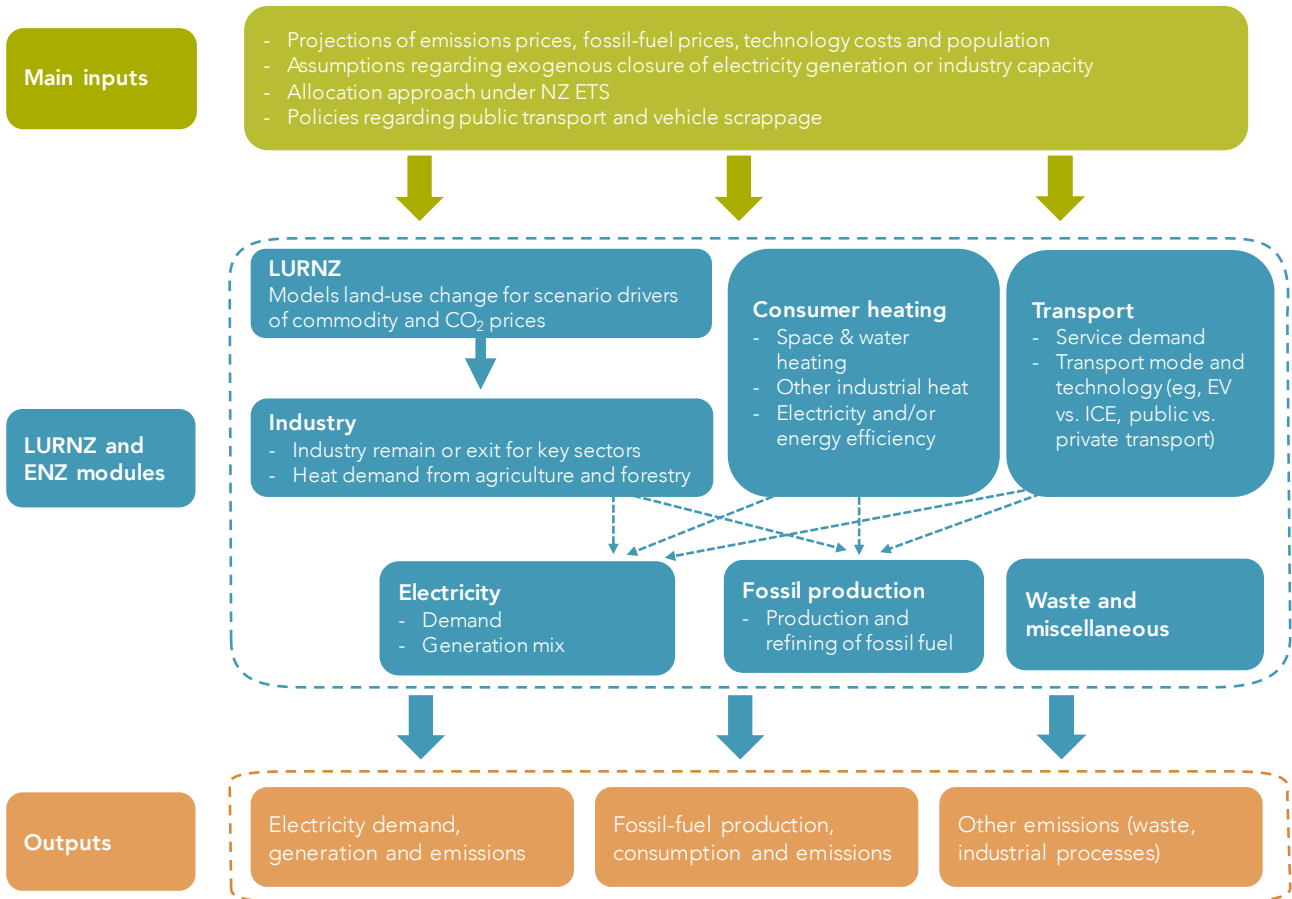
- a system of regression equations that estimate dynamic land-use responses to changes in economic drivers, such as commodity prices, at the national level; and
- a spatial model that relates land-use choices to various geophysical characteristics of the land, and to proxies for the cost of market access, land tenure and yields. The model disaggregates land into 25 hectare blocks.

LURNZ has a strong empirical basis. It requires relatively few assumptions about farmers' objectives and decision processes: results are largely driven by how land use has responded to its main drivers in the past. The model's underlying datasets and processes have been validated, and its results are consistent with data and trends at the national scale, including New Zealand's Greenhouse Gas Inventory.

Combining the models

Links between sectors are made through the outputs from one sector feeding into the inputs of another sector, both within and between models. For example, the outputs of LURNZ, in terms of meat and dairy production, feed into the ENZ module of industrial process heat which, in turn, feeds into the ENZ modules for electricity generation and gas production. Figure 3-5 illustrates how the models, sectors and modules are linked.

Figure 3-5 How the models, sectors and modules are linked



Source: Concept Consulting et al. (2018a).

The assumptions of the modelling

In common with other modelling, the CMV modelling makes a large number of assumptions about parameter values and how variables change over time. In particular, different assumptions about rates and types of technological change (and prices that result from them) characterise the Policy Driven, Disruptive Decarbonisation and Stabilising Decarbonisation scenarios.

Table 3.2 lists some of the more important assumptions – those common across the scenarios and those that differ. Concept Consulting et al. (2018a) contains a full list and description of the assumptions.

Table 3.2 Key scenario assumptions

Variable	Policy Driven	Disruptive Decarbonisation	Stabilising Decarbonisation
Universal assumptions			
ETS coverage	All sectors are covered, including agriculture. No international trading.		
Population growth (average to 2050) ¹⁹	1% a year		
Forestry emissions accounting	Averaging approach for radiata pine forestry with new forests credit up to 21 years after planting. No credit/debit after that if land is replanted. This reflects expected accounting method under New Zealand’s NDC. Average annual sequestration rate is 31.8 t CO ₂ e a hectare based on National Inventory Report lookup table.		

¹⁹ Population growth in the earlier years is significantly greater than in the later years, as noted in Statistics NZ’s central forecasts.

Variable	Policy Driven	Disruptive Decarbonisation	Stabilising Decarbonisation
ETS free allocations			
Free allocation of units to emissions-intensive, trade-exposed activities	From 2015 to 2020, allocation in line with current settings, with agriculture receiving a 90% allocation. From 2020, fast withdrawal of assistance, withdrawn at 3 percentage points a year from 2020 to 2030 and 5 percentage points a year from then on	Same as for Policy Driven	From 2015 to 2020, allocation in line with current settings, with agriculture receiving a 90% allocation. From 2020, slow withdrawal of assistance, withdrawn at 1 percentage point a year from 2020 to 2030 and 3 percentage points a year from then on
Industry			
Iron & steel and aluminium production	Future operation endogenously modelled based on New Zealand and international emissions prices	Exogenously specified closure in 2025	Future operation endogenously modelled based on New Zealand and international emissions prices
Transport			
Rate of cost reduction in EV batteries	Medium: 6% a year	High: 8% a year	Low: 4% a year
Rate of improvement in the fuel efficiency of the ICE vehicles	Medium	Medium	High
Extent of mode-shifting to public transport, walking and cycling, and car-sharing ²⁰	50% increase over 30 years in the proportion of trips by public transport, walking, and cycling; and a 20% increase in the proportion of car-sharing	75% increase over 30 years in the proportion of trips by public transport, walking, and cycling; and a 30% increase in the proportion of car-sharing	25% increase over 30 years in the proportion of trips by public transport, walking, and cycling; and a 10% increase in the proportion of car-sharing
Vehicle scrappage rates ²¹	Scrappage rates continue at historic rates	Scrappage rates are 25% higher than historic rates	Scrappage rates are 25% lower than historic rates
Electricity			
Rate of cost reductions in new renewable generation	Cost reductions for wind, solar and geothermal of 1.25%, 2.5% and 0.25% a year respectively	Cost reductions of 1.5 times the rates for Policy Driven	Cost reductions of 0.5 times the rates for Policy Driven
Agriculture			
Emissions intensity	Continuous improvement (year on year) in the efficiency of GHG emissions per unit of product produced, with dairy and sheep/beef	Same as for Policy Driven	Same as for Policy Driven, except that a methane vaccine becomes available after 2030: reducing dairy livestock emissions by 30%, and sheep/beef emissions

²⁰ The Medium scenario assumes a 50% increase over 30 years in the proportion of trips by public transport, walking, cycling, and a 20% increase in the proportion of car-sharing. The High and Low scenarios assume increased rates of 75% and 25% respectively (except for car-sharing which are 30% and 10%, respectively).

²¹ Scrappage indicates the proportion of vehicles scrapped each year. A high scrappage rate results in more vehicles being brought into New Zealand to meet the demand for transport, and results in a lower average life of a vehicle before it is scrapped.

Variable	Policy Driven	Disruptive Decarbonisation	Stabilising Decarbonisation
	intensity based on the "minimum efficiency" baseline scenario in Reisinger et al. (2016)		by 20%. 100% adoption rate is assumed
Horticulture area	Linear increase to 500 000 hectares by 2050	Linear increase to 1 000 000 hectares by 2050	Constant
Forestry			
Mix of tree species	Natives make up 33% of new forests	100% exotic	100% exotic

Source: Adapted from Concept Consulting et al. (2018a).

3.3 Modelling results

The modelling results paint a picture of a New Zealand in 2050 that has changed significantly from today. New Zealand's economic structure evolves over the next three decades to achieve its decarbonisation objective under a variety of potential futures. The modelling suggests movement away from some traditional industries, and the creation of new ones (for instance, electrified transport), and points to the important role that new technologies could play in enabling a low-emissions economy.

This section begins by describing the results of the six pathways (Policy Driven, Disruptive Decarbonisation and Stabilising Decarbonisation under the two targets for net emissions in 2050: 25 Mt CO_{2e} and zero). In line with the abbreviations in Concept Consulting et al. (2018a), the six pathways are: PD-25, PD-0, DD-25, DD-0, SD-25 and SD-0. Later, the section describes the results of the uncertainty analysis undertaken in the second stage of the modelling.

For each pathway, the modelling found emissions-price trajectories and associated pathways that succeeded in reducing emissions to the 2050 targets or, in the case of two pathways, to close to the targets. In doing this, the modelling also estimated the outcomes along each pathway for key attributes of interest including:

- cumulative net and gross emissions along each pathway;
- the change in structure of the energy, transport and industry sectors; and
- the change in size and structure of the agriculture and forestry sectors.

Emissions

The first notable result is that all pathways are feasible. That is, according to the modelling, New Zealand can achieve both the emissions target of 25 MtCO_{2e} and the more ambitious net-zero target by 2050 under each of the three scenarios²² (Figure 3-6).

However, the six pathways take different trajectories resulting in different cumulative emissions over the period. The Disruptive Decarbonisation pathways have the lowest cumulative emissions driven by relatively rapid decarbonisation (compared to other scenarios) in the 2020s. Under DD-25, emissions over the period 2016 to 2050 total 1.6 gigatonnes (Gt) of CO_{2e} – notably lower than the SD-25 or PD-25 pathways which each reach 1.8 Gt CO_{2e}. Under the more ambitious net-zero target, cumulative emissions in DD-0 are 1.3 Gt CO_{2e}, compared to just over 1.5 Gt CO_{2e} in SD-0 and 1.6 Gt CO_{2e} in PD-0.

Comparing the SD and PD pathways, although they achieve similar cumulative emissions over the full period (2016–2050), in the period to 2030 the PD pathways achieve greater emissions reductions than the SD

²² Due to modelling constraints, the Policy Driven and Stabilising Decarbonisation pathways reach close to, but do not reach the net-zero target in these results. PD-0 reaches emissions of 3.9 Mt CO_{2e} and SD-0 reaches 0.4 Mt CO_{2e} in 2050. This implies slightly higher emissions prices to reach the target.

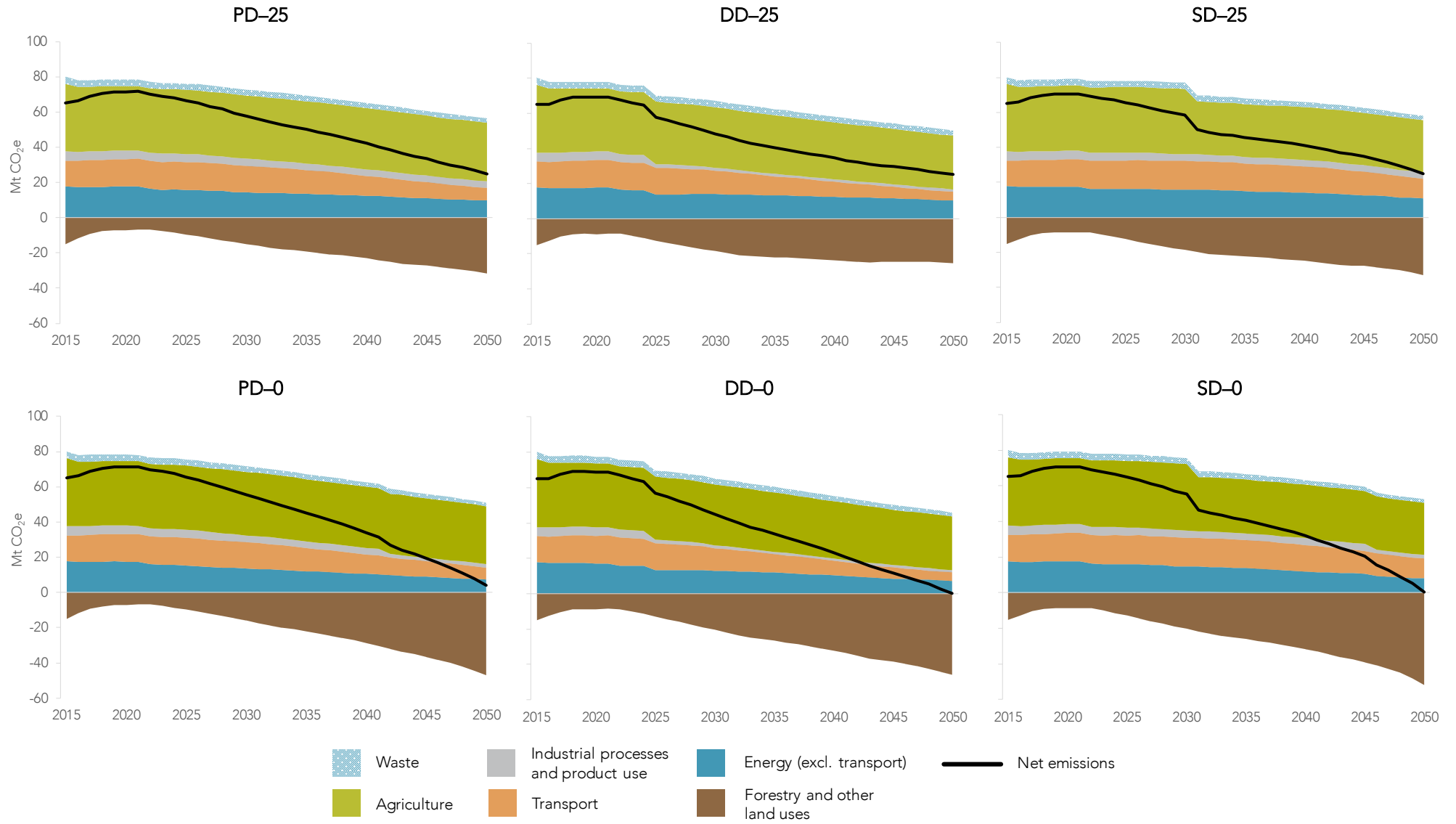
pathways. However, the introduction of a methane vaccine in 2030 sees emissions in the SD pathways drop rapidly and remain below those of the PD pathways for most of the period to 2050.

The pathways also differ in how much different emissions sources contribute to meeting the targets. In all pathways, absolute emissions reductions occur in every broad sector of the economy (Figure 3-7). The DD pathways have especially strong reductions in transport (due to high EV penetration) and industrial processes and product use (IPPU; due to an assumed closure of aluminium plants as well as iron and steel plants). The SD pathways have much smaller reductions in transport, but the largest reductions in agriculture and waste. In every pathway, agriculture has the smallest percentage reduction of any sector, but makes an important contribution due to agriculture's large absolute emissions. Transport and agriculture show very little change in emissions between pathways to the 25 Mt CO_{2e} target and pathways to the net-zero emissions target, reflecting a lack of responsiveness (within the model) to higher emissions prices.

Figure 3-8 shows the emissions reductions each sector contributes by 2050 in absolute terms, alongside the increase in sequestration from forestry. All pathways feature large shifts in land use from pastoral agriculture to forestry. In all but one pathway (DD-25), this expansion of forestry is by far the largest single contributor to net emissions reductions. Even for the 25 Mt CO_{2e} emissions target, the PD and SD scenarios rely heavily on increased forestry sequestration, accounting for 41% and 45% of total net emissions respectively. By comparison, DD-25 features larger gross emissions reductions, with forestry contributing only 25% of the reduction in net emissions. Under all three scenarios, the increase in ambition from the 25 Mt CO_{2e} target to the net-zero target mostly relies on further forestry expansion, with gross emissions only reducing by a further 4–6 Mt CO_{2e}.

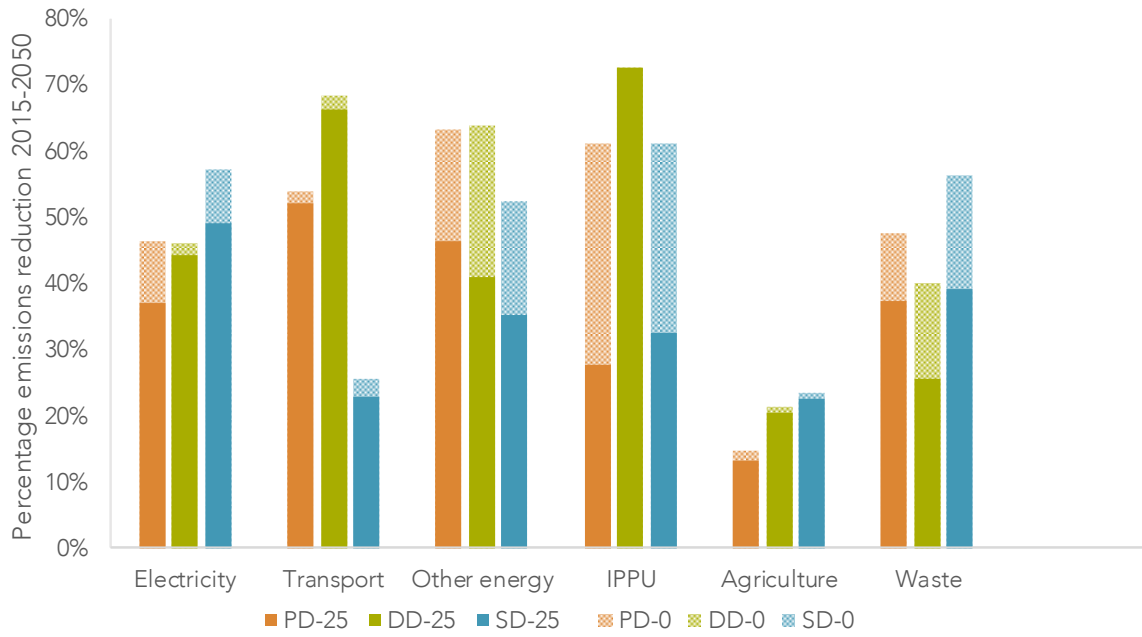
These results, showing that gross emissions are still high in 2050, have important implications for mitigation after 2050. It means that, to achieve or maintain net-zero GHG emissions, the SD and PD pathways in particular will either need to continue to rely on greater amounts of forestry sequestration, or make up the mitigation gap with other, potentially more expensive, options.

Figure 3-6 All pathways deliver large reductions in net emissions



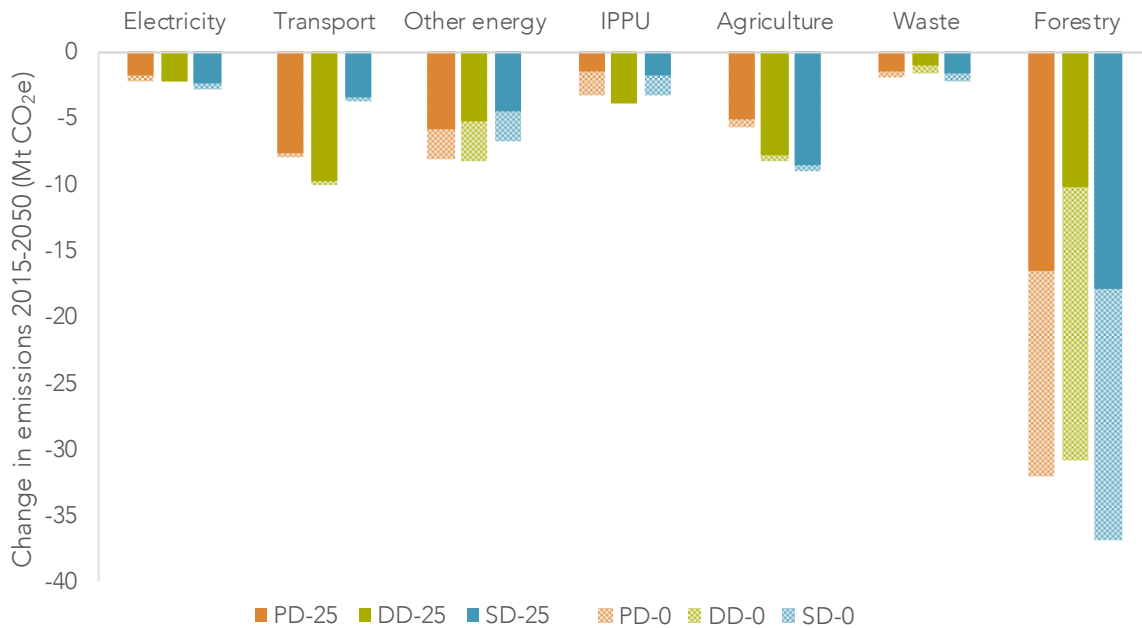
Source: Concept Consulting et al. (2018a).

Figure 3-7 Emissions reduce by varying proportions across sectors



Source: Concept Consulting et al. (2018a).

Figure 3-8 All sectors contribute meaningful emissions reductions, but forestry sequestration is especially important



Source: Concept Consulting et al. (2018a).

Notes:

1. 'Other energy' includes emissions from the generation of process heat and from other direct use of fossil fuels (eg, diesel for farm vehicles), and fugitive emissions from coal and gas production.
2. IPPU covers non-energy related emissions from industrial processes (eg, steel and cement production) and product use (eg, refrigerant gases).

Short-lived and long-lived gases

Chapter 9 discusses the different properties of short-lived GHGs, such as methane (CH₄), and long-lived GHGs, such as CO₂ and nitrous oxide (N₂O). To stop further warming of the atmosphere, emissions of long-lived gases must reach net-zero (measured in CO₂e) while emissions of short-lived gases must stabilise. To play its part in achieving the Paris Agreement’s 2°C goal, an important step for New Zealand is to reduce emissions of long-lived GHGs to net-zero levels (or below) by around mid-century and reduce emissions of short-lived GHGs from the current level.

The CMV modelling reflected prevailing international conventions by treating all GHGs in CO₂e terms using the standard GWP₁₀₀ metric. Consistent with this, the modelling used single CO₂e emissions targets in 2050, rather than separate targets for short- and long-lived gases.

The three modelled pathways to the 25 Mt CO₂e target achieve, or come very close to achieving, net-zero emissions of *long-lived gases* by 2050 (Figure 3-9). In the SD–25 pathway specifically, net emissions of long-lived gases are around 1 Mt CO₂e in 2050 but would reach net-zero in the following year. Further, short-lived GHG emissions are steadily falling in all three pathways (Figure 3-10), at an average rate between 0.4% and 0.8% in the 2040s. As Chapter 9 explains, this means that under these pathways New Zealand would no longer be contributing to further global temperature increases by 2050.

In the pathways to the net-zero emissions target (ie, net-zero emissions of *all* gases using CO₂e), emissions of long-lived gases reach net-zero several years earlier and are substantially negative by 2050.²³ Short-lived gas emissions are also falling at a faster rate than in the corresponding 25 Mt CO₂e target pathways. Therefore, in these pathways New Zealand ceases to contribute to further warming before 2050 and has begun to have a net cooling effect.

Figure 3-9 Emissions of long-lived GHGs are near or below net-zero by 2050

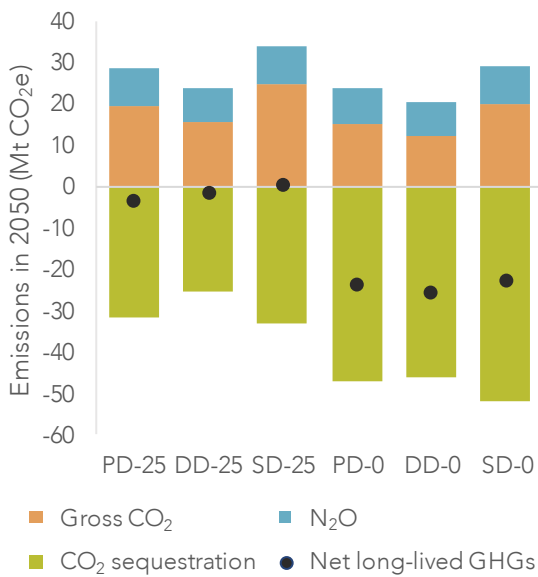
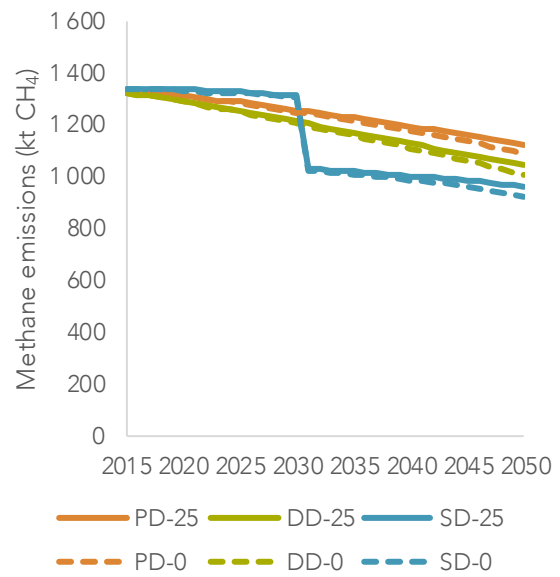


Figure 3-10 Emissions of short-lived GHGs fall in all pathways



Source: Commission analysis of Concept Consulting et al. (2018a).

Notes:

1. Emissions of HFCs (mostly short-lived gases) are not shown but fall to a very low level by 2050.

²³ Emissions of long-lived GHGs reach net-zero in 2038 in DD-0, 2042 in PD-0 and 2044 in SD-0.

Emissions prices

It is important to note that the modelling assumes that the government sets emissions prices up to 2030 according to its expectations under the different scenarios.²⁴ It is only beyond 2030 that emissions prices are generated by the model to achieve the 2050 emissions targets. Table 3.3 sets out the assumed prices at 2030 and the model-generated prices in 2050, and Figure 3-11 shows the full emissions-price trajectories.

The modelling indicates that emissions prices will need to rise strongly from their current levels to achieve the 2050 targets. The estimated range of prices in 2050 is \$75 to \$250 a tonne (t) of CO₂e.

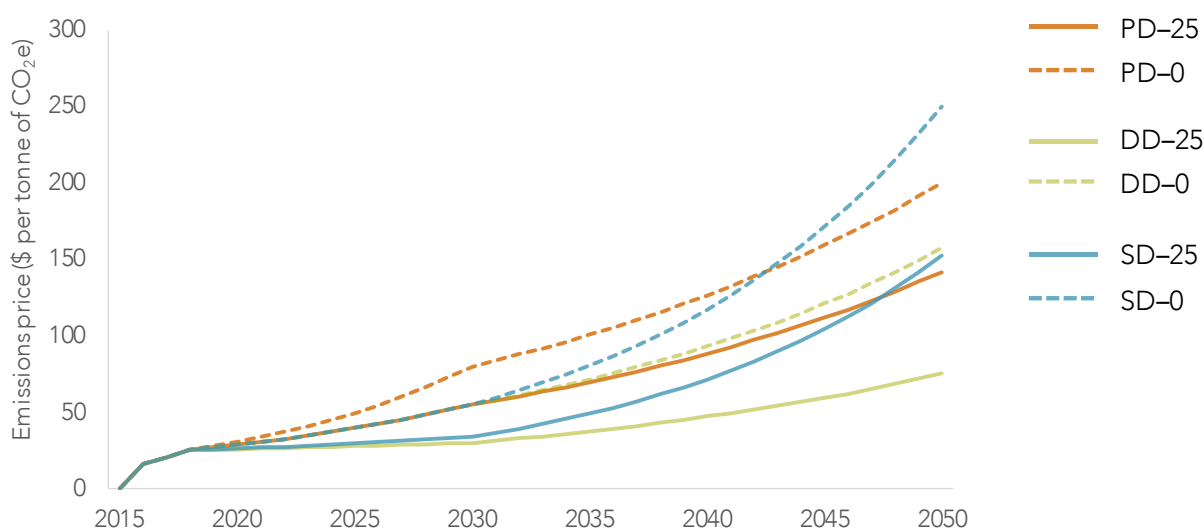
The analysis reveals significant differences in the emissions prices both between pathways and targets. First, the more ambitious net-zero target calls for much higher prices than the 25 Mt target. Comparing pathways, the DD pathways have much lower emissions prices than both the PD and SD pathways.

Table 3.3 Emissions prices vary by pathway at 2030 and 2050

Pathway	Assumed emissions price set for 2030	Reason for 2030 emissions price	Model-generated emissions price in 2050
PD-25	\$55	Reflects strong early policy action given expectation of slow technological change	\$142
DD-25	\$30	Lower price relying on fast technological change	\$75
SD-25	\$30	Same as DD-25	\$152
PD-0	\$80	Higher price needed sooner to achieve more ambitious 2050 target	\$200
DD-0	\$55	Higher price needed sooner to achieve more ambitious 2050 target, but not as high as PD-0 because of anticipated help from technology	\$157
SD-0	\$55	Same as DD-0	\$250

Source: Concept Consulting et al. (2018a).

Figure 3-11 Emissions price trajectories, 2015–2050



Source: Concept Consulting et al. (2018a).

²⁴ Under New Zealand's Emissions Trading System, the government does not set emissions prices directly. Rather, the government influences them through its control of the supply of emission permits or units. The government can set yearly emission caps. For a full description and discussion, see Chapter 4.

Energy and industry

Electricity

New Zealand's electricity system already has very low GHG emissions by global standards, and, as such, it does not feature heavily as a source of mitigation in itself. Yet the modelling does reveal a major shift in New Zealand's energy system, as it expands its electricity system to handle increased rates of electrification – predominantly in transport but also in industry and the residential sector. In all pathways, electricity demand grows by more than 45% from 2015 levels. It grows least in the SD pathways, with lower rates of EV penetration. The DD pathways see slightly higher demand growth, with high levels of vehicle electrification somewhat offset by a large drop in demand because of an assumption that the Tiwai aluminium smelter will choose to close from 2025. The largest growth is in the PD pathways, with moderate rates of electrification and higher industrial demand seeing total generation increase by 58% in PD–25 and by over 63% in PD–0.

The modelling projects that New Zealand's electricity system will move to higher proportions of renewable energy, but with some fossil generation remaining to provide infrequent “firming” generation.²⁵ The growth in electricity demand is met by the building of new renewable generation. Further, the remaining combined-cycle gas turbine (CCGT) generators are projected to be displaced from baseload operation by new renewable generation as emissions prices rise. A need remains for some peaking fossil generation to manage periods of particularly high demand, low renewable output, or both – for instance, dry years where hydroelectricity generation is low. Further, some industrial gas-fired cogeneration is projected to remain operational at projected emissions prices.

Overall, emissions from electricity generation fall by 2–3 Mt CO₂e from 2015 to 2050 while catering for the substantial growth in demand. The emissions intensity of the grid falls from around 110 grams of CO₂ a kilowatt hour (gCO₂/kWh) to between 32 and 45 gCO₂/kWh.

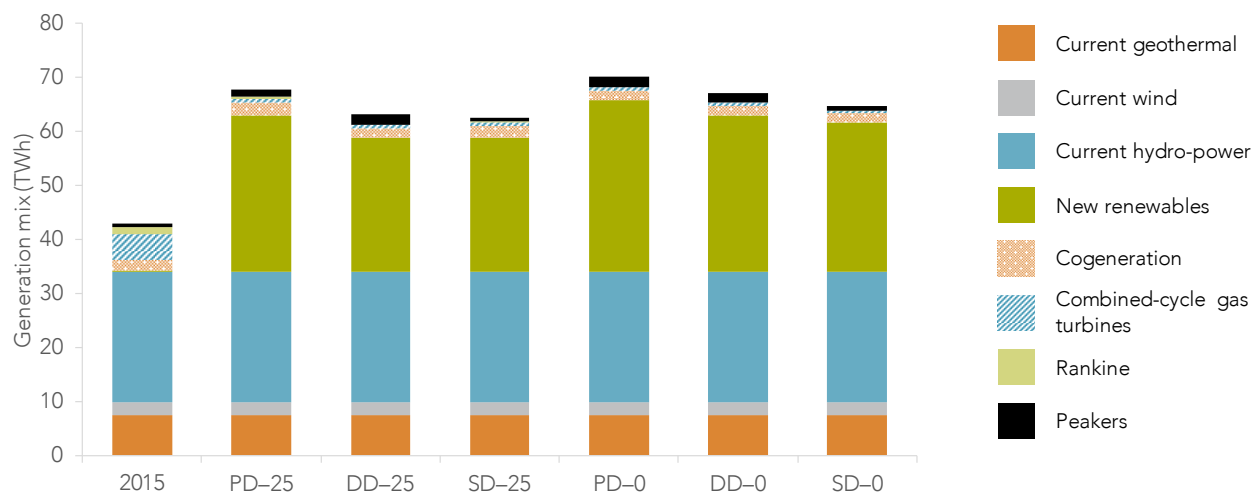
Wind generation is expected to grow to service much of the growth in electricity demand, alongside new geothermal and solar generation (particularly utility-scale solar). The extent to which these different technologies meet the growth in demand and displace existing fossil generation is sensitive to rates of technological change and the relative costs of technology, future emissions prices and the extent to which storage and demand-side responses can provide low-cost balancing of variable wind or solar generation.

Different plausible futures for these different drivers can materially affect how much growth in renewable generation comes from wind, geothermal and solar. Although the composition of the generation mix (both the type of new renewables, and the composition of remaining peaking fossil generation) is inherently uncertain, it is highly likely to be economic to build additional renewables to displace existing baseload fossil generation at projected emissions prices. This will provide the largest gain in terms of reducing emissions from the electricity sector. With the retirement of the baseload CCGT generators and a reduction in Rankine (coal) generation, emissions from geothermal generators are anticipated to be larger than the emissions from the remaining Rankine and Peaker generators (whose role is principally dry-year generation and winter generation). Figure 3-12 shows these compositional changes and Chapter 13 covers the electricity sector in greater depth.

Despite these large changes, the costs of both the energy-system network and generation remain at current levels or only slightly increase. Projected reductions in the cost of new renewable technology and the spreading of network costs over a greater demand base significantly counter-balance the effects of increased emissions prices and the building of additional renewable generation and network capacity on consumer prices. Total wholesale energy and network costs are estimated to increase slightly in the Policy Driven and Stabilising Decarbonisation pathways and remain broadly stable along the Disruptive Decarbonisation pathways.

²⁵ “Firming” generation is generation that adds to (or “firms up”) the supply of electricity when hydro or other renewable generation falls due to weather events.

Figure 3-12 All pathways involve substantial growth in electricity demand to 2050, provided mainly by renewables



Source: Concept Consulting et al. (2018a).

Transport

The switch from vehicles that run on fossil fuels to EVs is a key driver of emissions reductions in the energy sector. Battery technology has developed rapidly over the last five years. This is reflected in falling costs and an improving driving range for EVs. These two advances are allowing EVs to start competing with conventional vehicles on price. The three scenarios all assume this trend continues, but at different rates.

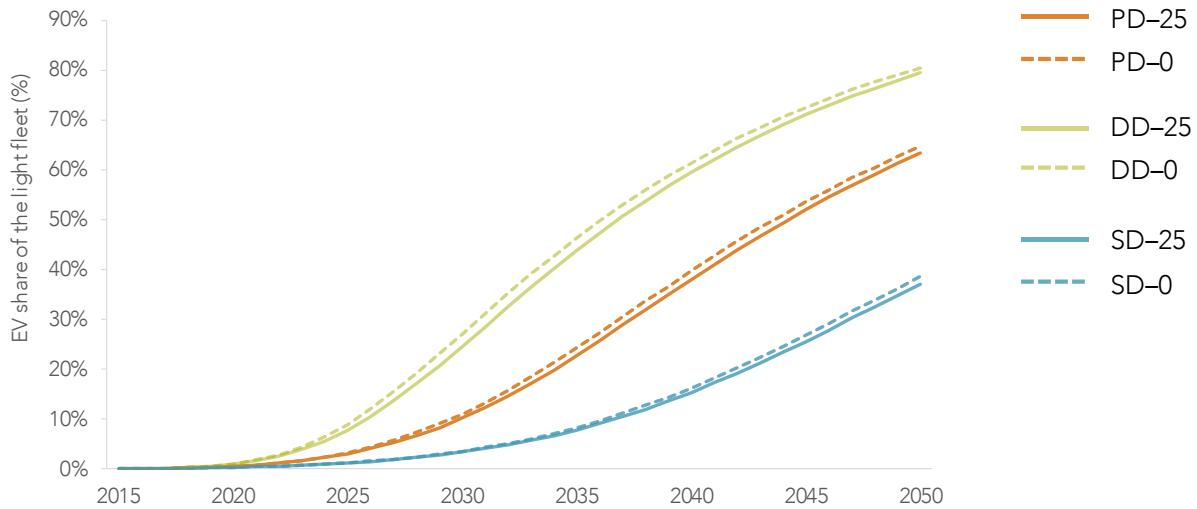
EV uptake is rapid in the DD pathways, reaching up to 80% of the light vehicle fleet by 2050 (Figure 3-13). The PD pathways see a more moderate penetration reaching 65% of the light fleet by 2050. Uptake is slowest under the SD pathways, due to a combination of slower reductions in battery costs and advances in the efficiency of ICE vehicles. Yet, even on these pathways, EVs reach almost 40% of the light fleet by 2050.

The modelling also sees significant adoption of electric buses and trucks, delivering emissions reductions in public transport and road freight. By 2050, the percentage of EVs in the heavy vehicle fleet reaches roughly 50% in the DD pathways, 25% in the PD pathways, and 10% in the SD pathways. Uptake of electric trucks begins much later than for light vehicles due to slower technological advancements.

The different rates of EV uptake lead to substantial differences in transport emissions across the pathways (Figure 3-14). Total transport emissions fall by around two-thirds from 2015 to 2050 in the DD pathways, but only by around one-quarter in the SD pathways. Most of the reductions come from the light vehicle fleet. Emissions from trucks continue to grow until at least 2030, and in the SD pathways are around 25% above their 2015 level in 2050. Emissions from domestic aviation fall appreciably, while the model assumes emissions from rail and domestic shipping remain at 2015 levels.

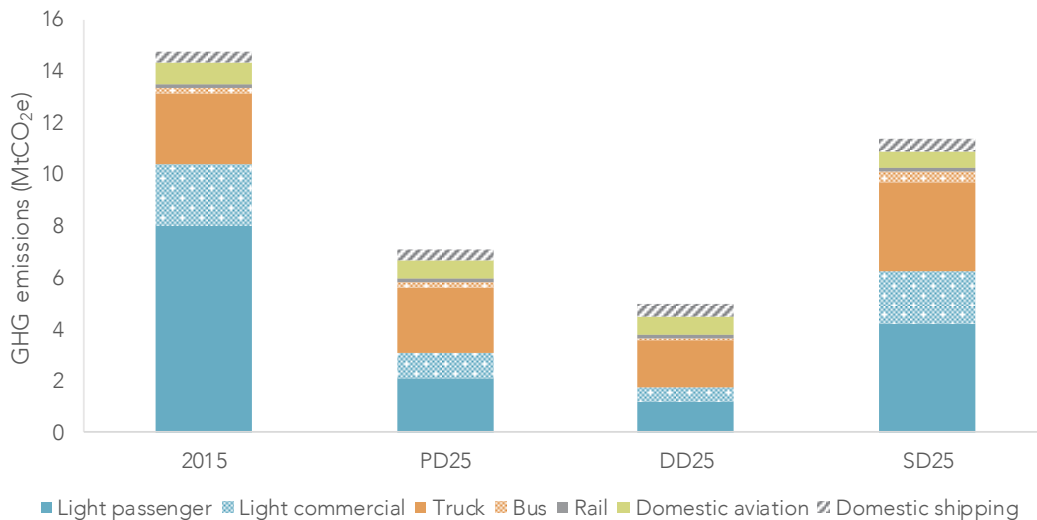
In the modelling estimates, costs associated with the transport system include externalities. For instance, the costs imposed on society through congestion or health impacts. Here, the PD pathways have better outcomes than the DD and SD pathways because increased use of public and active transport reduces congestion, demand for land, and road construction costs, and improves health outcomes. The modelling does not feature mode shifting for freight, but this too could deliver important co-benefits. Chapter 12 analyses the transport sector in greater depth.

Figure 3-13 Light electric vehicles form a substantial part of the fleet along all pathways



Source: Concept Consulting et al. (2018a).

Figure 3-14 Transport emissions in 2050 vary widely between the scenarios



Source: Concept Consulting et al. (2018a).

Notes:

1. This excludes international aviation and shipping.
2. Light passenger vehicles include cars, vans and people-movers; light commercial vehicles include goods vans or utility vehicles (utes), and trucks under 3 500 kg.

Heat and industrial processes

Lower emissions in industry come from two main sources – switching away from fossil fuels for generation of process heat and scaling back industries in which emissions are inherent in the production process (such as smelting iron and aluminium).

Along all pathways, higher emissions prices drive reductions in emissions from process heat particularly in the food processing and pulp and paper sectors, driven by several technical and process factors, including electrification, biomass uptake and energy efficiency.

Across the 25 Mt CO_{2e} target pathways, there is a large emissions variance for iron and steel and aluminium, reflecting the assumption that these operations cease in the DD pathways. Under the higher emissions prices needed to achieve net-zero emissions by 2050, production of iron and steel also ceases in the PD and SD pathways (which does not happen along these pathways with the 25 Mt CO_{2e} target).

The cessation of such production is driven by:

- the assumption that a world with such high carbon prices will see a shift away from steel (the steel-making process being inherently very emissions intensive); and
- New Zealand steel production being neither very low cost nor very low emissions, relative to overseas producers.

Yet considerable uncertainty exists around such assessments.

Fugitive emissions and waste

“Fugitive” emissions²⁶ from mining coal and producing gas decline significantly across all pathways as energy generation using these fuel sources declines, while emissions from geothermal are broadly stable. This reflects the ongoing importance of geothermal in New Zealand’s energy mix (Chapter 13). This means that, across all pathways, fugitive emissions from geothermal generation become the largest source of emissions from the electricity-generation sector. Emissions in waste also decline, driven by a reduction in the generation of waste across the economy and an increase in methane capture and combustion (Chapter 15).

Agriculture and forestry

The largest driver of net emissions reductions to 2050 is forestry, with agriculture playing a smaller but still important role. The major role that agriculture and forestry play in New Zealand’s economy means that the land sector is much more important to New Zealand’s emissions profile than in other developed countries (Chapter 9). Achieving emissions reductions in these sectors is central to the challenge of meeting New Zealand’s emissions targets.

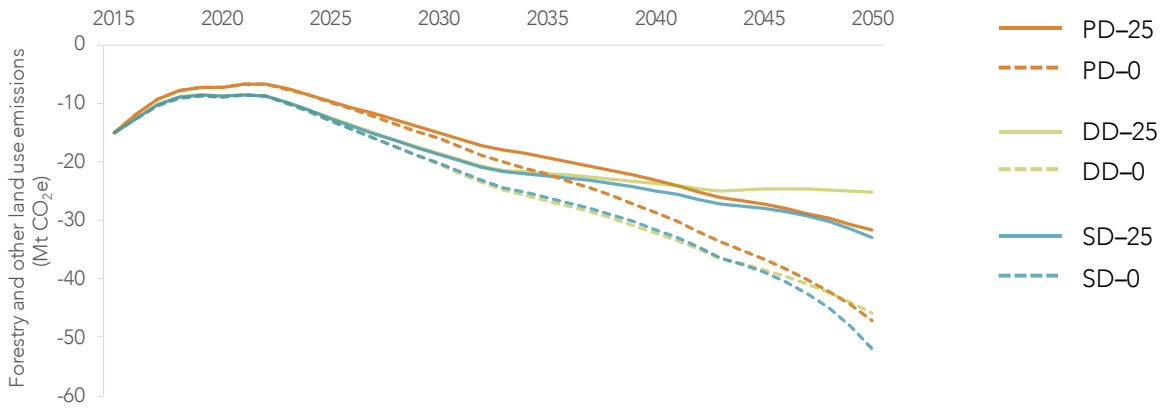
Carbon sequestration from forestry increases in all scenarios. In the 25 Mt CO₂e target pathways, forestry sequestration rises from about 15 Mt CO₂e in 2015 to about 25 Mt CO₂e by 2050 in DD–25, rising further to 32 Mt CO₂e in PD–25 and 34 Mt CO₂e in SD–25. Yet these levels of sequestration are dwarfed by the very large expansion of forestry in the net-zero target pathways as shown in Figure 3-15. Along these pathways, forestry sequestration increases to reach over 45 Mt CO₂e in both DD–0 and PD–0 and more than 50 Mt CO₂e in SD–0.

These large increases in forestry sequestration for both targets and across all pathways imply that further expanding forestry is a relatively low-cost mitigation option under the model specifications. This reflects the current knowledge of opportunities to reduce emissions. In the future, it is possible that cost-effective reductions in emissions could come from technologies that do not yet exist (or are not yet widespread, such as synthetic proteins), particularly if incentivised by higher emissions prices.

Emissions from agriculture decline under all pathways (Figure 3-16). The smallest relative fall is under the PD pathways, with emissions falling by 13% from 2015 to 2050 in PD–25 and by 15% in PD–0. Agricultural emissions along the other pathways fall by over 20%, with slightly larger reductions under the SD pathways than the DD pathways. The declines in the DD pathways occur gradually over the period (with land-use change from dairy to horticulture playing a significant role), while the SD pathways see abrupt change driven by the assumed introduction of a methane vaccine for pastoral agriculture in 2030. Differences in agricultural emissions between the 25 Mt CO₂e and net-zero targets are minor, with the tighter target driving only small changes in overall agricultural activity.

²⁶ Fugitive GHG emissions are emissions that escape as by-products of another process such as coal mining or oil and gas production. Fugitive GHG emissions are distinct from the GHG emissions caused when these fossil fuels are combusted. The use of geothermal energy also produces fugitive emissions.

Figure 3-15 Forestry sequestration increases from current levels

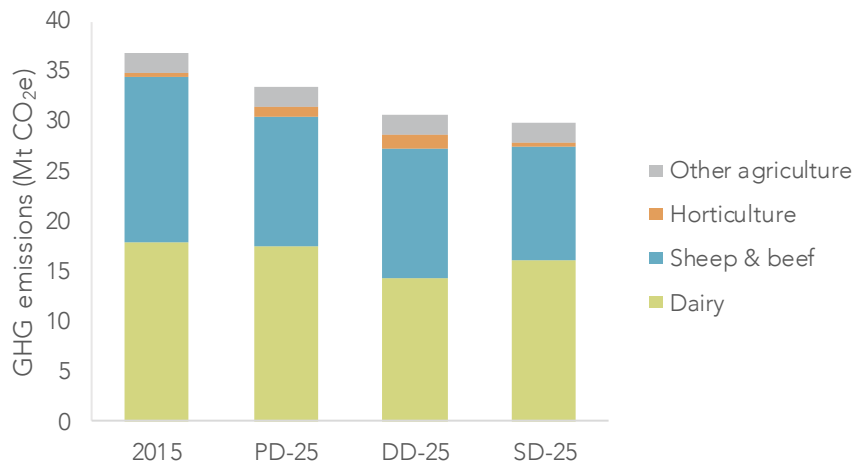


Source: Concept Consulting et al. (2018a).

These emissions outcomes reflect significant land-use changes in rural New Zealand (Figure 3-17). Under all scenarios, forestry sees a large expansion. The smallest increases occur under the DD pathways, with an additional 1.3 million hectares in DD-25 and 2.1 million hectares under DD-0. The largest land-use change occurs under the PD pathways, with:

- 2 million hectares of additional forestry under PD-25 (1.4 million hectares of new plantation forest and 0.7 million hectares of native forest);²⁷
- 2.8 million hectares of additional forestry under PD-0 (1.9 million hectares of new plantation forest and 0.9 million hectares of new native forest).

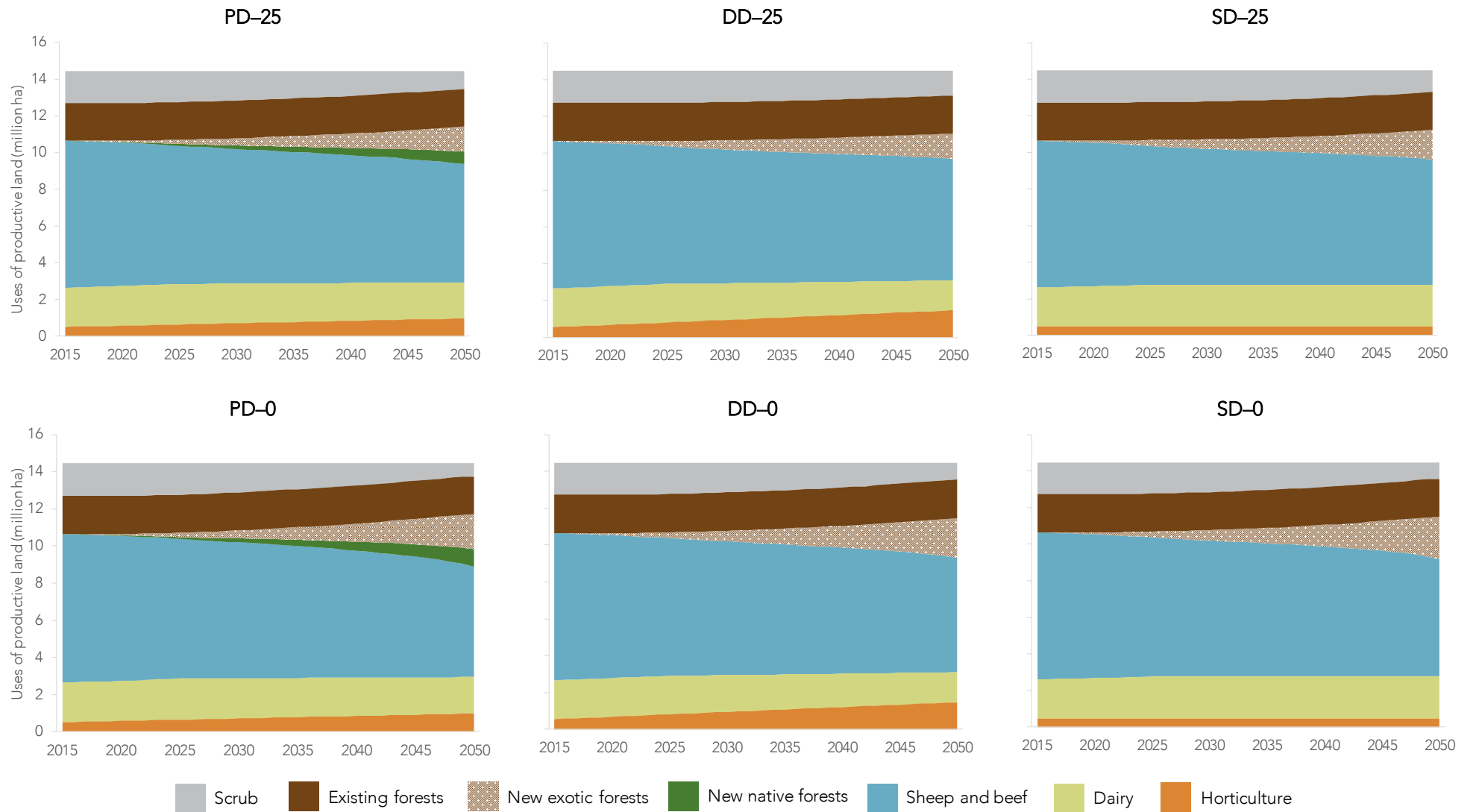
Figure 3-16 Agricultural emissions in 2050 by pathway under the 25 Mt CO₂e target



Source: Concept Consulting et al. (2018a).

²⁷ The PD pathways use an exogenous assumption that one-third of the additional forestry is native forest (Table 3.2).

Figure 3-17 Land use by pathway



Source: Concept Consulting et al. (2018a).

Land used for sheep and beef farming declines under all scenarios. It falls from about 8 million hectares in 2015, to 6.8 million hectares in SD–25, 6.6 million hectares in DD–25 and 6.4 million hectares in PD–25. Reductions are more pronounced under the net-zero target pathways, with the area declining to 6.4 million hectares in SD–0, 6.2 million hectares in DD–0 and 5.9 million hectares in PD–0. As a corollary, production of sheep and beef (proxied by stock units) declines in all pathways, by between 7% and 16%.²⁸

Land used for dairy farming increases under some pathways and falls in others. For instance, the SD pathways see dairy land use increase from 2.1 million hectares in 2015 to 2.3 million hectares in 2025 and then remain constant.²⁹ However, dairy land declines under the other pathways to 2 million hectares in the PD pathways and 1.6 million hectares in the DD pathways. Changes in the production of dairy products also vary. Dairy production increases by 25% in the SD pathways and 7% in the PD pathways. Yet it falls by 11% in the DD pathways.

Some of these land-use changes are spurred by the expansion of horticulture. The area of land used for horticulture is assumed stable at 0.5 million hectares under the SD pathways, but is assumed to double to 1 million hectares under the PD pathways and triple to 1.5 million hectares under the DD pathways. The model does not break down the increase in horticultural land use, given the variety of horticultural products and uncertainty about their future growth.

Better water quality because of reduced nitrate leaching into waterways will be a co-benefit of reduced emissions of nitrous oxide (N₂O) from agricultural soils. Water quality is likely to improve along all pathways, with the potential exception of the SD pathways. Emissions of N₂O decline by almost 10% under the PD pathways, and by almost 20% in the DD pathways. Yet in the SD pathways, emissions of N₂O increase marginally.

The scale of future change in land use up to 2050 is likely to vary considerably by region. Under all pathways, the greatest land-use change, in absolute terms, occurs in Canterbury, Otago, and Manawatu-Wanganui – mostly from conversions of sheep and beef farms. Under the net-zero pathways, the shift from sheep and beef farming between 2015 and 2050 affects between 11% and 14% of the land area of Canterbury and between 13% and 17% of the land area of Otago. Also, the increased area in forest could be close to 20% of the Gisborne region, 18% of the Wellington region, and 17% of the Nelson region. Large growth in horticulture (as well as forestry) reduces Taranaki's dairy land by between 35% and 57% in the DD-0 and PD-0 pathways. Waikato's dairy land falls by between 8% and 22%. By comparison, regions such as Bay of Plenty, the West Coast and Auckland experience more modest change.

F3.2

Modelling indicates that New Zealand can achieve low emissions (25 Mt CO_{2e}) or even net-zero GHG emissions by 2050. New Zealand's potential to achieve either of these targets stems from a confluence of factors, most notably the potential for significant increases in afforestation and a low-emissions electricity system facilitating the cost-effective decarbonisation of the wider energy sector. The modelled pathways rely on a combination of three key drivers – the expansion of forestry, changes to the structure and methods of agricultural production, and switching from fossil fuels to clean electricity and other low-emissions fuels in transport and process heat.

F3.3

In meeting the 25 Mt CO_{2e} target, all modelled pathways achieve or come very close to achieving net-zero emissions of long-lived GHGs by 2050, with declining methane emissions. This would mean that, by 2050, New Zealand would no longer be contributing to further global temperature increases.

²⁸ The production of stock units does not necessarily result in the same reduction in total production, with, for instance, the increased weight of livestock having the potential to offset part of the reduction in stock units.

²⁹ The modelling assumes a cap on land being used for dairy farming from 2025, as a proxy for regulation to address concerns about water quality.

F3.4

Land-use change varies across the six modelled pathways. Forestry land expands greatly across the six pathways while land for sheep and beef farming declines. Land for dairy farming increases under those pathways that see the development of a methane vaccine and falls in the other pathways. Without the methane vaccine and with disruptive advances in plant-based meat and dairy substitutes, land for horticulture (and cropping) is likely to expand.

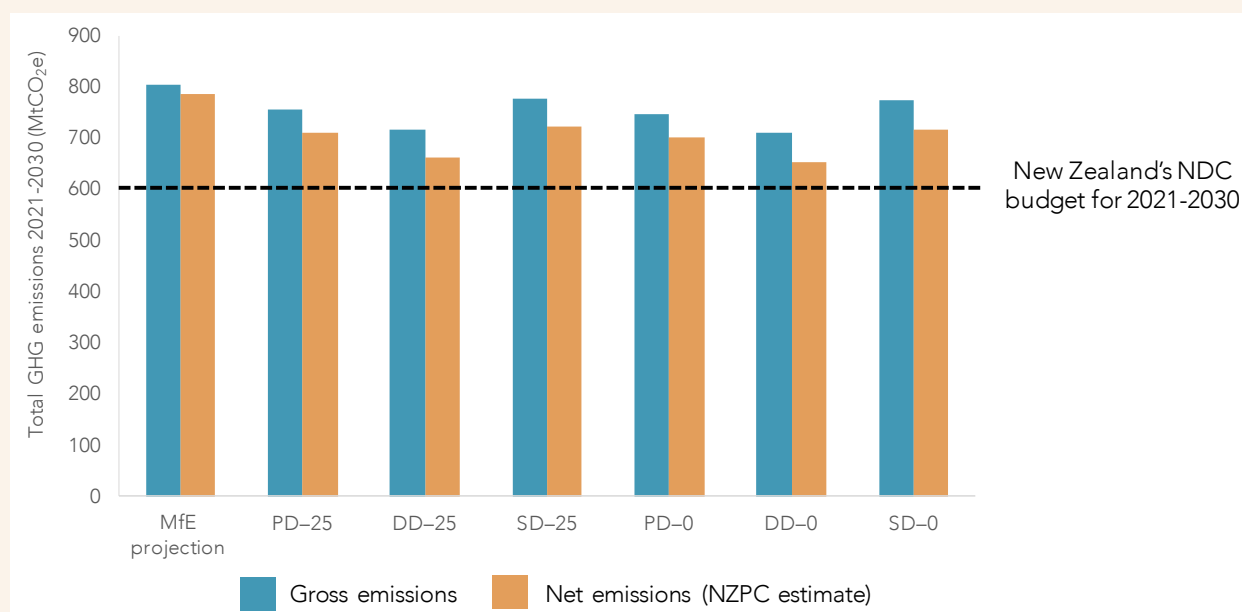
Box 3.3 The modelled pathways and New Zealand's 2030 target

New Zealand's First Nationally Determined Contribution (NDC) under the Paris Agreement commits to emissions in 2030 of 30% below 2005 gross emissions levels. As explained in Chapter 2, the contribution includes an emissions budget for the ten-year period from 2021 to 2030. MfE (2018g) provisionally estimates an emissions budget of 601 Mt CO₂e. MfE also projects that, under current policies, New Zealand's net emissions over the ten-year period will total 786 Mt CO₂e, leaving a large overshoot or "mitigation gap" of 185 Mt CO₂e. The NDC states that New Zealand intends to use international offsetting mechanisms (eg, purchase of international credits) in meeting its commitment.

The Commission's modelling focused on meeting domestic emissions targets in 2050 and did not incorporate any 2030 target. However, the Commission has analysed the results of the modelled pathways to examine how these track against New Zealand's NDC.

All six pathways have lower gross emissions over the 2021–2030 period than MfE's current policy projection (Figure 3-18). These range from roughly 710 Mt CO₂e to 720 Mt CO₂e in the DD pathways, 750 Mt CO₂e to 760 Mt CO₂e in the PD pathways, and 770 Mt CO₂e to 780 Mt CO₂e in the SD pathways. Compared with MfE's projection, these lower gross emissions paths would reduce the overshooting of the emissions budget by between 14% and 50%.

Figure 3-18 Total emissions from 2021 to 2030 compared with New Zealand's emission budget



Source: Commission analysis of Concept Consulting et al. (2018a); MfE (2018g).

Notes:

1. The Commission adjusted forestry sequestration estimates to address issues with the timing of planting and when sequestration is credited.
2. The MfE projection is based on current policies.

Looking at total net emissions for the period, the CMV results suggest that New Zealand's NDC could be mostly or even entirely achieved domestically. However, the Commission has identified two technical issues that make this outcome unlikely. The issues are the timing of forest planting and when the credits from sequestration are counted. In both cases, the modelling gives significantly higher estimates of forestry sequestration over the 2021–2030 period than seem warranted.³⁰ Using a conservative revision to the forestry sequestration estimates, the Commission finds total net emissions would range from around 650 Mt CO_{2e} to 660 Mt CO_{2e} in the DD pathways, 700 Mt CO_{2e} to 710 Mt CO_{2e} in the PD pathways, and 710 Mt CO_{2e} to 720 Mt CO_{2e} in the SD pathways.

Acknowledging the sensitivity surrounding forestry assumptions and accounting rules, the Commission concludes that none of the pathways – even those that achieve a net-zero target in 2050 – are likely to meet New Zealand's NDC through domestic emissions reductions alone.³¹ Even so, the pathways would significantly narrow the emissions budget overshoot to something like 50 to 120 Mt CO_{2e}.

F3.5

Even if New Zealand follows a pathway consistent with net-zero emissions by 2050, it is highly likely that domestic net emissions will overshoot the 2021–2030 emissions budget for New Zealand's first Nationally Determined Contribution.

Results of uncertainty analysis

So far, this chapter has presented results for the six pathways. These pathways are determined by a set of expectations about uncertain factors, such as technological change and prices, that turn out to be correct. That is, in these pathways the expected outcomes are realised.

The second stage of modelling aimed to reveal insights into the effects of uncertainty about the medium- to long-term future. As explained in the previous section, CMV constructed a set of model runs that follow one of the three scenarios up until 2030. Then, at that point, actors (such as the government, individuals or businesses) observe the state of the world and readjust their expectations about, and strategies for, the future from 2030 onwards. In the uncertainty analysis, four "uncertainty variants" are possible from 2030 onwards, and actors make decisions reflecting the variant that occurs. Among the actors, the government sets its policies to meet an emissions target of 25 Mt CO_{2e} in 2050 (Figure 3.4).³² This simulates, in a crude fashion, a potential course correction as future information is revealed. Section 3.2 further describes the modelling methodology and Figure 3-4 introduces the four uncertainty variants.

Concept Consulting et al. (2018b) gives further details of the results and conclusions from the uncertainty analysis. This section presents some high-level findings.

Emissions and emissions prices

Like the first-stage modelling results, all scenario–variant combinations succeed in meeting the 25 Mt CO_{2e} emissions target.³³ But they show considerable variation in their emissions trajectories and in the contributions from different mitigation sources. In all uncertainty variants, cumulative net emissions are lowest when strategies up to 2030 are based on the DD scenario and highest when based on the SD

³⁰ First, the LURNZ model averages the yearly planting rate over the first decade modelled (2013–2022). This results in much higher planting rates than have actually occurred between 2013 and now. Even if compensated by more planting later, this will mean lower sequestration in the 2021–2030 period. Second, CMV used a yearly average sequestration rate per hectare of new forest until it reaches long-term average carbon stock. The Commission understands the Government's proposed accounting method would use a sequestration curve that starts slow before ramping up, also reducing sequestration in the 2021–2030 period (and increasing it in subsequent periods). These two issues relate mainly to timing and have little effect on the results over a longer timeframe.

³¹ As explained in Chapter 2, meeting the emissions budget for the 2021–2030 period is far more challenging than meeting just a point-in-time target in 2030. New Zealand's emissions are starting well above the yearly average required over the period due to heavy reliance on the use of temporary offsets to meet earlier emissions reduction commitments. This means emissions would need to fall much more steeply than the 2030 target suggests in order to stay within budget.

³² The uncertainty analysis looked at the 25 Mt target only – not the net-zero target.

³³ Under either the Policy Driven or Disruptive Decarbonisation starting scenarios, the Innovation-disrupting-existing-industries variant outperforms the emissions target at the lowest emissions price paths modelled.

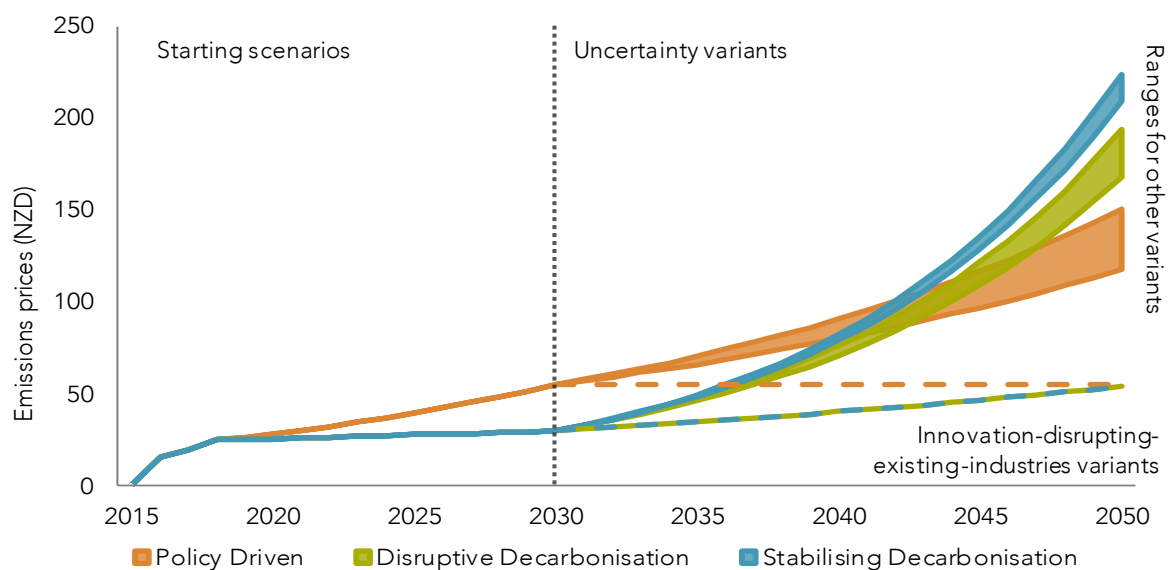
scenario. This reflects, in part, the early closure of aluminium as well as iron and steel manufacturing under the DD scenario, and the slow start to forestry planting in the SD scenario.

The modelling estimates a wider range of emissions prices to reach the 25 Mt CO₂e target compared to the first-stage results. The lowest price is roughly \$55 – \$20 less than the previous \$75. The highest price is roughly \$220 – \$70 more than the previous \$150. This wider range is mainly because (as explained earlier in Box 3.1) the second stage varied the assumptions about the prices of fossil fuels, commodities and international emissions across the scenarios and uncertainty variants. In contrast, the first stage kept these assumptions the same across the pathways. The shift in expectations about the prices of agricultural and forestry commodities relative to each other appears to have a particularly important influence on the emissions prices generated by the model. These prices affect the economics of land-use change to forestry, and as already seen, forestry is a key driver of overall emission reductions.

Looking at the full suite of scenario–variant combinations (Figure 3-19), two features of the emissions prices stand out.

- If the Innovation-disrupting-existing-industries variant occurs from 2030, then the emissions prices required to achieve the 25 Mt CO₂e target are low at around \$55 a tonne in 2050 irrespective of the initial scenario choice. If this variant occurs after starting with the PD scenario, the emissions price does not need to rise at all after 2030 for emissions in 2050 to fall to well below the target (around 17 Mt CO₂e).
- Starting with the PD scenario leads to the lowest emissions prices in 2050 in all uncertainty variants.³⁴ Conversely, starting with the SD scenario consistently requires the highest 2050 emissions prices. The largest difference occurs in the Innovation-stabilising-existing-industries variant, where starting under the PD scenario limits the 2050 emissions price to around \$140 compared with \$220 under the SD scenario.

Figure 3-19 Price ranges for emissions in scenarios and uncertainty variants



Source: Concept Consulting et al. (2018b).

Notes:

1. Price paths use the same colours as in the initial scenario (2015–2030). The dotted lines after 2030 show the Innovation-disrupting-existing-industries uncertainty variants. The solid shaded areas show the range for the other three uncertainty variants.

Land-use changes

The overall levels of additional forest by 2050 across the scenario–variant combinations range from 1.5 to 2.2 million hectares. This is a very similar, but slightly higher, range than in the first-stage modelling of the 25 Mt

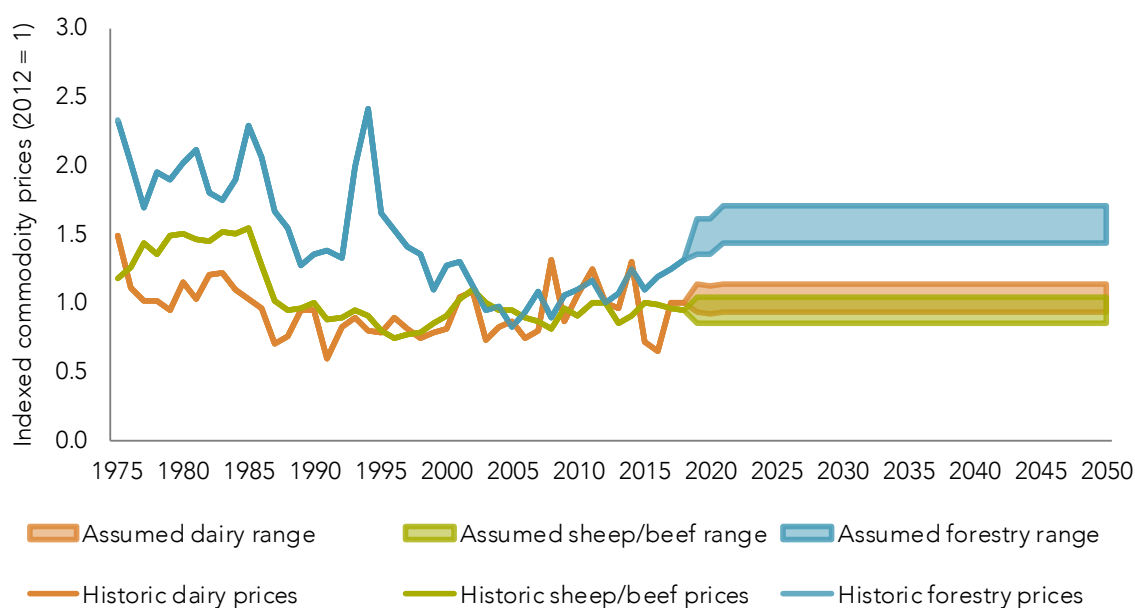
³⁴ Except in the Innovation-disrupting-existing-industries variant, where the difference is reflected in lower emissions being achieved at the same price.

CO₂e target. The upper end of the range occurs under the PD scenario and related Moderate-technological-change variant, which assumes a government policy of one-third of afforestation in native forests.

As noted, different assumptions on relative forestry and agriculture commodity prices lead to notable changes across scenarios compared with the first-stage results. In the second-stage modelling, the DD scenario (and aligned uncertainty variant) assumes agricultural commodity prices 10% below baseline assumptions and forestry commodity prices 10% above baseline. This change leads to significantly more afforestation (an extra 0.3 million hectares compared with the first stage) and, as seen above, has a flow-on effect of enabling lower emissions prices across the economy. The SD scenario (and aligned uncertainty variant) featured the inverse assumption, with higher agriculture product prices and lower forest product prices. This causes a reduction in afforestation compared with the first-stage results, and the need for significantly higher emissions prices. Up to 2030, where the emissions price is the same in both these scenarios, forestry expands twice as fast in the DD scenario as in the SD scenario.

This result highlights a strong sensitivity in the LURNZ model to these shifts in relative commodity prices. The assumed changes in long-run prices are relatively small compared with the changes seen over the last 30 years (Figure 3-20). LURNZ is a largely empirical model that is calibrated to historical observed responses by landowners to economic drivers such as commodity prices. So, this sensitivity may be a real phenomenon. Given the key role of forestry sequestration in the pathways to ambitious emission-reduction targets, further research in this area would be valuable.

Figure 3-20 Historic and assumed changes in relative agriculture and forestry commodity prices



Source: Concept Consulting et al. (2018b).

Notes:

1. The shaded ranges show the range across the different scenarios and uncertainty variants.

F3.6

In Motu's Land Use in Rural New Zealand model, future changes in land use are highly sensitive to assumptions about relative prices for agricultural and forestry commodities. It is unclear to what extent real-world decision making would be as sensitive as this. Due to the strong reliance on afforestation in most of the modelled pathways, this sensitivity flows through into the emission prices that the model generates. Further research into the economics of land-use decisions is warranted.

Response to slow international action

A fourth uncertainty variant ("slow-international-action") sought to examine the possible impacts of slow international action on New Zealand meeting the 25 Mt CO₂e target. As section 3.2 describes, this variant

features a low international emissions price and other linked assumptions on technology and prices, along with a slow phase-out of free allocations in the NZ ETS. Counter-intuitively, this variant resulted in slightly lower emissions prices compared with the Moderate-technological-change and Innovation-stabilising-existing-industries variants. Concept Consulting et al. (2018b) offer the following explanation:

Of these other variants, the Slow-international-action variant has the lowest prices. These prices are likely to be driven by a combination of variant-specific assumptions and the impact of higher relative emissions prices on competitiveness. It appears that the closure of, or reduced production from, iron and steel in this variant drives part of the differential [...]. In addition, compared with the Innovation-stabilising-existing-industries variant, the smaller price differential between agricultural and forestry products in the Slow-international-action variant reduces the relative marginal cost of abatement in the land section. Further, the assumed expansion of native forestry in the Moderate-technological-change variant likely reduces the land available for lower-cost mitigation from plantation forestry which pushes up its emissions price relative to the Slow-international-action variant (p. 27).

As noted, the modelling shows one instance where, shortly before 2050, the differential between the emissions prices faced by New Zealand's emissions-intensive producers and their international competitors rises to a level where the model predicts the closure of iron and steel production could occur. This highlights the risk of some adverse impacts and importance of policy flexibility to respond to the pace of global action.

Given the level of nuance and the uncertainties inherent in predicting the effect of slow international action on commodity prices, it would be unwise to draw overly broad conclusions from this result. Even so, the modelling suggests that the risk of slow international action does not pose a serious threat to New Zealand pursuing the 25 Mt CO₂e target, if managed through appropriate policy settings to protect trade-exposed producers.

Sensitivity to higher population growth and slower removal of free allocation

The final part of the uncertainty analysis was to examine the sensitivity of the results to two factors: the rate of population growth and the rate of withdrawal of free allocation in the NZ ETS. CMV tested each sensitivity using an alternative model run with all other assumptions held identical to the PD scenario for the whole simulation period (2015-2050).

The modelling indicates that higher population growth modestly increases the emissions prices required to achieve the 25 Mt CO₂e target. In this sensitivity run, population grows at an average rate of about 1.3% a year, compared with about 0.8% a year in the base case. This means that New Zealand's population is around 19% larger in 2050 than in the base case. This higher growth rate increases emissions through two main channels: increased demand for transport and for residential and commercial energy. The emissions price in 2050 rises to around \$165, compared with around \$150 in the base case. Emissions increase most in the transport sector – particularly heavy transport, which is still largely dependent on diesel in 2050. This increase is offset mostly through an extra 90 000 hectares of afforestation driven by the higher emissions price.

A slower withdrawal of free allocation is also found to modestly increase emissions prices. In this sensitivity run, CMV assume the government withdraws free allocation at a rate of 3 percentage points a year, compared with 5 percentage points a year in the base case. This means free allocation is not fully removed until the late 2040s, as compared with the late 2030s. The emissions price in 2050 rises to around \$170 – around \$20 higher than in the base case. Here the largest effect is a reduction in the amount of land-use change to forestry due to the higher rates of free allocation for livestock farming. The higher emissions price drives a greater reduction in gross emissions, particularly through increased fuel switching to biomass and electricity for process heat.

F3.7

Modelling indicates that higher population growth and slower withdrawal of free allocation would each modestly increase the emissions prices required to meet targets.

New Zealand's transition to a low-emission's economy: what can models really tell us?

Several modelling exercises have attempted to throw light on important aspects of New Zealand's transition to a low-emissions economy, such as the Infometrics and Landcare modelling used to inform New Zealand's first NDC that set emissions targets for 2021–2030 (Daigneault, 2015; Infometrics, 2015); and the Vivid Economics report *Net Zero in New Zealand* for Globe NZ (Vivid Economics, 2017a). More recently, in addition to the CMV modelling undertaken for this inquiry, MfE commissioned NZIER to use its computable general equilibrium (CGE) model to estimate the impacts on a range of macroeconomic indicators of reaching different emissions targets (MfE, 2018b; NZIER, 2018). At the time of publication, NZIER Stage 1 results were available. Stage 2 is refining the modelling and is still in progress.

The NZIER Stage 1 and CMV models have generated very different estimates of the emissions prices needed for New Zealand to reach low or net-zero emissions by 2050. This variation has occurred even though NZIER modellers took assumptions (about new technologies such as a methane vaccine, EVs and renewable electricity generation) from the CMV modelling. Both exercises estimated the emissions prices needed for New Zealand to reach net-zero emissions by 2050. In addition, CMV modelled a target of 25 Mt CO₂e by 2050 (or about 60% below 1990 levels) and NZIER used a more ambitious target of emissions declining to 75% below 1990 levels. Yet, for all targets, the NZIER model estimated emissions prices very much higher than the CMV modelling, as indicated in Table 3.4.

Table 3.4 Comparison of emissions prices needed to reach targets in CMV and NZIER modelling

2050 net emissions target	Innovation scenario	Explanation for 2050 emissions price in terms of innovation scenario	Model-generated emissions price in 2050 / t CO ₂ e
CMV model			
25 Mt CO ₂ e (60% below 1990)	Disruptive Decarbonisation	Lowest price out of all CMV first-stage scenarios because of strong technology effects, substantial afforestation and a less ambitious target.	\$75
25 Mt CO ₂ e	Stabilising Decarbonisation	Higher price needed, because of both weaker help from technology and less forestry.	\$152
Zero	Disruptive Decarbonisation	Higher price to achieve a more ambitious 2050 target.	\$157
Zero	Stabilising Decarbonisation	Highest price to achieve a more ambitious 2050 target; less help from technology; less forestry.	\$250
NZIER Stage 1 model			
75% below 1990	Agricultural and energy innovation (separately and together)	With both types of innovation, and a less stringent target, the lower bound is the lowest 2050 price among the NZIER scenarios. The upper bound reflects agricultural innovation only – that is, a methane vaccine, lower global demand for meat and dairy, more horticulture and substantial sequestration from forestry.	\$580 – \$1607
Zero	Agricultural and energy innovation (separately and together)	With agricultural and energy innovation, the price is at the lower bound. The very high upper-bound price reflects no forestry above the baseline and energy innovation only – that is more rapid energy efficiency improvements; EV uptake to 95% of light vehicle fleet and 50% of heavy vehicle fleet; 98% renewable electricity from 2035.	\$652 - \$2092

Note: Among the CMV scenarios, the Policy Driven scenarios are not shown because their 2050 prices are intermediate between those in the Disruptive Decarbonisation and the Stabilising Decarbonisation scenarios.

The NZIER Stage 1 estimated emissions prices are high in comparison with other models. Stiglitz and Stern (2017) report a review of emission-price trajectories generated by six Integrated Assessment Models (IAMs) considering four different baselines. For five of the IAMs, the prices in 2050 required to achieve the Paris goal of keeping temperature change below 2°C all lay below US\$250 a tonne of CO₂e, some well below. The sixth model had prices ranging between US\$400 and US\$1000. Earlier this year, Westpac NZ published a study by EY and Vivid Economics that used CGE modelling (Westpac NZ, 2018). The study estimated the emissions price required in 2050 for New Zealand to reduce its 2050 net emissions to 20 MtCO₂e was NZ\$145 a tonne of CO₂e.

Emissions prices indicate the marginal cost of emissions abatement by businesses and households. So the very much higher emissions prices in the NZIER Stage 1 scenarios are directly related to the high costs of reducing emissions to target levels. The NZIER's CGE model can estimate these costs in terms of lower GDP, lower real gross national disposable income (GNDI) per household and lower real wages. The emissions prices correlate with these measures. For example, the NZIER scenario with energy-only innovation and a net-zero target estimates real GNDI per household in 2050 is nearly \$47 000 (or 13.6%) below that in the scenario of New Zealand's current target of 50% below its 1990 emissions (NZIER, 2018, p. viii). The model estimates that this same scenario will experience average annual growth of GDP over 2017 to 2050 that is more than 0.6 percentage points below a "no further climate action" baseline. At 2050, this equates to a GDP of around \$85 billion below even the 50% target.

If NZIER's Stage 1 prices and costs are realistic, this is a concern. Before examining how realistic they are, two important points should be noted about loss figures that can make action against climate change look costly:

- Growth is still positive in the trajectories with action against climate change. By 2050, real GDP and average incomes are a lot higher than today – just not as high as in the baseline case of no further action.
- Implicit in a "no further climate action" scenario is the assumption that New Zealand can free ride on the rest of the world acting to prevent highly damaging climate change that would severely impact economic activity and living standards. As NZIER itself notes, "...we do not consider the physical impacts of climate change on crop yields, coastal erosion, human and animal health, or infrastructure damage from storms" (NZIER, 2018, p. ii). Free riding in this way is not a tenable position for New Zealand to take.

Putting these two points together suggests that the economic losses indicated by NZIER's Stage 1 findings are based on a misleading comparison. Even so, what can explain such a large gap between the lower emissions prices in the CMV modelling and the much higher emissions prices in the NZIER Stage 1 model? Should policymakers and the wider public take more notice of one or other set of prices, or other indicators generated by the models?

Economic models vary hugely. Choosing the right model for the task at hand is vital (Rodrik, 2015). The above models use different approaches to simulate the emissions intensities of New Zealand's main economic activities. They also differ in how they expect emissions prices, technology and regulation to influence behaviour and cause economic actors to change their consumption and business activities towards activities with lower emissions.

The NZIER tailors an existing dynamic CGE model to investigate the different emissions targets. It is a complex and comprehensive model of the entire New Zealand economy split into 111 industries with flows of goods, services and payments between them and similar flows to and from households, the government and other countries (international trade and investment). It produces macroeconomic results such as GDP, GNDI, employment and exports. It incorporates various types of constraints such as those relating to households' budgets, government spending, balance of payments, terms of trade, labour and capital constraints.

As noted, the CMV modelling joins an energy and transport model specifically designed to model GHG emissions with a detailed model of land-use choices (LURNZ). Those choices include how different land uses emit or sequester GHGs – such as dairy and forestry respectively. The broad difference between the two approaches is that NZIER's model has depth in the comprehensive web of equilibrium connections across

the economy, while the CMV models have depth in the granularity of their modelling of emissions in New Zealand and the behaviours that influence them.

The approaches also have similarities. Neither attempts to explain technological change, even though technology plays a very important role in reducing emissions. The time horizon modelled in both cases – out to 2050 – is very long. Most quantitative models do not attempt to model more than three to five years out from the present. As Chapter 4 will describe, momentous economic transitions can and do occur over three to four decades. These transitions can see radical changes in technologies, institutions, preferences and economic activity.

The problem for modelling is that such fundamental changes are impossible in many cases to imagine, let alone capture in a model. Most models work on the assumptions that technology is static, or will change using modest increments that are imposed on the model by assumption. CGE models are constructed to satisfy standard neo-classical economic conditions of diminishing marginal returns and diminishing marginal products which mean that, following a disturbance or “shock”, the economy will converge to a predictable steady-state equilibrium. The problem is that changes in technology and economic structure over three or more decades are large and not perturbations within an existing structure. The forces at play are non-linear and discontinuous, characterised by increasing returns, path dependencies and tipping points where new technologies supplant old ones. These types of changes are very difficult to model. As Zenghelis (2016) observes:

Economic factors that are subject to economies of scale, capital and institutional lock-in, irreversibilities, new networks and path-dependencies are particularly hard to estimate empirically. ...

The problem is that the dynamics which are most pertinent and interesting when it comes to simulating the future in relation to climate change policy are those which are hardest to model. The result is that, more often than not, they are simply not modelled; and consequently the models tell us little about what such a future is likely to bring. They are especially unhelpful in projecting the long-run cost and benefits of policy. (pp. 182-183)

The most powerful and least predictable driver of change is new technology. Very few economic models attempt to capture the determinants of technological change. None of the empirical models used to simulate climate policy in New Zealand do so. But the CMV modelling is set up to take technological change seriously – by having scenarios of very different types and magnitudes of technology change that bear on emissions.

The treatment of technology in NZIER Stage 1 followed CMV to some extent, yet the modelling also investigated what would happen if innovation were restricted to “agriculture only” or “energy only”. In each case, this has the effect of putting an enormous burden on the emissions price to reach the targets without innovation happening in the “other half” of the economy. This is particularly so without agricultural innovation because that is defined to include forestry sequestration. As the CMV modelling indicates, forestry sequestration is a very important source of low-cost mitigation in New Zealand. With both types of innovation in the NZIER model “switched on”, it is not surprising that the emissions prices required to reach the targets, and the associated economic costs, are much lower (although the prices are still much higher – at \$652 for the net-zero target – versus \$157– \$250 in CMV).

The explanation for this remaining large price difference is difficult to pin down. It most likely lies in the nature of CGE models – that they are creatures of the current economic structure with behavioural responses limited by multiple constraints within a large complex model with all its diminishing marginal returns and other neo-classical features. In addition, unlike CMV, the NZIER Stage 1 model has no mechanism to capture land-use change which, as noted, is a very important influence on emissions in New Zealand. The Commission understands that NZIER’s Stage 2 modelling will include such a mechanism and other refinements. While the Stage 2 results are not yet available, they are likely to show lower emissions prices to meet different targets than in Stage 1.

In summary, all modelling needs to be treated with caution, particularly over such long periods as three or more decades. In a synthesis report on the modelling for the 2050 targets, MfE (2018h) expressed this well:

The models are not perfect predictions or forecasts:

the economy, technologies, and land uses will evolve and change in the next 32 years, sometimes in ways difficult to understand now. The models cannot capture unforeseen technologies developing or new sectors emerging in response to higher emissions prices as we do not know today what these are likely to be. (p. 10)

Yet, confronted with very different estimates of emissions prices in the two modelling approaches, the Commission puts more weight on the sorts of emissions prices estimated in the CMV modelling because of the way it has captured technology, includes land-use change and because of how CGE models are tied to current economic structures and modest changes within them.

F3.8

All modelling over periods as long as three or more decades needs to be treated with caution. Over such timescales, the economy, technologies and land uses will evolve and change in unpredictable ways. Computable General Equilibrium models are suited to modelling perturbations within an existing economic structure rather than these long-term shifts. Also, modelling a low-emissions transition in New Zealand needs to incorporate land-use change because it is a large source of emissions and sequestration of GHGs.

3.4 Modelling insights: conclusions and links to the rest of the report

The results outlined above reveal a noticeably different New Zealand economy and a very different emissions profile in 2050 compared to today. Given the scope and scale of potential changes in the economy and emissions prices within and between the pathways, and with and without uncertainty, this section considers in more detail some of the key findings and the broader insights for climate policy.

New Zealand can substantially decarbonise its economy with effective emissions pricing

The modelling results suggest that New Zealand can substantially decarbonise its economy with higher emissions prices. These prices, although much higher than New Zealand's current emissions price, would be comparable to what are likely to be necessary in the rest of the developed world to limit global warming to under 2°C, consistent with the Paris Agreement. Under a 25 Mt CO₂e target in 2050, the domestic emissions prices required are below Paris-consistent global carbon prices until well after 2035, and below or towards the lower bounds of the Paris-consistent global carbon prices in 2050 (Figure 3-21).³⁵ This reflects several factors, most notably the potential for significant increases in afforestation and New Zealand's low-emissions electricity system facilitating the cost-effective uptake of EVs.

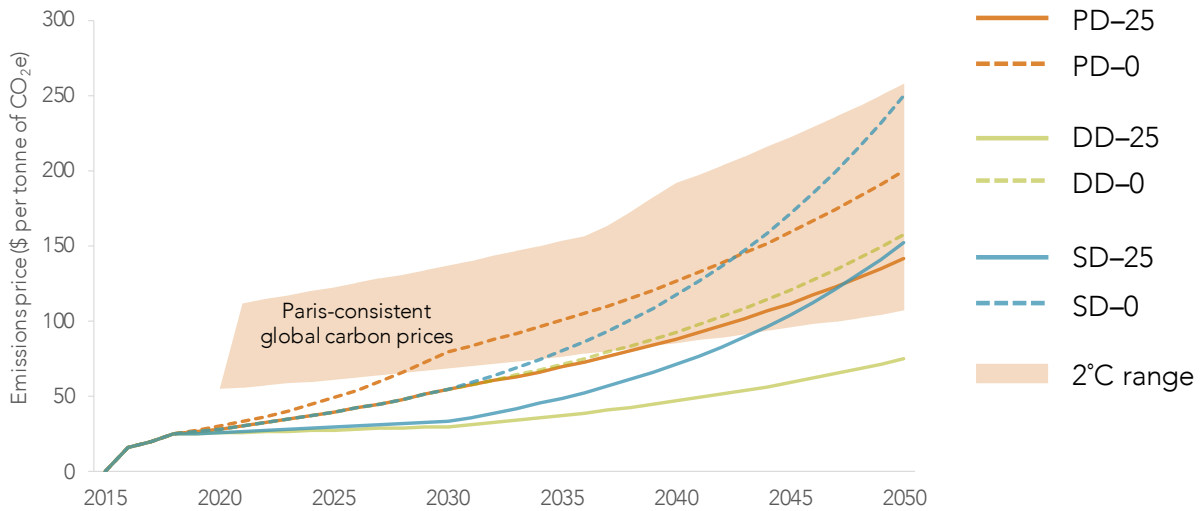
The lowest emissions prices and the lowest cumulative emissions over the 2016–2050 period occur in the Disruptive Decarbonisation pathways. This shows the power of technology to change an economy towards lower emissions without the need for high emissions prices – even if that power disrupts existing structures. The emissions prices needed are particularly low in the DD–25 scenario, where they remain far below the anticipated envelope of emissions prices consistent with the Paris Agreement.³⁶ Among the uncertainty variants, the emissions price in the 2030s and 2040s could be even lower (and well below the Paris envelope) if this period sees technology of the Disruptive Decarbonisation type.

When moving to the more ambitious target of net-zero emissions in 2050, the prices are either toward the middle of the envelope of Paris-consistent carbon prices (for PD–0 and DD–0), or toward the upper bound of these anticipated prices (for SD–0).

³⁵ See Note 1 under Figure 3-21 for an explanation of global carbon prices that are consistent with the Paris Agreement. These prices are used here as a benchmark against which to compare the emissions prices that the modelling has indicated are needed to achieve domestic emissions reductions in New Zealand consistent with a net-zero target either by 2050 or in the second half of the 21st century.

³⁶ A natural question is what would be the effect of raising New Zealand's emission prices to the lower boundary of the Paris-consistent envelope over 2020 to 2030 (ie, the prices that are set exogenously in the modelling)? The modelling did not investigate this question.

Figure 3-21 Emissions prices to achieve net-zero-consistent emissions reductions, NZ\$



Source: Concept Consulting et al. (2018a).

Notes:

1. Global carbon prices that are consistent with the Paris Agreement are based on the range of estimates developed by the Carbon Pricing Leadership Coalition and under the International Energy Agency’s Sustainable Development Scenario to meet the Paris Agreement commitment to limit global warming to below 2°C. Some of these estimates extend only to 2030 and some to 2040, not to 2050. Vivid Economics has extended the price series at the lower of their implied real growth rate or 3% a year, to approximate the real rate of interest. Prices are translated to New Zealand dollars using an exchange rate of 0.74 USD/NZD.

An important insight about emissions prices which the uncertainty analysis brings out is that taking early, strong action on the emissions price to 2030 (the PD scenario) positions New Zealand to have lower emissions prices beyond 2030 compared to choosing other scenarios up to 2030, irrespective of what state of the world is realised after 2030 (Table 3.5).³⁷

Table 3.5 Emissions prices after 2030 are lowest when strong early action is taken before 2030

Scenario pre-2030	Emissions prices in 2050 under uncertainty variants		
	Moderate technological change	Innovation stabilising existing industries	Slow international action
Policy Driven	\$150	\$141	\$118
Disruptive Decarbonisation	\$185	\$193	\$168
Stabilising Decarbonisation	\$219	\$224	\$209

Source: Concept Consulting et al. (2018b).

F3.9

Modelling indicates that New Zealand has the potential to decarbonise towards net-zero GHG emissions at emissions prices in the range of \$150 to \$250 per tonne of CO_{2e} by 2050. Although a significant increase from today’s price, these prices are comparable to those expected to be needed in other developed countries to reduce emissions to levels consistent with the Paris Agreement ambition of keeping global temperature rise to below 2°C.

Should disruptive technological change and associated market conditions eventuate, New Zealand’s emissions reduction targets may be achieved at very low emissions

³⁷ The Innovation-disrupting-existing-industries variant after 2030 is omitted from the Table because the price is little different no matter which scenario is adopted before 2030.

prices. If this does not occur and innovations instead allow existing industries to prevail, significantly higher emissions prices may be needed.

A portfolio of mitigation options is least cost, but forestry dominates....

A clear majority of net emissions reductions along all pathways are sourced from three broad areas: forestry, agriculture, and switching from fossil fuels to clean electricity and other low-emissions energy sources in transport and process heat. This implies that any New Zealand decarbonisation strategy should focus on these opportunities (Figure 3-7).

The fact that lower emissions occur in three broad areas of the economy in response to a strong, single emissions price indicates that a portfolio of mitigation options is least cost. It is not the case that the best mitigation opportunities lie in just one part of the economy. Diverse parts of the economy can and need to make their contributions if New Zealand is to reach its ambitious targets.

According to the modelling, concerted expansion of the forestry sector is required to put New Zealand on a path consistent with net-zero emissions by the middle of the 21st century. Forest sequestration provides 25% to 45% of the net emissions reductions required to meet the 25 Mt CO_{2e} target. Under the net-zero target, sequestration from forestry dominates – it provides about half of the required reduction in net emissions and so would do most of the “heavy lifting” (Figure 3-8).

...while agriculture and switching from fossil fuels to low-emissions fuels are also critical

Agriculture is also a significant source of mitigation. All pathways see a continued reduction in pastoral agriculture, with sheep and beef farming being outcompeted by alternate uses. If development of a methane vaccine that reduces emissions intensity is successful, this will likely limit, but not fully offset, the need for land-use change. In the 25 Mt CO_{2e} target pathways, reductions in emissions from agriculture are responsible for between 13% and 22% of total net-emissions reductions, and between 9% and 18% of emissions reductions in the net-zero target pathways.

Transport is a major driver of emissions reductions in the energy sector. The pace of technological development and uptake of low-emissions vehicles is of primary importance for the transport sector (Figure 3-13). Along the 25 Mt CO_{2e} target pathways, reductions in emissions from transport, primarily electrification of the transport fleet, are responsible for between 8% and 24% of total net-emissions reductions, and between 6% and 16% of emissions reductions along the net-zero target pathways. In turn, the expansion of EVs increases demand for electricity generation, which the modelling suggests will be most cost effectively met through additional renewable generation.

Other sources deliver between 20% and 30% of net-emissions reductions. Within this, process heat and industrial processes contribute between 14% and 21%. These reductions are mainly achieved by fewer emissions from:

- process heat in areas such as food processing;
- industrial processes such as aluminium, cement, methanol, and iron and steel production; and
- refrigeration.

Social and political preferences will influence the attractiveness of drawing on these different areas of mitigation opportunity. In addition, the modelling of uncertainty variants shows that some pathways up to 2030 make for more robust and resilient choices with respect to future uncertainties.

F3.10

All the modelled pathways show that the reductions in net GHG emissions come mainly from forestry, agriculture and from replacing fossil fuels with clean electricity and other low-emissions energy sources in transport and process heat. New Zealand's decarbonisation strategy should therefore focus on this portfolio of mitigation opportunities. The dependence on forestry sequestration is particularly strong in the case of the target of net-zero GHG emissions by 2050.

Stronger near-term action can constrain future costs and insure against risks of slow technological progress

The modelling of uncertainty variants, including the ability of decision makers to adjust policy settings at an intermediate point after observing the extent and types of technology development and the progress of other countries in combatting their emissions, has yielded useful insights. The most powerful insight is the potential value of early, strong action in the form of higher emissions prices in the period from now to 2030.

The costs of early, strong action are the short-term costs of higher emissions prices for emitters and consumers of emissions-intensive products and fuels. Yet this early action will set in train decisions and actions that have benefits. Some of these benefits show themselves in the modelling results. Others are not captured by the modelling, yet are no less important. The benefits of strong, early action captured in the model are that it will:

- put New Zealand in the best position to achieve targets at lower cost over the following decades, regardless of the uncertainty variant that eventuates after 2030. It is a form of societal insurance against slow technological progress and provides options if faster emissions reductions turn out to be needed to keep warming to a safe level;
- yield outcomes that achieve lower cumulative emissions to 2050;
- provide the most protection against high-carbon investments that lock in emissions for many years into the future;
- promote an early start to expanding forestry which can then continue at a steady rate throughout the period to 2050, rather than face the challenge of having to plant at very rapid rates at the end of the period; and
- create the space to devote a portion of new forestry to native species that grow and sequester carbon more slowly, yet which will continue to absorb CO₂ well after 2050. Native species can also provide cultural and biodiversity benefits.

The benefits not built into the model are also very important. Early action to raise emissions prices will also:

- induce more low-emissions innovation which, as the modelling demonstrates, is crucially important to a transition with lower costs and higher benefits;
- insure against high future international carbon prices by reducing the need for New Zealand to make large future outlays to purchase international units to meet its emissions-reduction obligations; and
- give more impetus to moving away from path dependence on high-emissions technologies and economic structures – particularly when early higher emissions prices are combined with strong leadership on policy direction and institutional reform and government support for low-emissions innovation and investment.

That said, the potential exists for some early actions to have unintended consequences. The modelling indicates that even with high emissions prices, some residual fossil generation is required as the least-cost means of providing back-up generation at winter peaks and when dry years deplete hydro lakes – accounting for some 1-3% of generation. The modelling indicates that prematurely forcing a move to 100% renewables generation through measures other than the emissions price would be higher cost (see also

Chapter 12). Higher electricity prices would reduce the rate of uptake of EVs and electric process heat, and thus reduce the rate of decarbonisation of these sectors which are the dominant source of New Zealand's energy-related emissions (Chapter 13).

F3.11

Pathways that feature stronger government action in the near term constrain future carbon costs and reduce the risk of long-term targets becoming unattainable if technological progress is slow. If disruptive technological innovation does occur, early action would enable much lower future costs in all cases. This lends support to an approach combining robust early policy action with strong and effective government support for innovation.

F3.12

New Zealand's transition to a low-emissions economy will be a long journey to a known and desired destination, but through very uncertain terrain. It would be foolhardy to try to pin down the best route for this 32-year journey to 2050 in advance. Rather, the situation calls for careful preparation, a capability for adaptation, and a balance between responsiveness to new information and policy stability. This approach will best equip the country to deal well with whatever terrain emerges.

Transitioning from forest sequestration may prove challenging

While afforestation provides a key means for reducing net emissions in the short term and medium term, challenges still exist in the longer term. Figure 3-22 shows gross emissions (ie, before the effect of forestry sequestration) along each of the six pathways. In each case, gross emissions in 2050 are only 28% to 43% lower than in 2015.

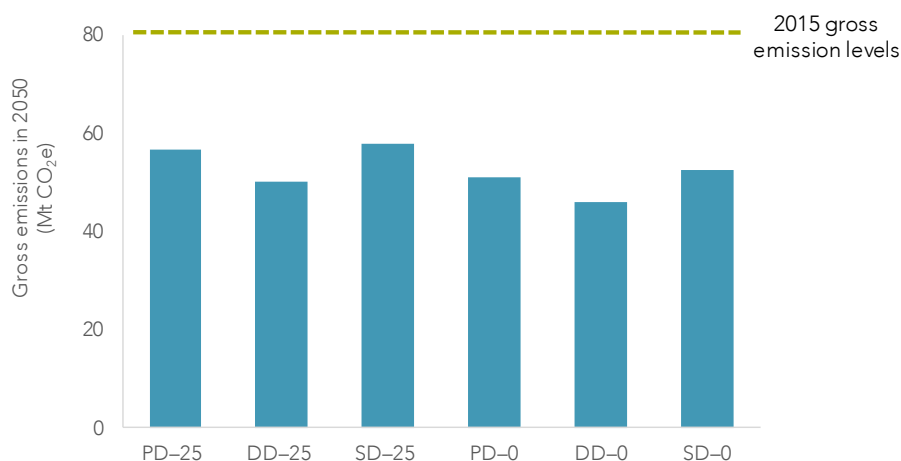
To continue to reduce emissions beyond 2050 (or to stay at net-zero emissions beyond this date), New Zealand would either need to find ways of reducing these emissions or continue to sequester emissions from forestry. Such sequestering could be achieved by:

- some combination of further transition to forestry in land-use patterns – which could be achieved if technological and cost breakthroughs (such as synthetic proteins) are realised and in use; or
- a transition from plantation forestry to permanent forestry. Using the CMV modelled pathways as a base, New Zealand Carbon Farming estimated that if 50% of new forestry planting were permanent rather than rotational (ie, for harvest and replanting) it would yield an additional 10.4 Mt CO_{2e} a year of removals by 2050 and 37 Mt CO_{2e} a year by 2070 (sub. DR293, p. 2). This additional sequestration is significant.

At the emissions prices indicated by the modelling, significant movement from harvested forestry to permanent carbon forestry is likely. The modelling does not capture this dynamic.

F3.13

While afforestation provides New Zealand with a very effective means for reducing net emissions in the short term and medium term, it is unlikely to continue to do so in the longer term since achieving such reductions would entail planting more and more land in trees. New Zealand will need to make additional cuts in gross emissions in the longer term. Such cuts will be costly in the absence of technological breakthroughs.

Figure 3-22 Along all pathways New Zealand's gross emissions fall by less than 50%

Source: Concept Consulting et al. (2018a).

The distinctive features of each scenario require careful consideration

Each scenario has distinctive features. These must be considered carefully because of their implications for managing economic and social change and taking account of future uncertainties.

Distinctive features across the scenarios and their associated pathways are noted below.

- The **Policy Driven** pathways require higher emissions prices in the short term to constrain emissions, but then see these prices grow at a slower rate to 2050. They see a large expansion in forestry production and moderate increases in dairy production, but large reductions in output from sheep and beef. At the same time, policy to expand native forestry may bring biodiversity and other environmental benefits and provide sequestration at a slower pace but over longer time periods. Support for public transport can reduce air pollution and congestion, but this support must be balanced against the potential for increased government costs.
- The **Disruptive Decarbonisation** pathways have the lowest cumulative emissions, lowest gross emissions, and lowest emissions prices. However, under these pathways, economic activity could be lost within New Zealand from the assumed closure of iron and steel and aluminium production. Lower renewable generation costs will flow through to lower electricity prices and higher EV penetration. The disruption from synthetic protein may see lower dairy production, but large increases in land dedicated to horticulture and forestry.
- The **Stabilising Decarbonisation** pathways result in the highest emissions prices by 2050, but they avoid a degree of economic disruption in the process. They see the largest increases in dairy production, and smallest falls in sheep and beef production. But this means they are also likely to deliver the worst outcomes of the pathways for water quality. The pathways retain iron, steel and aluminium production longer than the other pathways. The rate of expansion in EVs is slower. This could mean lower capital costs for vehicles, but higher fuel costs.

In addition to the differences across pathways, the choice of a less or more ambitious target brings its own trade-offs. As expected, a more ambitious target results in higher emissions prices, more forestry and the potential for greater structural change. However, the analysis of targets does not simply relate to the costs of mitigation, but also to the costs incurred from climate change, and an assessment of New Zealand's appropriate contribution as part of a global response. As noted, the economic dynamics modelled do not account for all the potential advantages stemming from early action on New Zealand's part; for instance, stimulating innovation in the development of new technologies and processes (Chapter 6).

Impacts of population growth and the pace of withdrawal of free allocation

As described in section 3.3, a sensitivity test of the impact of a faster rate of population growth indicates the need for higher emissions prices for New Zealand to reach its targets. But the effect is modest. The higher

population growth rate increases emissions through two main channels – increased demand for transport and for residential and commercial energy. But the impact of the former is muted because of the decarbonisation of large parts of transport leading up to 2050.

Notable also is that the impact of a growing population on New Zealand's emissions will only prove to be modest if per-person emissions fall dramatically. The modelling shows that net emissions per head must fall substantially from about 15 tonnes of CO₂e per person in 2015 to around 4 tonnes of CO₂e per person by 2050. The more the population grows, the more per-person net emissions will have to fall.

As also noted, slowing down the rate of withdrawal of free allocation to emissions-intensive, trade-exposed firms relative to that assumed in the main pathways requires higher emissions prices to reach a given 2050 emissions target. In the scenario used to check this, greater industry assistance (ie, slower withdrawal of free allocation) had little impact on production choices and led to an emissions price approximately \$20 a tonne of CO₂e higher by 2050. This suggests that, should international action be slower than anticipated, scope exists to address risks of emissions leakage by slowing the withdrawal of free allocations while having only a modest upward effect on emissions prices.

Links between modelling insights and the rest of the report

This chapter on modelling sets the scene for many later chapters in the report. The modelling has suggested that two of the most important influences on New Zealand's path to low or net-zero GHG emissions are emissions pricing and new technology. Emissions pricing is examined in depth in Chapter 5. Technology is a strong focus in Chapter 6, which examines the role of innovation in facilitating lower emissions. Chapter 7 examines the investments needed to implement new technology across the economy. Technology also features prominently in the chapters on land use, transport, electricity, and heat and industrial processes (Chapters 11, 12, 13 and 14 respectively). Some results from the modelling are examined in greater detail in these chapters.

The modelling indicates that the biggest opportunities for reducing net emissions lie in three areas: forestry, agriculture, and switching from fossil fuels to clean electricity and other low-emissions energy sources in transport and process heat. These areas are examined in depth, with Commission recommendations for policy changes in the chapters on land use (which covers both forestry and agriculture), transport, electricity, and heat and industrial processes.

Different pathways have very different impacts on different sectors and the people who work in them. Some government policies such as social policies are not included in the modelling. Social policies can help people who face disruption from the transition to low emissions to make changes in their lives. Chapter 10 is about a transition that is inclusive.

Chapter 9 examines the important issue of whether to treat GHG gases that are relatively short-lived in the atmosphere (such as methane) differently to long-lived gases (such as CO₂). This is an important issue for New Zealand because over 40% of the country's gross emissions consist of methane from agriculture. The modelling reported in this chapter can distinguish short-lived GHGs and long-lived GHGs. Notably, pathways that achieve the 25 Mt CO₂e target by 2050 achieve close to net zero emissions of long-lived GHGs while the net-zero pathways achieve net-negative long-lived gases.

Chapter 8 is about the laws and institutions to support a transition to a zero-emissions destination. The modelling shows it will be a long journey that requires steady progress towards the objective stretching over many years. Without suitable laws and institutions this journey is unlikely to happen in a democracy with three-year parliamentary terms and subject to strong pressures to award political priority to short-term, immediate problems. The laws and institutions must provide clarity and steadfastness of purpose, and transparency about progress. Yet they must contain the flexibility to take stock and, if necessary, change direction in the light of new information along the way.

4 Transitions

Key points

- Transitions are fundamental and intense periods of structural shift, representing the cumulative effect of major changes in supply and demand across the economy. They are different to the normal processes of economic change where jobs and businesses are created and destroyed every day.
- In the long-run, a transition to a low-emissions economy will require a complete shift away from fossil fuels. This will be an immense change given that economic prosperity since the Industrial Revolution has been predicated largely on maximising the value of energy from fossil fuels. However, over the next 30 years, the potential for significant afforestation in New Zealand allows for a more gradual transition, particularly in those parts of the economy where there are few low-cost options to reduce emissions.
- Awareness of the drivers of change and taking a systems perspective in understanding how change happens, will be important. It will also be necessary to continue to improve the underlying productivity performance of the New Zealand economy, as flexible and innovative economies will be much better able to profit from the opportunity that the low-emissions transition represents.
- New Zealand can reflect on other transitions that have occurred in recent history, such as the market reforms of the 1980s, to help to understand the scale of the transition required, and the value in acting early to avoid the need to make abrupt change that can make adjustment difficult.
- Changes in passenger transport, electricity generation and land use over the past 30 years also provide useful reference points for the likely nature of change required in these sectors during the transition to a low emissions economy.
- In most cases, the change required over the next 30 years will be of a similar magnitude to that experienced in the recent past. However, the nature of change will present some specific challenges. For example, the projected demand growth rates for electricity are of a similar magnitude to past trends. But a key difference is that future demand will need to be met through intermittent renewable generation, such as wind.
- Similarly, the overall rate of land use change required during the transition is comparable to that which has occurred in the past. But change will need to be heavily skewed toward afforestation, with sustained planting over the next 30 years, potentially at an annual rate approaching the highest ever recorded.
- Core policy and institutional elements that will provide the underlying foundation of the transition include stable policy conceived and implemented on a long-term timeframe, enabling innovation and information, and price signals to motivate behaviour change. Achieving these will not guarantee a successful transition, but are the minimum necessary components to set New Zealand on a trajectory towards achieving its low-emissions goals.

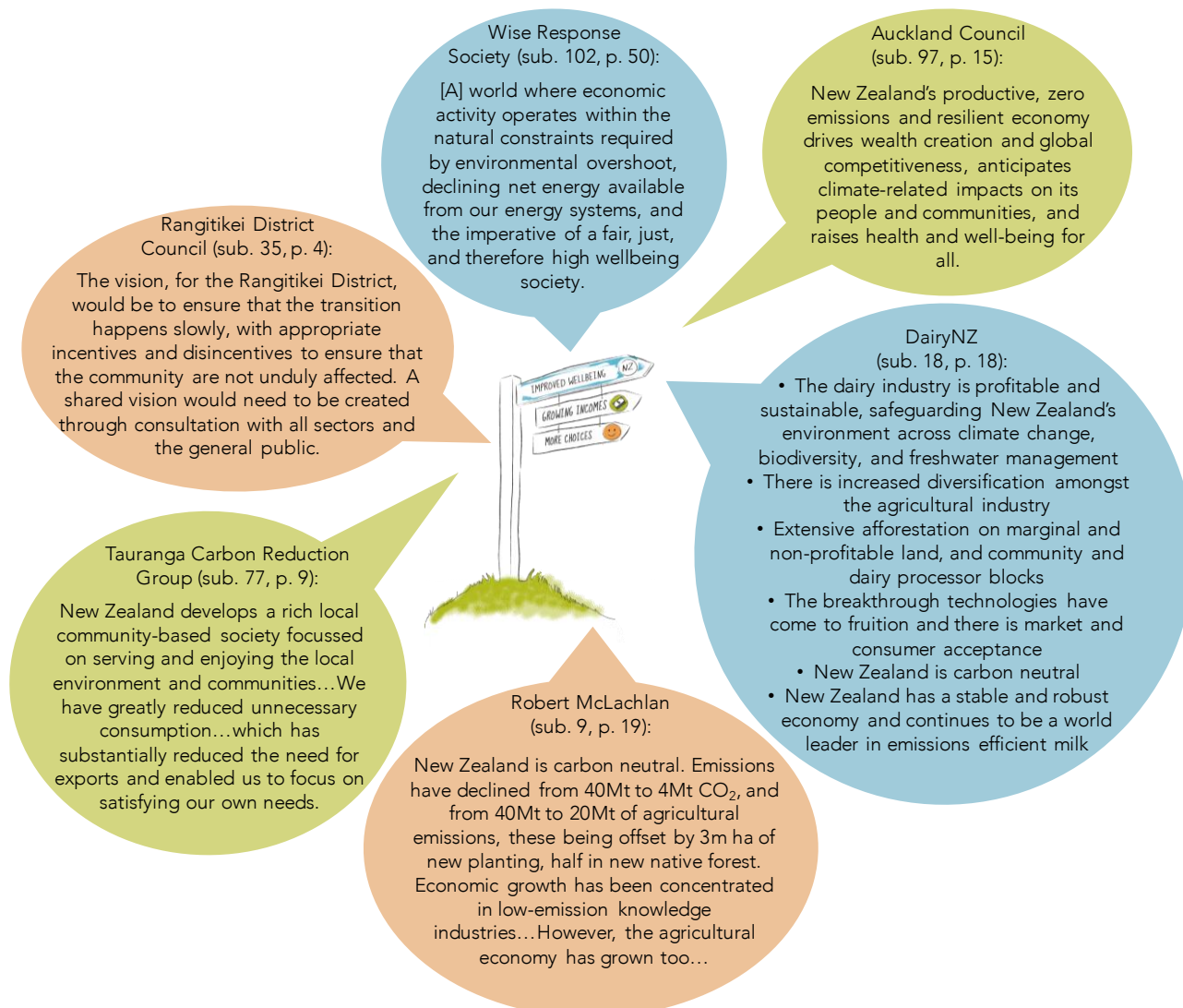
New Zealand has a dynamic economy that is constantly adapting in response to changes in technology and consumer preferences. And as with previous economic changes of various scales, the move to a low-emissions economy will create new opportunities and jobs besides replacing current roles and firms.

But what is a “transition”? What might it involve and what are the key drivers of change? By drawing on lessons from the past and expectations about the future, this chapter illustrates the potential nature of a 30-year transition to a low-emissions economy and outlines the necessary minimum characteristics for a transition that maximises opportunities and grows incomes and wellbeing.

4.1 What is a “transition”?

It can be hard to imagine what exactly the transition to a low-emissions economy will involve. The issues paper for this inquiry asked submitters to explain their long-term vision for a low-emissions economy, and multiple ideas were put forward (Figure 4-1).

Figure 4-1 Submitters’ long-term visions for a low-emissions economy



Notes:

1. Quotes have been shortened – see individual submissions for more detail on the visions outlined by each submitter.

But what exactly will the period of change be like *on the way* to this future state? And how might it be different to major periods of economic change that have occurred in the past? A transition from one type of economy to another involves changes in multiple and interconnected systems such as energy, transport and agri-food. While sometimes only apparent in retrospect, these transitions “do not come about easily, because existing regimes are characterised by lock-in and path dependence, and oriented towards incremental innovation along predictable trajectories” (Geels, 2010, p. 495).

A “transition” is different to normal economic change

Economies change constantly. However, there is a difference between the economic dynamism of the “everyday processes of churn” (GHK, 2011, p. 13) that occur in a market economy and the fundamental structural change of a transition.

Economic change happens every day...

As people respond to new opportunities, and to fluctuations in prices and demand, the economy changes. Two of the key processes of everyday economic change are firm entry and exit, and job creation and destruction. Official statistics show many people leave existing jobs or start new ones every month. Many changes are the result of seasonal job patterns (eg, tourism, agriculture) or worker choices (eg, starting work, retirement, moving to a better job). From a wider economic perspective, the more relevant statistics are jobs created, jobs destroyed and their net change. The Commission estimates these were 7.35%, 6.61% and 0.74% in 2015/16.³⁸

While emissions mitigation policies will reduce the demand for some goods, services and skills, they will create new investment opportunities and new forms of employment. Some of these trends are already evident in the United States (Box 4.1). They are also likely to continue – the International Labour Organisation estimates that 24 million jobs will be created globally (more than offsetting the loss of 6 million jobs) by 2030, if action to limit warming to 2°C occurs (ILO, 2018).

Box 4.1 The growth of low-emissions employment

US Department of Energy statistics reveal the impact that low-emissions technologies are already having on employment in the United States.

[S]olar employment accounts for the largest share of workers in the Electric Power Generation sector. This is largely due to the construction related to the significant buildout of new solar generation capacity. Solar technologies, both photovoltaic and concentrating, employ about 374 000 workers, or 43 percent of the Electric Power Generation workforce. This is followed by fossil fuel generation employment, which accounts for 22 percent...and supports 187 117 workers across coal, oil and natural gas generation technologies. (p. 28)

The 2017 USEER [US Energy and Employment Report] also shows that 2.2 million Americans are employed, in whole or in part, in the design, installation, and manufacture of Energy Efficiency products and services, adding 133 000 jobs in 2016. (pp. 8–9)

Currently, more than 259 000 employees work with alternative fuels vehicles, including natural gas, hybrids, all electric, and fuel cell/hydrogen vehicles, an increase of 69 000 jobs in 2016. Hybrids, plug-in hybrids, and all electric vehicles make up over 76 percent of this number, supporting 198 000 employees. (p. 9)

Source: US Department of Energy (2017).

These changes in the allocation of resources are a normal part of economic growth. For example, younger firms tend to be more productive than mature firms and have higher employment growth rates – especially in their early years (S. J. Davis et al., 2008). Also, whether jobs are created or destroyed in sectors with higher or lower productivity rates has a substantial effect on overall economic prosperity (Conway, 2016; Meehan, 2014). It is important to recognise that change can be traumatic and represent substantial upheaval for the individuals involved. Yet they are also a major source of overall economic productivity for New Zealand as a whole.

...but structural change is more significant

The type of structural change that a transition represents goes beyond micro or firm-level creation and destruction. Structural shift is just that – a radical change in the make-up of the economy and the activities and firms it comprises. A transition is the cumulative effect of major changes in supply and demand across the economy, which combine together to “produce particularly intense periods of change and restructuring” (GHK, 2011, p. 64). Another definition explains transitions as

a set of connected changes, which reinforce each other but take place in several different areas, such as technology, the economy, institutions, behaviour, culture, ecology and belief systems. A transition can be seen as a spiral that reinforces itself; there is multiple causality and co-evolution caused by independent developments. (Rotmans et al., 2001, p. 16)

³⁸ Calculated quarterly, then averaged over four quarters to remove seasonal variation (Stats NZ, 2018b).

The outcome of the transition depends on how successfully economic actors (individuals, firms, and regional or national economies) are able to respond to new challenges and opportunities (Dietrich, 2012).

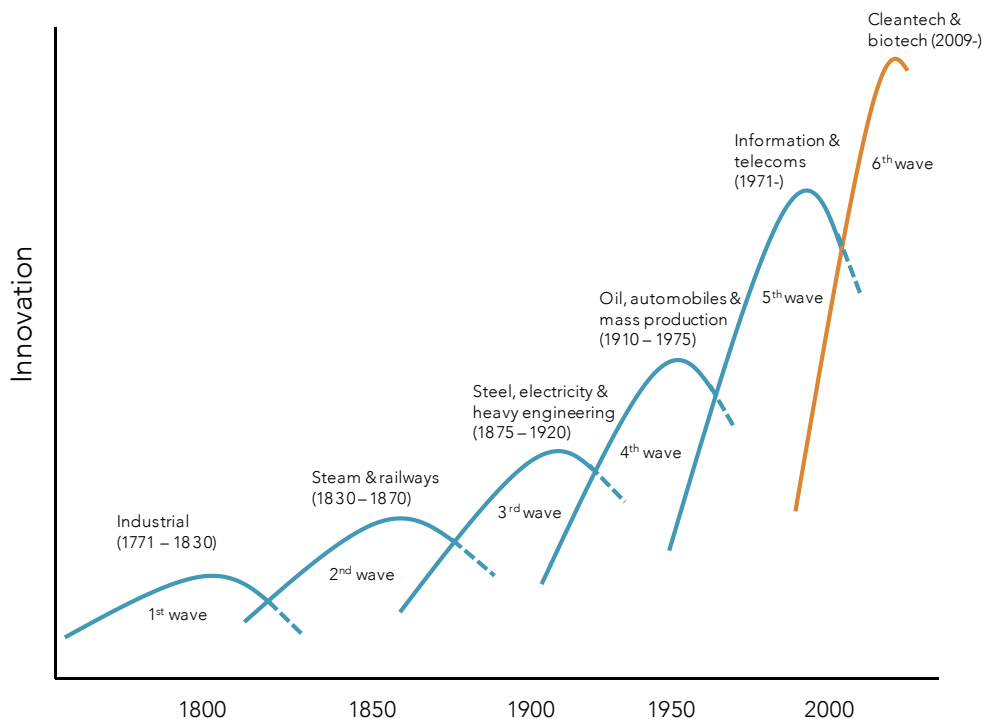
Critically, a transition is also about the decline of incumbents, just as much as it is about the emergence of new firms, technologies and opportunities (Fouquet & Pearson, 2012). If they are unwilling or unable to adapt and take advantage of new opportunities, these incumbents will tend to fight to protect the status quo (Wesseling et al., 2014). These power struggles are important because they can strongly influence the pace and nature of the transition.

Transitions therefore commonly involve struggles including business struggles between incumbents and new entrants (which involve industry structures, market power, alliances and strategies), discursive struggles in public debates (which involve claims and counterclaims, framing contests, and arguments over credibility and legitimacy) and political struggles over goals, policy frameworks and the setting of specific instruments. (John Pennington, sub. DR282, p. 4)

Transitions occur over different timeframes, and these timeframes are an important feature of the ability of individuals, firms and institutions to adjust to change. A transition may be abrupt, or it may be gradual and more difficult to perceive or measure. Particularly if a change isn't due to crisis, or an explicit policy direction, it may only be in retrospect that the true scale of a transition is apparent. The lens through which a transition is viewed is also relevant – change on a global scale may seem very fast or slow, depending on whether it is compared to changes occurring at the level of a region, city or country.

Major structural transitions in the global economy have, since the beginning of the industrial revolution, accompanied successive waves of disruptive and pervasive technological change (Figure 4-2). For instance, successive waves of economic prosperity have arisen from the adoption of new steam and electrical energy technologies and the invention of the internal combustion engine. The course of these transitions has often been slow, with periods of weak productivity growth as, collectively, firms and workers acquire the knowledge and skills and learn how to use them to best effect.³⁹ Yet cumulatively, these waves of innovation have transformed economic and social life over the course of two centuries and resulted in large increases in global incomes and well-being.

Figure 4-2 Waves of innovation



Source: Stern (2015, p. 37).

³⁹ See, for example, the discussion of information communications technology in Chapter 8 of *Boosting productivity in the services sector: Final report* (NZPC, 2014a)

Some predict, as is shown in Figure 4-2, that a new cycle is beginning that is linked to the low-emissions transition (Allianz, 2013; Papandreou, 2015; Stern, 2015). They predict that the cycle will see the labour productivity gains of the information technology cycle replaced by an increase in resource and energy productivity (Allianz, 2010). As with earlier transitions, it is possible that there will be an initial period of slower productivity growth as the new technologies are developed and bedded in. However, as discussed in the following section, thinking of the low-emissions transition as an incremental improvement, or even another wave of the same magnitude as many previous waves, may be inadequate (Fouquet & Pearson, 2012; Rifkin, 2011; David Henley, sub. DR212).

F4.1

A transition involves an intense period of change and restructuring that is different to the everyday processes of change in a market economy.

4.2 Why is the low-emissions transition beyond 2050 different to previous transitions?

The transition required to meet emissions targets in 2050 will entail significant change across the economy. However, the potential for significant afforestation during this period allows for these changes to happen more gradually. Beyond 2050, more comprehensive change will likely be required, because there will be a point at which New Zealand can no longer rely on forestry sequestration to offset large volumes of emissions.

Zenghelis (2016) notes that fossil fuels have been central to the enormous growth in global living standards since the onset of the Industrial Revolution 250 years ago. Decarbonising the global economy is, therefore, a fundamental shift in our contemporary economic structure. This is not just about energy generation in the narrow sense, like the electricity used to heat homes or power industrial processes (although this will also need to change). It also requires a transformation of nearly every single product, service or process that relies on the combustion of fossil fuels at any point in its life-cycle. Addressing climate change and stabilising global temperature at *any* temperature – 1, 2, 5 or even 10°C above pre-industrial levels – means getting long-lived greenhouse gases to net-zero at a minimum (Chapter 9). This represents an immense scale of change required in the global energy system, and at a speed much faster than any previous major energy transition (Box 4.2).

Box 4.2 Stimulating the speed of the low-emissions energy transition

A global shift away from fossil fuels is the lynchpin for the low-emissions transition. Concepts such as remaining carbon budgets (Chapters 2 and 9), show that this shift needs to happen rapidly (before the second half of this century) and comprehensively to achieve the goals of the Paris Agreement. For New Zealand, this means a nearly zero-emissions electricity sector (Chapter 13), and ultimately a reorientation away from goods and services that rely on fossil fuel combustion.

But energy transitions “have in the past tended to be relatively rare events whose complex and long drawn-out processes unfolded over decades and sometimes centuries” (Fouquet & Pearson, 2012, p. 1). To overcome this major challenge of timing (Smil, 2017), three lessons from past transitions can be drawn on to help stimulate the speed of the low-emissions energy transition.

The most important lesson is that an energy transition is only successful when the new energy source is cheaper than the incumbent energy source. In the initial phase where it is not yet cheaper, the energy source must offer enhanced characteristics for which customers are willing to pay a price premium (such as ease of use or cleanliness), to achieve some market penetration. But for these new energy sources to break out of niches and achieve widescale uptake, innovation and major economies of scale are needed so that they can then become price competitive enough to replace incumbents. Therefore, policy that stimulates both the development of alternative energy sources and its broad uptake (such as

emissions pricing that penalises emissions-intensive energy sources) is needed to achieve an accelerated transition.

Price fluctuations also stimulate energy transitions because they help to foster innovation into alternative energy sources and technologies. While these are unlikely to be encouraged by governments, if they occur, they could be capitalised on by way of an aligned and targeted innovation and investment system (Chapters 5 and 7) to accelerate the energy transition.

Finally, transitions are about the decline of incumbent technologies and industries as much as the rise of new ones (section 4.1). Policies that explicitly aim to destabilise the old (eg, a feebate for low-emissions vehicles, Chapter 12) as well as to create the new (eg, research support for agricultural mitigation technologies, Chapter 6) will need to be among the range of options for governments to actively consider (Kivimaa & Kern, 2016).

Chapter 1 of this report identified the nature of climate change as “super-wicked” (Levin et al., 2012). This is due to various factors, including the challenge of timing (ie, climate change is a “one-shot” problem) and of discounting. In terms of timing, because of the long-lived nature of certain greenhouse gases (GHGs) (Chapter 9), it is imperative to discourage new investments in long-term, high-emitting assets. For example, if all planned coal-fired power plants globally are actually constructed, the chance of limiting temperature increase to below 2°C is small (Ottmar et al., 2018).

Climate change also represents an extreme problem of public policymaking. The problem requires a concentrated global response – even large subsets of nation-states cannot solve this issue alone. But, because climate change is a tragedy of the commons (Chapter 5) more extensive than any previous experience, it is unsurprising that no “out-of-the-box” public policy solutions or institutional arrangements are available and easy to draw on to “fix” the problem. It is also an unprecedented public goods problem. Unlike other types of pollution (such as air or river pollution) that are physically constrained (even over large areas), GHG emissions in any part of the world affect the atmosphere of the entire earth. This also means that the incentive to free ride on others’ mitigation efforts is even greater.

4.3 Taking a systems perspective

The type of fundamental, long-term and multi-dimensional change anticipated to form part of the low-emissions transition will be radical and pervasive (Geels et al., 2016). Such a transition is not just about changes in technology over time; it is also about changes in markets for goods and services, user practices, policies, and cultural and social values (Markard et al., 2012). As Geoff Scott (sub. DR154, p. 1) notes, “change is not an event but a complex learning and unlearning process for all concerned”.

Various ways of thinking about the world explain transitions differently. For example, some parts of neoclassical economics see them as gradual adjustments to changes in prices and technology, while the strategy literature focuses on their nature as “strategic dilemmas for firms” (Geels, 2010, p. 497) in terms of decision making under uncertainty. Lenses that emphasise conflict understand that transitions are driven by shifts in the balance of power between the new and the old. Those who see change as a process of incremental adaptation are also challenged by others who see change as more discontinuous and radical (Schumpeter, 1939).⁴⁰

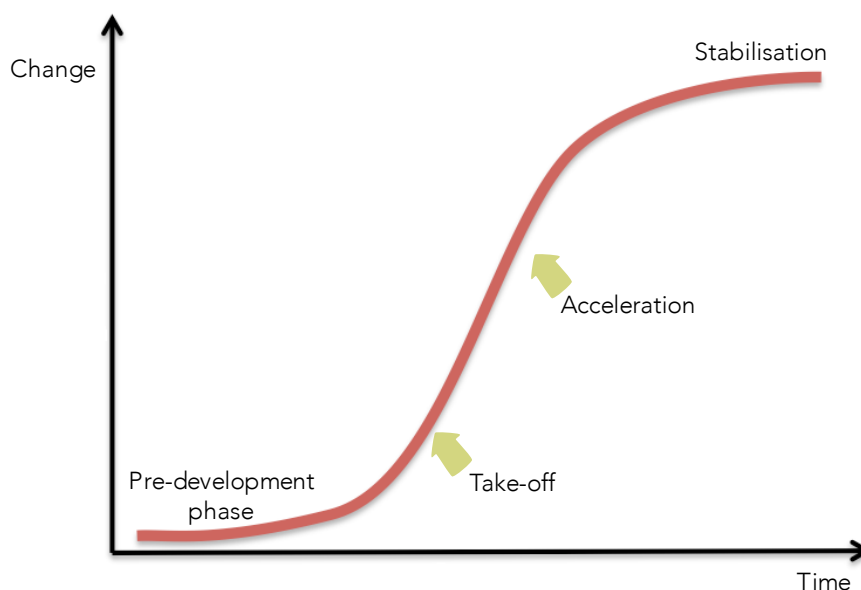
Yet what is clear across these, and many other, strands of research, is the vital importance of taking a systems perspective when understanding and preparing for the large-scale change that a transition represents (Farla et al., 2012). This requires paying attention to the ways that various elements of a transition can interact, such as its scope (which elements will differ, and how), the period over which change occurs, the

⁴⁰ See also Schumpeter’s concept of “creative destruction”. Calling it the essential fact about capitalism, Schumpeter (1942/2003, p. 83, emphasis in the original), defines creative destruction as the “process of industrial mutation...that incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one”.

parties involved in and affected by the transition, and the way the transition manifests in particular physical scales and locations as opposed to others (Hansen & Coenen, 2015).

A systems perspective also highlights how transitions comprise “a transformation from slow dynamics to quick development and instability, reverting to relative stability” (Rotmans et al., 2001, p. 17). In other words, major changes can happen quickly and radically destabilise existing activities, but they are generally preceded by long periods of preparation that increasingly snowball to work against the stability and inertia of the status quo. Figure 4-3 shows this stylised S-shaped curve of four phases of the transition, while acknowledging that this neat description may not always accurately capture the sometime chaotic nature of change (including the way incumbents push back against threats). It also should not be understood as suggesting that there is a single path to the transition – the same end point may be reached using multiple different pathways (Chapter 3).

Figure 4-3 The four phases of transition



Source: Rotmans et al. (2001).

Even so, this stylised depiction does indicate why long-term commitments to fostering innovation (a core driver behind the technological advancements that drive change) are so important, despite the pay-off being potentially uncertain and distant into the future (Chapter 6). It is also why understanding coordination failures, particularly for technologies that seek to destabilise incumbents (such as replacing fossil fuels with bioenergy or other low-emission energy technologies), is critical.⁴¹

Looking at transitions as changes to complex, multi-faceted systems highlights the potential for the low-emissions transition to create *more* than just the sum of its emissions reductions parts (eg, as narrowly expressed in the national emissions inventory). If the necessary conditions for a successful transition are achieved, the low-emissions transition offers potential for improved wellbeing as New Zealand identifies and capitalises on new emissions-reducing technologies and opportunities. Chapter 10 focuses on the co-benefits of the low-emissions transition. Submitter David Henley (sub. DR212, p. 3) draws together these themes of substantial economic change and a systems perspective, noting that the

[t]ransition conversation & approach would benefit from being primarily framed as an economic transition (that is also low-carbon) – that incorporates the multiple societal challenges & opportunities we face in the 21st Century, rather than a primary focus on GHG reductions (although these are obviously crucial). Given this would - by default - be a more systemic conversation & framing, it is also likely to ultimately be more impactful in reducing emissions.

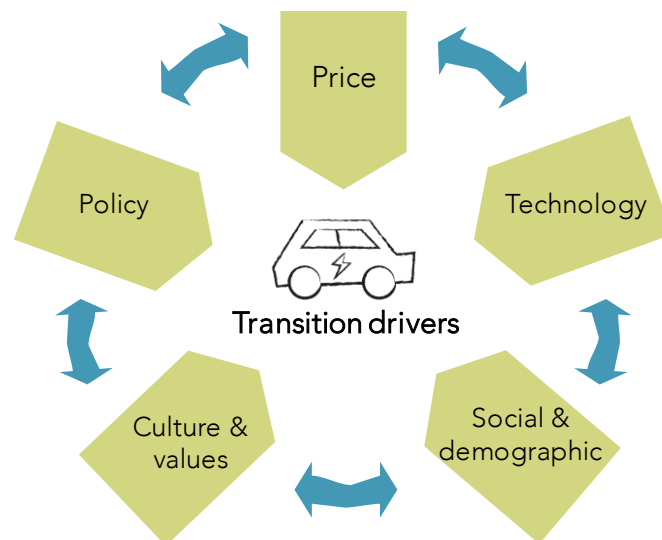
⁴¹ Another strand of literature also discusses what are known as “sustainability transitions”. These are “long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption” (Markard et al., 2012, p. 956). They highlight the multi-level perspective of transitions, which implies that “change only breaks through if developments at one level gel with developments in other domains” (Rotmans et al., 2001, p. 20).

Finally, as with any other transition, the transition to a low-emissions economy will also require a concentrated period of high-stakes decision-making under conditions of uncertainty. Establishing stable and credible climate policy settings will be vital in enabling the private sector and civil society to plan and take long-term decisions.

4.4 Key drivers of transition

Figure 4-4 shows five of the key drivers of change in an economic transition – price, technology, social and demographic shifts, culture and values, and policy. But it is important not to view any of these drivers of change in isolation. While one driver may be a dominant force for change in certain transitions, multiple drivers interact and influence each other according to the specifics of time and place.

Figure 4-4 Key drivers of change in an economic transition



- Sudden or gradual changes in the **price** of a product or service can dramatically alter an economy. A substantial and permanent drop in price can make it no longer viable to continue with existing economic activity. This outcome may lead to firm or industry closure or re-orientation towards other activities. But, price shifts can also make technology increasingly available to a wider segment of the population, contributing to social and demographic change. For example, the average price of air travel per mile travelled has dropped by approximately 40% over the last 30 years (Perry, 2012), contributing to substantial changes in patterns of work (L. Wang & Chen, 2018).
- The development and adoption of new **technology** is a well-known driver of change. In the United States, the advent of running water, washing machines and other household technologies reduced the time spent on household chores by nearly 70% – from 58 hours a week in 1900 to 18 hours a week in 1975 – and led to a substantial increase in women working outside the home (Cardia, 2008). Technology can also lead to rapid and sometimes disruptive change, leaving incumbents behind both within sectors and across the economy (such as the shift from the horse and cart to the internal combustion engine).
- **Social and demographic** factors are clearly linked to economic performance (Bryant, 2003; Prskawetz et al., 2007). For example, increasing global population results in higher demand for housing, leading to changes in demand (and possibly also in prices) for housing commodities such as wood and steel (FAO, 2011). The change away from large families (the New Zealand fertility rate in 2017 was 1.81 births per woman, down from a high in 1961 of 4.31 births per woman (Sargent, 2018)), also influences the structure of the economy. This so-called “demographic transition” to smaller families is shown to increase the economic success and social position of descendants for up to four generations into the future (Goodman et al., 2012).
- The **culture and values** held by society are an important transition driver because they co-create the social licence for policy change, influence consumer and business willingness to accept and adopt new technologies (eg, willingness to accept risk), and guide the nature of institutions governing the transition

(Chapter 10). The increasing discomfort in New Zealand with economic activity that creates environmental harm (such as waterway pollution) has, in part, been driven by changes in social values (Warne, 2017).

- Finally, transitions may be driven by **policy** decisions. This includes single, large policy decisions, such as signing up to treaties or major policy reforms, or the cumulative effect of a series of smaller policy decisions that push in a similar direction (Kivimaa & Kern, 2016). For instance, the Trans-Tasman Travel Arrangement (1973) and the Australia New Zealand Closer Economic Relations Trade Agreement (1983) are examples of major policy decisions that have both had significant impacts on New Zealand's demographic makeup and economic structure (APC & NZPC, 2012b; A. M. C. Smith, 2018). Policy decisions catalysing structural change may arise at multiple levels, from international commitments made by New Zealand as a nation–state (such as signing up to the Paris Agreement), to significant decisions at a national level (such as the specific policy decisions that the New Zealand Government considers necessary to honour the Paris Agreement).

Taking a systems perspective will be important to understand how these drivers are likely to interact in the low-emissions transition. For example, emissions pricing (Chapter 5) will be a core driver of change in the low-emissions transition and is a complex combination of policy (the decision to enact a pricing mechanism), price (the actual effect), and technology (as the price aims to, in part, spur the development of low-emissions technologies to replace high-emitting technologies).

F4.2

Five of the key drivers of change in an economic transition are price, technology, social and demographic shifts, culture and values, and policy. These interact and influence each other according to the specifics of time and place.

4.5 Learning from history

New Zealand has witnessed numerous major transitions throughout its history. One example is the Māori urban migration from the 1940s to the 1980s. In 1945 26% of the total Māori population lived in urban areas. Yet by 1986, nearly 80% of Māori lived in towns and cities (Meredith, 2015). This significant demographic shift played an important role in the composition and culture of New Zealand society. It resulted in changes to fertility rates (Easton, 2012), and the development of new forms of collective identity such as urban marae and urban Māori authorities (Keiha & Moon, 2008).

Another example from recent history is the process of economic reform begun in 1984. This sweeping programme of market liberalisation included fundamental changes to monetary, fiscal, trade, regulatory and social policy (James, 1999; G. Scott, 1996). These policy changes occurred in response to two main factors. First, the state was not effectively managing itself, and therefore hampering the performance of the wider economy. Second, due to a number of events and crises affecting the economy. These included the accession of the United Kingdom to the European Communities in 1973 (forcing New Zealand to find new export partners) and the second oil shock of 1979. As former Secretary of The Treasury John Whitehead (2005) summarises, “New Zealand was living on borrowed time, very heavily borrowed. The status quo simply was not sustainable”.

Even so, this concentrated period of change led to substantial disruption across the New Zealand economy. The newly deregulated economy was then exposed to the effects of the 1987 international stock market crash, which led to widespread business failures in New Zealand. Combined, these events had large and persistent socio-economic effects. Māori were particularly affected, as they were disproportionately employed in industries that experienced major job losses (such as government-managed industries like forestry, railways and the post office, as well as other industries such as freezing works). Māori unemployment was 25% by 1992, compared to the overall rate of 10% (Manatū Taonga, 2018).

Both of these periods of major change provide reference points that help to provide a sense of the scale of the low-emissions transition – although, as with these examples, the changes arising from the low-emissions transition will be more disruptive for some people than for others. While all parts of New Zealand society will see some effects (such as changes in commodity prices), for some it will be particularly apparent. These

include businesses and regions highly dependent on activities that will be exposed to increasing emissions prices (Chapter 10).

These periods also provide lessons for the low-emissions transition. Significant social or economic change can lead to persistent effects continuing over decades. As with the Māori urban migration, the low-emissions transition is also likely to see changes occurring in the make-up of urban and rural communities, and the movement of workers, businesses and families around New Zealand in search of new opportunities created by the changing economic landscape. The reforms of the 1980s help to show that attempts to postpone necessary change are likely to be self-defeating and may exacerbate disruption when change does emerge. In other words, the transition is likely to be significantly more difficult and costly when change is delayed unnecessarily (ESRB Advisory Scientific Committee, 2016; OECD, 2017c).

But, if the transition pathway can be signalled well in advance, and necessary change is not unduly delayed, policy decisions can help to foster a trajectory that improves incomes and wellbeing for the greatest number of people. To achieve this, ongoing commitment from government, a productive and innovative private sector and buy-in from communities and households (Chapter 10), will be vital (Ahrens, 2007).

4.6 Establishing the conditions to handle change well

A vibrant and dynamic economy that is already successfully facilitating change daily will find it easier to navigate the longer-term shift to a fundamentally different structure. At the heart of this is the concept of productivity. Two fundamental components of productivity growth are innovation and technology diffusion. Both discussed in detail in Chapter 6, these will be critically important for the low-emissions transition. This is because the transition relies so heavily on the development, and diffusion throughout the economy, of alternatives to existing, high-emitting activities.

While some low-emissions technologies already exist that have significant potential to lower New Zealand's emissions (such as electric vehicles (EVs), Chapter 12; and waste mitigation technologies, Chapter 15), other low-emissions technologies have not been developed yet. Much of this innovation will originate offshore and New Zealand will be a technology-taker. But some innovation will also occur domestically. These local innovations are more likely to occur in areas where New Zealand has existing comparative advantage, but may also occur in areas that cannot be predicted today. Yet, even where new technologies are created, an economy that learns well, through technology diffusion and the uptake of new skills, will be better equipped to participate in, and take advantage of, the low-emissions transition than an economy that does not.

But, in general, the New Zealand economy is not as nimble and productive as it could be. One of the reasons behind New Zealand's relatively poor productivity performance is that "New Zealand firms are small in international comparison and competition is weak in parts of the economy". The consequence is that "firms do not grow much and there are many small, old firms in the economy, consistent with poor resource allocation and a lack of 'up or out' dynamics" (Conway, 2016, p. 2). Flexibility will also be important. Being able to more easily shift resources from less productive to more productive activities will be needed in the low-emissions transition as employment and business opportunities change.

So, while a transition is different to the normal process of everyday change (section 4.1), ensuring that the underlying fundamentals of the economy are in good shape will play as critical a role in the transition as the specific policy levers and decisions that are focused directly on mitigating emissions.

Conway (2018) identifies several areas necessary to improve New Zealand's productivity performance, including improving the matching of skills to jobs, making investment easier and more effective, and strengthening the economic return from science and innovation. If the potential of the low-emissions transition is to be captured, focusing government attention on these areas will continue to be necessary.

F4.3

The characteristics of successful, high-productivity economies include openness to innovation, adaptability, and the capacity to mobilise capital, labour and other resources to take advantage of new opportunities. These characteristics are all important for the successful transition to a low-emissions economy.

4.7 Sectoral transitions

The previous chapter examined potential pathways and changes over time that may be expected across the New Zealand economy. It highlighted three key areas that will be major drivers of the transition: replacing the combustion of fossil fuels with electricity and other low-emission fuels (such as in transport, with a shift to EVs); substantial afforestation, and changes to the structure and methods of agricultural production.

However, how does the period of change over the next 30 years to 2050 compare with the previous 30 years? This section highlights three sectors – passenger transport (as a key sector where electrification will be particularly revolutionary), electricity and land use – and contrasts the scale and pace of change that New Zealand has experienced since 1990, with the type of change needed to achieve a low-emissions economy.

Passenger transport

Over the last 30 years, passenger transport in New Zealand has undergone changes of both a transformative and an incremental nature. The main transformational change has occurred in the vehicle market, following the phasing out of tariffs and import restrictions on vehicles which began in the late 1980s. Before this, nearly all cars entering the fleet were locally assembled at one of 13 assembly plants throughout the country, employing nearly 6 000 people (Willis, 1994). However, the Government recognised that it “was cheaper and more efficient for cars to be assembled in the country where they were made” (Pawson, 2014). As phasing out began, local assemblers struggled to compete with new and used cars imported from other countries, with about half of the assembly plants closing by the end of the 1980s. The last plant closed in 1998, when all remaining tariffs were removed. Local vehicle component industries also saw firm closures and job losses.

While this represented enormous changes for the vehicle industry in New Zealand, car buyers benefited from lower prices and an influx of cheap, second-hand cars – mainly from Japan. Sales of used imports grew to dominate the market, exceeding new light vehicle sales in almost all years since 1995 (Motor Industry Association, 2018). Prices of both new and used cars fell by 36% in real terms between 1987 and 2000.

This period of dramatic transition is notable in comparison to the trend of mostly steady and gradual change in the transport sector over recent decades. The vehicle fleet takes decades to turn over, transport infrastructure and urban form are slow to change, and travel behaviours can be stubborn once established. However, as discussed in section 4.1, smaller changes happening at the margins can have large cumulative effects over time.

Overall transport emissions grew by 71% from 1990 to 2016 (MfE, 2018d) – nearly double the growth in population. Even so, this growth was not continuous. Indeed, emissions from passenger transport remained almost flat for the decade from 2005, until recently beginning to grow again. An analysis of the underlying drivers of emissions reveals three distinct phases of change in vehicle use and purchasing patterns (Table 4.1). These phases of change correspond quite closely with trends in real petrol prices, which fell, then grew, and then fell again (Figure 4-5; Figure 4-6).

Table 4.1 Phases of change in New Zealand’s passenger transport patterns

Phase of change	Characteristics
1990–2005	New Zealanders travelled more and made more trips by car. Total distance travelled on roads per person grew by 16%, and the share of trip legs by public transport, walking and cycling fell by around 10%, 20% and 60% respectively. Per person vehicle ownership grew strongly from 1995 and the number of households with two or more vehicles overtook the number with one or no vehicles. The average size of vehicle engines also increased.
2005–2012	The trend of increasing personal travel reversed. Light passenger vehicle travel per person fell by 10% and the share of travel by public and active transport modes held steady. The number and average engine size of vehicles entering the fleet decreased, and their average fuel economy improved.

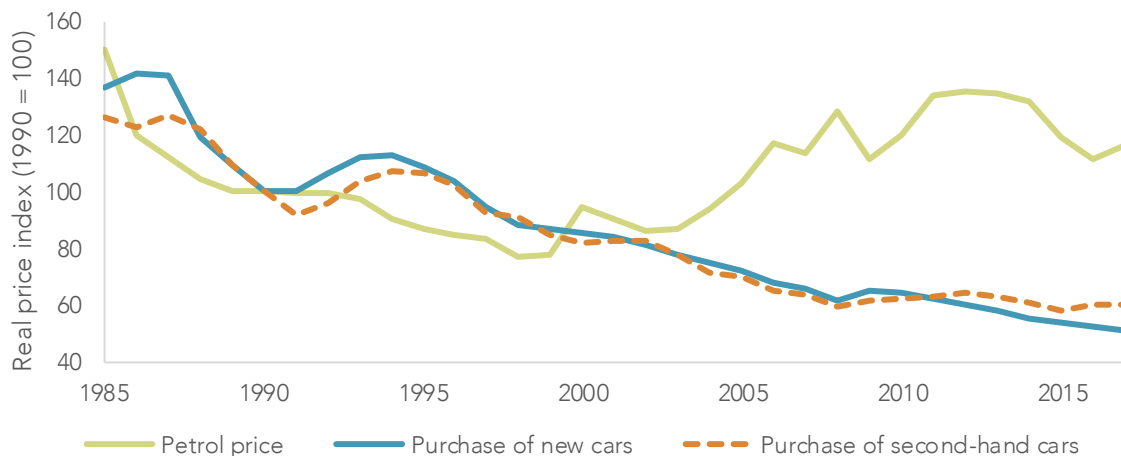
Phase of change	Characteristics
2013–present	This period shows a return to pre-2005 patterns, with travel per person and light vehicle registrations growing by a greater amount each year since 2013. The average engine size of vehicles entering the fleet is increasing and their fuel economy has plateaued.

Source: MoT (2015, 2016a, 2016c); Motor Industry Association (2018).

This analysis suggests that changes in fuel prices are linked to observed changes in travel behaviour and vehicle choice. However, some caution is required as many other factors also influence vehicle use (MoT, 2014a). These factors include increased urbanisation; the rise of telecommunications and online connectivity; increased subsidisation of and investment in public transport (particularly in Auckland); and demographic and social changes, with younger generations driving less than previous cohorts. All these trends look likely to continue into the near future.

The changes in transport patterns have had important consequences. If average fuel economy and travel per person had both remained at 2004 levels, New Zealand’s emissions from light passenger vehicles in 2015 would have been around 1.4 megatonnes of carbon dioxide equivalent (Mt CO₂e) or 18% higher. The changes also mean that despite a 27% increase in petrol prices over this period, per person expenditure on fuel for light passenger vehicles only increased by 9%.

Figure 4-5 Real prices of petrol and motor cars, 1985–2017

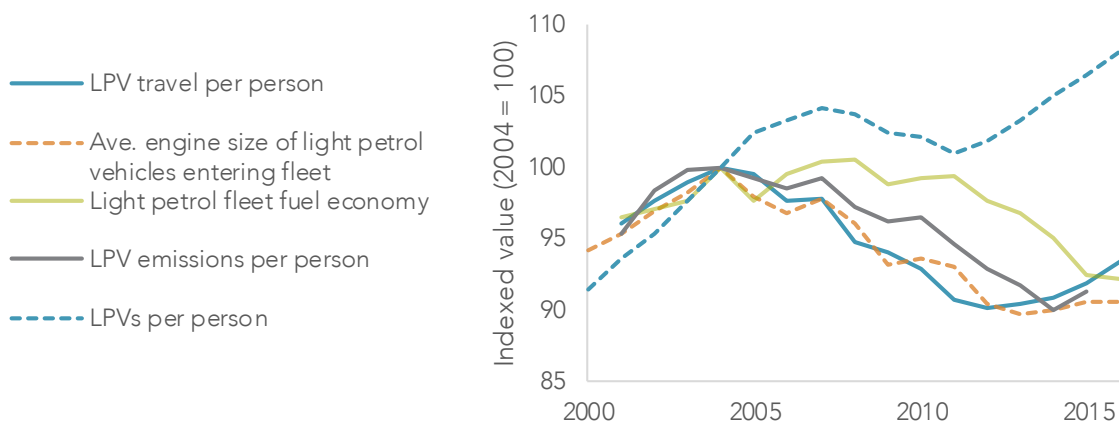


Source: MBIE (2018c); Stats NZ (2017d).

Notes:

1. Car prices are “quality-adjusted” to account for perceived value of new and improved features (eg, airbags, engine performance).

Figure 4-6 Trends in light passenger vehicles (LPVs) and their use, 2000–2016



Source: MoT (2016a).

Notes:

1. 95% of vehicles in the light petrol fleet are LPVs.

Looking to the future

Looking forward over the next 30 years, the transition to low-emissions transport is also likely to involve both incremental and more visibly transformational change. The modelled scenarios presented in Chapter 3 assume relatively modest changes in aggregate travel behaviour, in keeping with past trends. Vehicle travel per person declines slightly, while the most ambitious scenario sees a 75% increase in the share of trips by public transport, walking and cycling, and a 30% increase in the proportion of car-sharing. More radical changes in future travel demand and behaviours are possible (MoT, 2014a). As shown above, the cumulative effects could be substantial.

For most New Zealanders, the key shift will be in the types of vehicles they are driving and how these are fueled. A transition of the light fleet to EVs appears most likely at present, but other technologies such as high-efficiency fossil fuel-vehicles and liquid biofuels could also play an important role.⁴² The timeframes and nature of the shift to low-emissions vehicles are also uncertain and depend heavily on the pace of technological development. The scenarios presented in Chapter 3 span a range of possible futures. At one end of the spectrum, EVs undergo explosive market growth and make up 95% of light vehicles entering the fleet by 2030. By 2050, fossil fuel-vehicles would be an increasingly rare sight on New Zealand's roads, with 80% to 90% of all light vehicles and more than half of heavy vehicles running on electricity or other low- or zero-emissions energy sources. At the other end of the spectrum, a slower reduction in the relative cost of EVs leads to a much more gradual uptake. In this scenario, only 20% of light vehicles entering the fleet in 2030 are EVs, and most travel is still being done in fossil fuel-vehicles in 2050. As a result, emissions from road transport in 2050 are more than double that of the first scenario.

The radical takeover of EVs seen in some scenarios and projections may appear unlikely today. Yet, based on a continuation of current technology trends, mainstream projections suggest that it will be possible to buy a medium-sized EV with comparable range to a fossil fuel-vehicle sometime around the mid-2020s for the same upfront price without subsidy (Bloomberg New Energy Finance, 2018b). Continued reductions in battery costs would see price-parity reached across progressively larger vehicle classes. Since EVs are also much cheaper to run – EECA (sub. DR326) states this is equivalent to paying 30 cents a litre for petrol in today's prices – and have lower maintenance costs, EVs would significantly undercut fossil-fuel vehicles on total cost of mobility. On this basis, even without a concerted effort to reduce vehicle emissions, a shift towards electrified transportation would likely still occur.

In the Commission's view, as EVs approach price-parity (which could happen earlier with policy support), a tipping point towards rapid uptake is highly plausible. While it did not involve uptake of new technologies, New Zealand's experience with deregulation of vehicle imports (discussed above) demonstrates that rapid changes in the vehicle market can occur when buyers are offered a similarly attractive option at lower prices. A further historical example is the conversion of vehicles to run on compressed natural gas (CNG) and liquefied petroleum gas (LPG) after the 1979 oil shock. World oil prices spiked, and the Muldoon Government offered interest-free loans for CNG and LPG vehicle conversions, along with subsidies to build refuelling infrastructure (The Dominion Post, 2009). Rapid uptake saw the share of converted vehicles rise to around 10% of the fleet by the mid-1980s, before falling as the Lange Government removed subsidies and oil prices went into decline.

The low-emissions transition will also impact the automotive service industry. For mechanics, growth in EVs and other low-emissions vehicles will create additional training needs in the short-term, and potentially reduce employment in the long run due to the simpler engine and lower maintenance requirements of EVs (Pullar-Strecker, 2016). Fuel retailers may have emerging opportunities in providing fast-charging for EVs, but it seems probable that most charging will happen at home and at work. Declining numbers of fossil-fuel vehicles would likely lead to further consolidation in service stations, the number of which has already declined from around 2 500 in 1990 (Hale & Twomey Ltd, 2008) to around 1 200 today (Polkinghorne, 2016). Associated fuel retailing jobs have already declined by around 25% since 2000 (Stats NZ, 2017d).

Yet even with rapid growth in EV sales, the transition will take decades. Most New Zealanders buy their vehicles in the second-hand market, and those on low incomes tend to be constrained to purchasing older

⁴² This section focuses on passenger transport. In freight and other heavy vehicle transport modes, barriers to electrification are generally higher and so it will remain important to consider a wide portfolio of alternative technologies and mitigation options (Chapter 12).

vehicles at a low price point. It will take time for EVs and other low-emissions vehicles to work their way through the fleet for all to benefit from the cheaper mobility these will provide. In the meantime, fossil-fuel vehicles are likely to see increased fuel costs. Rising emissions prices will play a role, but, as in the past, changes in oil price and exchange rates could have much larger effects. Importantly, comparatively lower fuel prices are anticipated in a future where EV uptake occurs rapidly at a global scale and in New Zealand, due to weaker global oil demand and relatively lower emissions prices. In other words, even people who are not driving EVs will likely be better off in a future with rapid EV uptake. Chapter 10 further discusses equity dimensions of the transport transition and how government can help to manage these.

However, growing popularity and market share of EVs could have hard-to-predict dynamic effects on markets and social preferences, which may lead to a faster transition than currently envisaged. For example, societal attitudes could shift rather suddenly against the use of fossil-fuel vehicles – similar to how views towards smoking have evolved. If all service stations began to disappear at the same time, this could lead to “range anxiety” eventually becoming more of an issue for people still driving fossil-fuel vehicles. Effects such as these could combine to drive faster depreciation and turnover of existing fossil-fuel vehicles in the fleet.

Finally, there is the potential for autonomous vehicles and new “mobility-as-a-service” models to radically disrupt the transport sector. Some predict that this could occur in the next decade, while others anticipate a much slower and more staged uptake (Box 12.3, Chapter 12). This could lead to fundamentally transformed patterns of travel and vehicle ownership. However, these changes may vary substantially depending on setting. For instance, urban areas may see significantly faster uptake of EVs and autonomous vehicles, but these technologies may be less well-suited to rural areas.

Electricity

The electricity sector has witnessed significant changes over the last 30 years in New Zealand. They include changes in market structure, demand, types of generation, and the way electricity prices are distributed between different types of users.

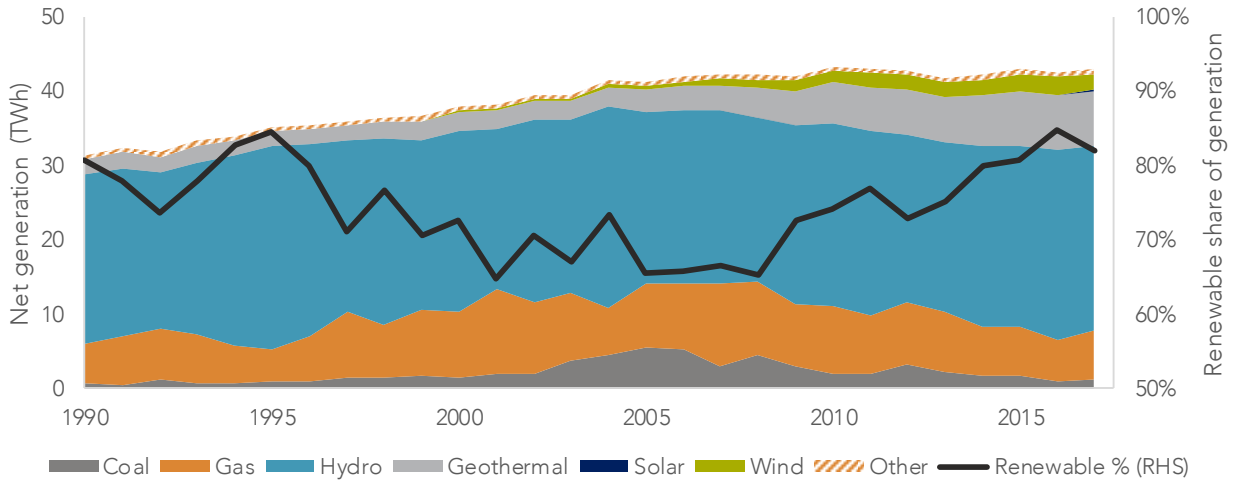
As with transport, major market reforms occurred in the electricity sector, beginning in the mid-1980s (MBIE, 2015). From a highly centralised system, with significant political involvement in generation investment decisions and price setting, the electricity system is now characterised by competing “gentailers” (generators and retailers) and independent, publicly owned and regulated operators of transmission and distribution networks (Transpower and local lines companies). This decentralisation also led to the development of new markets operating within the electricity system to manage risks and improve market efficiency (Chapter 13).

For many decades, New Zealand’s electricity demand grew steadily at an average rate close to 2% a year. Total demand more than doubled from 1975 to 2005, from approximately 17 terawatt-hours (TWh) to approximately 39 TWh a year (MBIE, 2018b). Up until 1990, new hydropower projects covered most of this additional demand, with the remainder met through increased use of natural gas. But installed hydropower capacity effectively reached a plateau in the early 1990s due to a combination of physical, environmental and cost barriers (Kelly, 2011).

In response to this plateau, efforts intensified to develop alternative renewable generation options. For example, the Government issued a Renewable Energy Policy Statement in 1993 aiming to “facilitate the development of cost-effective renewable energy” (MBIE, 2015, p. 8). But commercial wind energy prospecting was only just beginning in New Zealand (Pyle, 2016), while geothermal power was at the time limited to two power stations. Most of the growth in electricity demand from 1990 to 2005 was instead met through increased use of coal- and gas-fired generators (Figure 4-7). Over this period, the share of generation from renewable sources fell from 81% to 66% (MBIE, 2016b, 2018b) and electricity emissions grew from 3.5 million tonnes CO₂e (MtCO₂e) to 9.0 MtCO₂e (MfE, 2018d).⁴³

⁴³ This excludes fugitive emission from geothermal electricity generation.

Figure 4-7 Electricity generation by source, 1990–2017



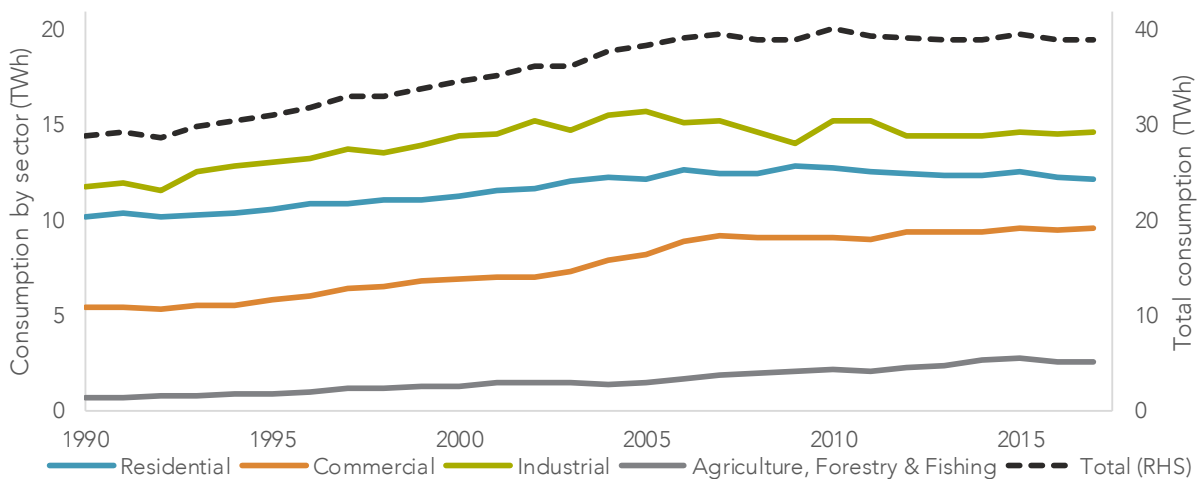
Source: MBIE (2018b).

Notes:

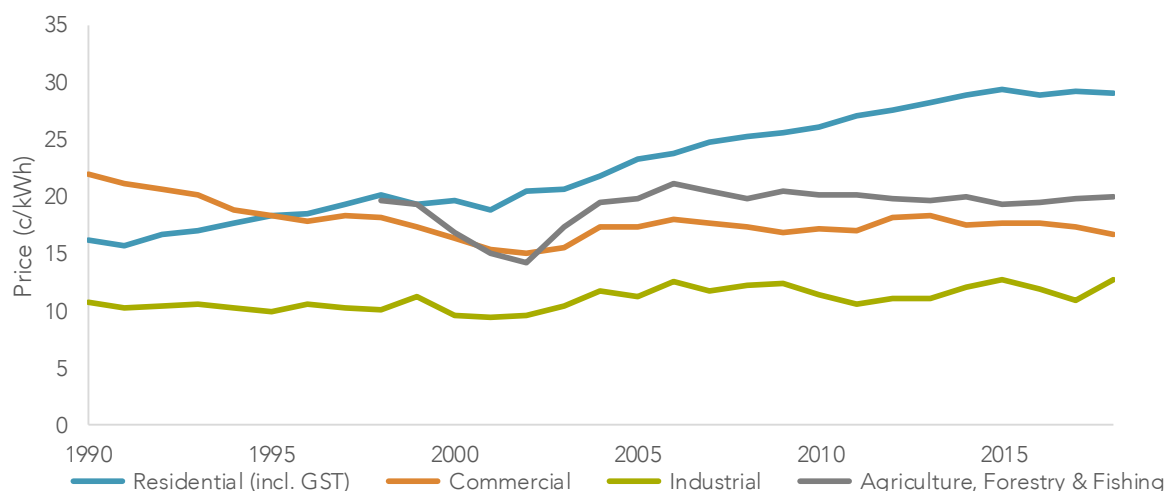
1. Other is mostly wood and biogas, plus very small amounts from oil and waste heat.

These trends have reversed in recent years. A burst of construction of new geothermal plants and wind farms together with an unexpected flattening in demand combined to drive down coal and gas generation. The share of renewable generation rebounded to reach 82% in 2017 (MBIE, 2018b). Electricity demand has remained flat for the last decade and has fallen slightly in the residential and industrial sectors (Figure 4-8). The average household is consuming 7% less electricity today than five years ago (MBIE, 2018e). Determining why this demand reduction has occurred is complex, with many interrelated factors to consider (Batstone & Reeve, 2014). Price changes are likely part of the story, but do not provide a straightforward explanation. Since 1990, real electricity prices for residential consumers have grown by 79% on average but have flattened off since 2015 (Figure 4-9). Over the same time, prices for industrial consumers rose 18%, and prices for commercial consumers fell 24%. The different trends reflect a redistribution of the costs of the electricity system among different types of users to more closely match relative costs of supply and distribution (Electricity Authority, 2014).

Figure 4-8 Electricity consumption by sector, 1990–2017



Source: MBIE (2018b).

Figure 4-9 Real electricity prices by sector, 1990–2018

Source: MBIE (2018c).

Finally, the costs of renewable generation have fallen sharply over recent years to become, in many cases, either cost-competitive with, or less costly than, fossil-fuelled generation. The costs for solar photovoltaic (PV) and onshore wind energy have been particularly noticeable. For example, the price for a PV module has dropped by about 80% since 2010 and the global weighted average cost of electricity from onshore wind fell 18% between 2010 and 2016 (IRENA, 2017). Internationally, some wind farms now regularly deliver wholesale electricity for \$60 a megawatt-hour (MWh). In New Zealand, similar trends are evident. The cost of wind generation in New Zealand has fallen in line with global trends (eg, due to cheaper components for wind turbines) with recent projects achieving wholesale rates of approximately \$70 a MWh (Pyle, 2016). However, the financial attractiveness of solar PV in New Zealand is currently highly sensitive to location, discount rate and type of retail tariff (Miller et al., 2015).

Looking to the future

Electrification across many parts of the economy, and particularly in transport, will be needed to achieve a low-emissions economy (Chapter 3). The modelling undertaken for this inquiry finds that electricity generation will likely need to increase by between 45% and 63% by 2050 (Concept Consulting et al., 2018a). Modelling undertaken for Transpower predicts electricity demand will more than double by 2050:

To give an idea of the size of this challenge and to reinforce the need for significant investment in New Zealand's energy future, 60 TWh of new generation equates to ~2 TWh per year – roughly equivalent to 4.5 typically sized wind farms with ~60 turbines each. (Transpower, 2018b)⁴⁴

In likelihood, this additional demand will be met through a portfolio of generation sources, including geothermal, wind and solar.

While this is a large expansion in absolute terms, the projected demand growth rates are of a similar magnitude to what has occurred historically. The key difference from the past is that future demand growth will need to be largely met through intermittent renewable generation, such as wind. This means that resource adequacy in dry years will remain the key challenge at the national level (Chapter 13), and that demand response and storage technologies will also be needed to manage variability.

Despite these substantial shifts in the electricity system, many households and businesses may experience little change in how they use electricity. But emerging technologies – such as solar PVs, batteries, EVs, and smart appliances – will enable households to become active participants in the electricity market, rather than simply consumers. These technologies are already becoming more widespread. About 72% of New Zealand homes have smart meters – the highest uptake in the world of any country where installation is not mandatory (ERANZ, 2017).

⁴⁴ Transpower's estimate of 60 TWh of new generation includes replacing existing plant (particularly fossil) that would be retired by 2050.

Technologies like smart meters allow electricity users to moderate their demand in response to information linked to usage (eg, differences in prices between peak and off-peak times). Demand response is likely to become a more important part of the electricity landscape in a low-emissions future. It, along with other technologies like distributed energy, may also have other co-benefits, such as to “provide consumers with greater choice, promote competition, improve reliability of supply and reduce costs” (Electricity Authority, sub. DR384, p. 3).

The International Energy Agency (IEA) estimates the demand response potential in European and North American markets at up to 20% of peak demand (Vivid Economics, 2017a). In New Zealand, Transpower (2018b) identifies demand response, driven by artificial intelligence, playing a role in helping to achieve a low-emissions electricity sector, particularly in combination with real-time pricing, so that users can provide instantaneous demand response to reduce reliance on fossil-fuelled peaks. At a household level, this is likely to be most visible in relation to EV charging, with consumers being able to react to higher market prices at peak times and manage their charging behaviour in response. The IEA finds capacity requirements for standard EV charging needs could be nearly halved if managed charging regimes are implemented (Vector, 2018b). Chapter 13 discusses the regulatory arrangements needed in New Zealand to achieve an effective demand-response capability.

The future evolution of electricity prices is uncertain and, as in the past, could differ substantially for different users. Prices are subject to a range of interacting factors such as demand growth, generation mix, transmission and distribution impacts, and potential policy changes (eg, removal of the current low-user tariff option). In terms of the cost of generation, Concept Consulting et al. (2018a) foresees wholesale electricity prices falling, driven by continued cost reductions for wind and solar. However, other analysis such as by Stevenson et al. (2018) predicts that wholesale prices will rise under a higher emissions price. The effects of the transition on network costs, which make up a significant component of prices, particularly for residential consumers, are very uncertain. Even so, Transpower (2018b, p. 6) concludes that “a renewable future based on New Zealand’s abundance of renewable energy resources is likely to offer the lowest-cost energy future for consumers”. For a successful transition, it will be important that electricity prices do not rise excessively and discourage fuel switching from fossil fuel energy sources.

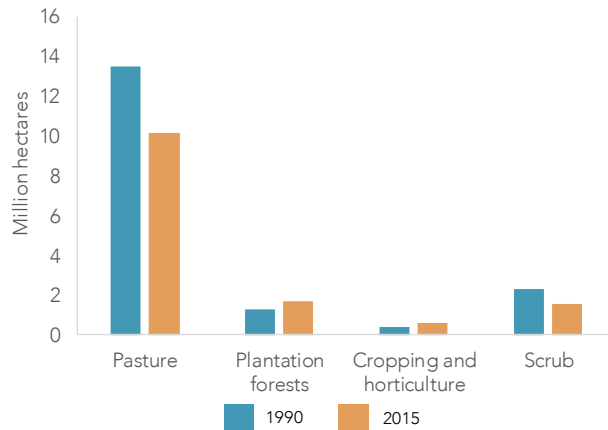
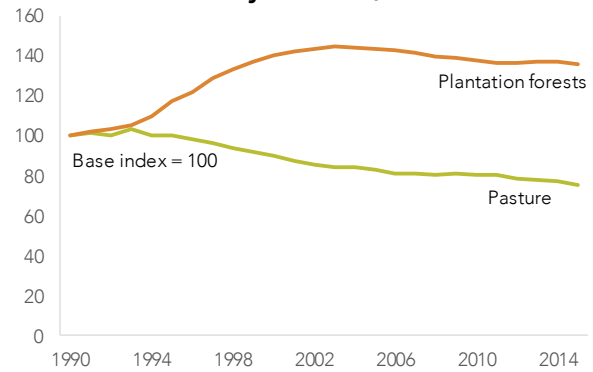
As discussed above, demand-side technologies could play an important role in bringing future costs down, both for individual users and for the whole system. Continued improvements in the building stock and adoption of more energy-efficient lighting and appliances will also help households and businesses to reduce their energy bills (Chapter 16). For example, a standard LED lightbulb uses up to 85% less electricity than a traditional incandescent light bulb (EECA, DR326, p. 16), and lighting currently makes up about 13% of the average household’s electricity use (EECA, 2018b).

Another implication of increased electrification is the need for a skilled workforce to build and deliver this increased generation capacity. New Zealand currently has a shortage in a number of relevant occupations including electrical engineers, civil engineers, construction project managers and qualified electricians – these occupations are listed on Immigration New Zealand’s long-term skill shortage list (MBIE, 2018d). To meet projected growth in the sector, further upskilling of the domestic workforce will be vital and needs to begin now to avoid workforce shortages. This is particularly important given the increased global demand for skilled labour in this area, meaning that New Zealand may be unable to look to other countries to meet gaps in the supply of skilled workers (Transpower, 2018b).

Land use

Over the last 25 years, New Zealand has experienced significant changes in land use (Figure 4-10 and Figure 4-11), including:

- a steady reduction in pastoral farmland;
- a substantial rise in plantation forest land in the mid-1990s, and a subsequent small decline in the 2000s;
- a significant increase (from a low base) in land used for horticulture and cropping; and
- a large shift away from beef cattle and sheep farming towards dairy cattle farming.

Figure 4-10 Absolute changes in rural land use between 1990 and 2015**Figure 4-11 Relative trends in pastoral and forestry land use, 1990–2015**

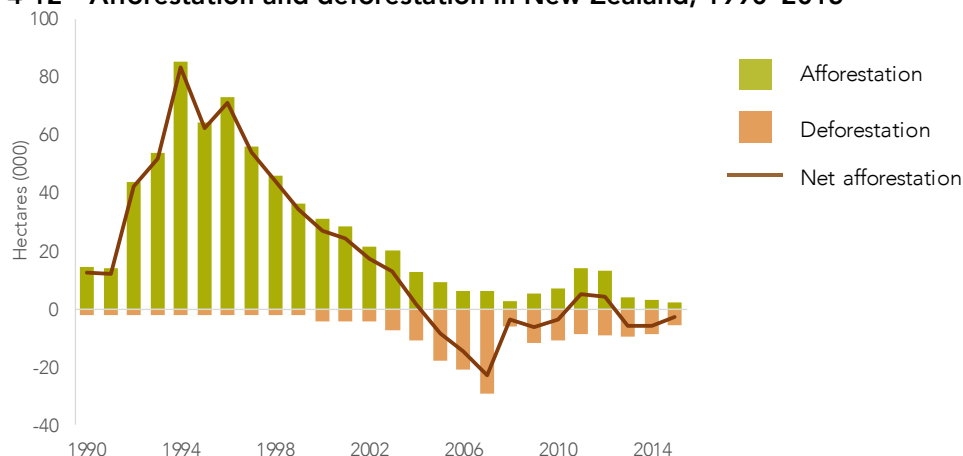
Source: MPI (2016); Stats NZ (2017a).

Notes:

1. Estimates of agricultural land use are taken from the annual StatsNZ agricultural production census. As StatsNZ did not undertake census surveys between 1997 and 2001, estimates for this period are linearly interpolated.
2. Estimates of forestry only include plantation forests. Natural forests, excluded from these estimates, make up approximately 29% of New Zealand's land area.
3. In Figure 4-10, the total area of rural land decreased between 1990 and 2015 by about 3.5 million hectares, or in percentage terms by about 20%. This is a result of rural land being converted to non-rural uses. Rural land includes all farm land and plantation forests.

Roughly 3 million hectares (or around 30%) of pastoral farmland shifted to other uses between 1990 and 2015 – an average of 130 000 hectares each year (Figure 4-10).⁴⁵ A large proportion of these 3 million hectares was converted to non-farming uses, such as urban development, conservation, and other public purposes.⁴⁶

A smaller proportion of pastoral farmland was converted to forests. New Zealand's plantation forests increased in area by about 450 000 hectares, or in percentage terms by about 35%, between 1990 and 2015. The increase in New Zealand's forest land was largely due to a temporary boom in planting in the 1990s. High timber prices, combined with a collapse in farm prices from the late 1980s and enthusiasm for forestry as a retirement nest egg, stimulated this boom. Since 2000, planting has fallen to historically low levels, while deforestation has increased (Figure 4-12) (MfE, 2017f).

Figure 4-12 Afforestation and deforestation in New Zealand, 1990–2015

Source: MfE (2017f).

Note: MfE has limited information on deforestation before 2000 and on deforestation from pre-1990 forests before 2008. MfE therefore assumes that deforestation of pre-1990 natural forests occurred at the same yearly rate before 2008, and that deforestation for all other forests was zero before 2000.

⁴⁵ The trend away from pastoral farming had started earlier with the removal of government agricultural subsidies from the mid-1980s (Vitalis, 2007). This shift was reinforced by a fall in agricultural commodity prices and a later spike in log prices in the 1990s (Kerr & Olssen, 2012).

⁴⁶ In particular, around 425 000 hectares were transferred to the conservation estate through "whole property purchases" or because of tenure review under the Crown Pastoral Land Act 1998 (Land Information New Zealand, pers. comm., 15 March 2018; Department of Conservation, pers. comm., 19 March 2018).

Horticulture and cropping land has also grown and diversified (Stats NZ, 2018c). Its share of land increased from 2% to 4% between 1990 and 2015. Within the horticultural sector, the area of land in wine production increased sevenfold from around 5 000 hectares to 36 000 hectares (Horticulture New Zealand & Plant & Food Research, 2015; HortResearch, 1999). Kiwifruit production also saw rapid growth, with export revenues increasing from about \$35 million in 1980 to \$756.8 million in 2007 (Peden, 2008b). Using Stats NZ data, the Commission estimates land for cropping increased by around 142 000 hectares over the period.

Livestock farming shifted substantially from sheep and beef farming towards dairy farming, particularly in the South Island (Figure 4-13 and Figure 4-14). Before 1990, around 95% of New Zealand's livestock were sheep and beef cattle. The dairy herd has since nearly doubled, while sheep numbers halved, and the beef cattle herd fell by 20%. The comparatively high profitability of dairying was the main driver of conversions of sheep and beef farms to dairying (Kerr & Olssen, 2012).

Figure 4-13 Livestock numbers across sectors, 1990–2017

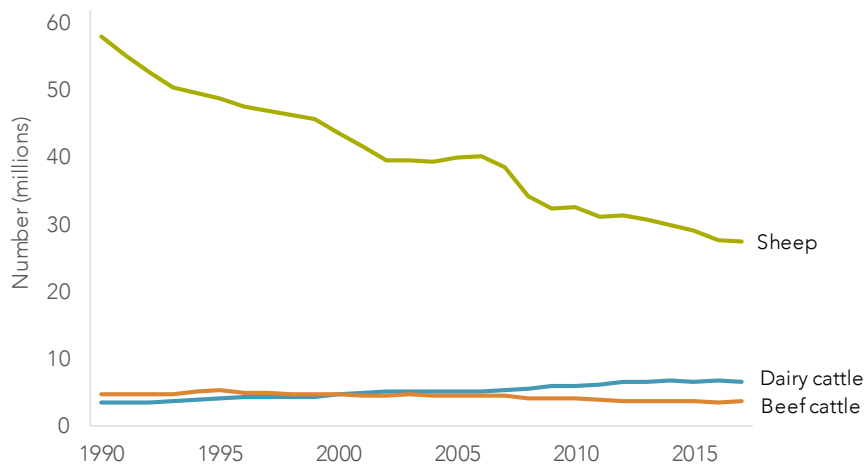
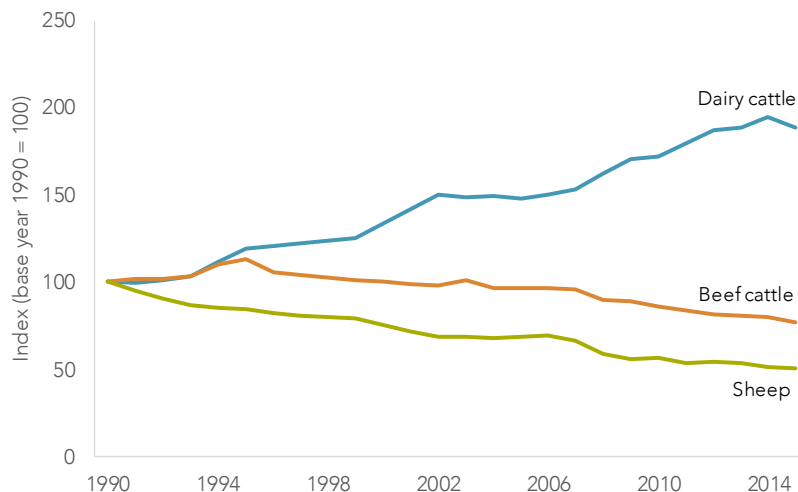


Figure 4-14 Relative growth in livestock numbers across sectors, 1990–2017



Source: Stats NZ (2017a) for both Figures 4.13 and 4.14.

This period saw significant intensification of dairy farming, and consolidation of smaller dairy farms, especially in the South Island (Stringleman & Scrimgeour, 2008). Notably, the number of dairy farms fell from about 16 000 in the mid-1980s to fewer than 12 000 today. In terms of herd size, the average dairy farm today is about two and a half times larger than three decades ago (LIC & DairyNZ, 2016). The range of dairy products expanded from traditional cheese and butter, to include milk powder and casein (Peden, 2008a).

The removal of government subsidies for farming in the mid-1980s, including minimum prices, input subsidies, low-interest loans, and tax incentives, was influential in driving the initial move away from pastoral farming. Although some policies were introduced to assist farmers, the impact of the changes on commodity and land prices were damaging for some businesses and communities.

While forced sales of farms and the exit of farmers out of the primary sector were smaller in number than anticipated, the social fabric of these rural communities changed as a result of the decrease in population, the shift in demographic profile and the subsequent downsizing of services in the rural areas. Government assistance in the form of debt restructuring, credit mediation, business planning, and transition funding, helped mitigate the impact. However, social pressures were immense with mental health issues coming to the fore for some, while many others drew on social assistance (MPI, 2017g, p. 6).

More generally, the shift away from sheep and beef farming and the intensification of dairying had real impacts for many rural communities across the country. In 1986, 11% of the New Zealand workforce was employed in the primary sector. This reduced to 7% by 2006 (Callister & Didham, 2010). Some rural areas (especially remote areas) experienced population decline as a result. But gains in farming efficiency, triggered somewhat by the government's deregulation, have led to growing incomes for the majority of agricultural workers (Vitalis, 2007). Related to the reduction in pastoral farmland, the major development of peri-urban areas and the "proliferation of lifestyle blocks" since the 1970s has also blurred the boundaries between rural and urban areas in many cases (Stats NZ, 2018c).

Looking to the future

The transition towards a low-emissions land sector over the next 30 years will also likely involve transformative land-use change. The biggest driver of change is likely to be rising emissions prices (Chapter 5 and Chapter 9).⁴⁷

A rapid expansion in new forest planting is likely to characterise the transition. Modelling in Chapter 3 indicates New Zealand's forestry plantation would need to more than double in size relative to its current area. Achieving this would involve a much more sustained pace of afforestation compared to past trends (Figure 4-15, see also Chapter 11). Such an expansion of forestry would also place substantial demands on the forestry industry, in terms of transporting and processing products. Improvements in industry capability and infrastructure would almost certainly be required to meet this demand. Depending on the mix of forest types, the expansion of native forests could also afford biodiversity and cultural benefits to communities (Chapter 10).

In other ways, future land-use change may follow recent trends. The share of land used for sheep and beef farming decreases by between 21% and 26% from 2015 to 2050 under the Commission's modelled pathways (Chapter 3). This is primarily a result of sheep and beef farms converting to forestry. The scale of change is broadly comparable with the changes observed since 1990, and would also see a steady reduction in pastoral land. This is not to downplay the challenge of the transition away from sheep and beef farming over this period for many businesses and households.

While not likely to continue its steady expansion, dairy farming may be less vulnerable to large shifts in land use compared to sheep and beef. Chapter 3's modelling suggests that the future trend for dairying is unclear – two pathways suggest a decrease of between 7% and 22% of dairy's share of land use between 2015 and 2050, while one pathway shows a 7% increase. The development of technologies to reduce cattle emissions (eg, a methane vaccine) will be an important factor. A reduction in the use of land for dairy farming would also potentially see significant growth of horticulture and cropping – even greater than since 1990.

⁴⁷ Note that all data in this section refers to the modelled pathways towards a net-zero 2050 target.

Figure 4-15 Scale of forest planting needed to achieve net-zero emissions compared with past trends

Source: Concept Consulting et al. (2018a); MPI (2017f).

Notes:

1. The dashed line represents the average rate of forest planting across the three modelled pathways (Chapter 3) that is needed each year (on average) to achieve a net-zero emissions target.

Because of future land-use change, some regions could experience quite dramatic changes, while others are likely to experience only modest change (Chapter 3). The modelling suggests that Canterbury, Otago and Manawatu-Wanganui will see the greatest absolute land-use change, due largely to conversions of sheep and beef farms. Notably, new forest planting could cover up to 20% of the Gisborne region, while Taranaki's dairy land could reduce by close to 60% as horticultural and forest land expands.

Trends in the changes in the make-up of rural communities are also very likely to continue over the period to 2050. For example, replacing about half of Taranaki's dairy farms with horticultural farms and forest plantations (one of the modelled outcomes) would lead to steady changes in the types of local services over time. An increase in forest-related services for many communities seems likely. Changes in the mix of agricultural production in communities could also result in significant flows of migration between regions, as local labour markets adjust, and workers move to match their skills and expertise with the right job opportunities (or to learn new skills). Some rural towns, especially those currently dominated by sheep and beef farming, may face population decline.

Other drivers of change will influence land use beyond the need to transition to a low-emissions economy. These will need to be on the radar of government and the private sector as they make decisions about land-use investments and strategies. Existing trends are likely to continue, such as long-term shifts towards urbanisation, global trends in food production (such as traceability from the farmer to the consumer, efforts to reduce food waste, and the rise of synthetic proteins), and concerns around other environmental factors (such as issues around access to freshwater and water pollution). For example, Local Government New Zealand (LGNZ) expects the further concentration of the population in cities will lead to "a 'hollowing-out' of many mid-sized towns and rural areas across New Zealand, which have previously served industries that have declined, relocated, or are predicted to do so in the future" (LGNZ, 2016, p. 14).

Other trends will emerge that will interact with the low-emissions transition. For example, in a recent report on megatrends affecting New Zealand's working environment, Infometrics (2018) estimates that rural areas will be heavily affected by automation – much more so than urban centres. In the context of long-term trends towards urbanisation, automation therefore presents a particular challenge to provincial areas.

[E]ven if we assume there is roughly a 1:1 replacement of redundant automated jobs with newly created jobs within New Zealand, it seems extremely heroic to suppose that many of these new jobs will spring up in provincial towns and rural areas. (Infometrics, 2018, p. 12)

The effects of climate change will also likely affect land use in New Zealand, as explained in Box 4.3.

Box 4.3 How will climate change affect agriculture and forestry in New Zealand?

Future climate change caused by global warming might make some current uses of land unsustainable or uneconomic. For instance, changes in rainfall patterns and in mean temperature could change the relative profitability and suitability for particular commodities of some land use (MfE & Stats NZ, 2017; NZAGRC, 2012). Effects of climate change, including the incidence of drought, will vary across countries, with impacts on trade. Increased frequency of severe storms could make some land more prone to erosion or make some tree species more suitable for planting than others.

Climate-change effects on agriculture in New Zealand could be both direct (through productivity) and indirect (through world prices). Stroombergen (2010) modelled both for the period up to 2070 balancing the effects of longer and more frequent droughts against improved growing rates as a result of a higher concentration of CO₂ in the atmosphere ("carbon fertilisation"). Stroombergen found drought alone was likely to benefit New Zealand relative to other producing countries, through higher world agricultural commodity prices (see also NZAGRC, 2012). Yet carbon fertilisation (which affects world producers equally) could reduce or even overturn New Zealand's advantage. The model inevitably does not include many real-world complexities, such as increasing world demand for food, and for biomass for energy; changing tastes; increased conversion of agricultural land to forestry in competitor countries; and increased frequency of severe storms.

The effect of climate change on forests in New Zealand is also uncertain. Generally higher mean temperatures are likely to favour some species relative to others (Rangitikei District Council, sub. 35) and, together with carbon fertilisation, increase growing rates (Watt et al., 2008; Scion, sub. 67, DR366). Higher mean temperatures are likely to affect the prevalence of plant, insect, and other biotic pests, though the severity is uncertain. Forests in some regions of the country, and on some terrain, are likely to be vulnerable to a higher incidence of extreme wind events or, potentially, to fire.

International measures to mitigate climate change could also affect agricultural commodity prices for New Zealand. The effects will depend on New Zealand's emissions pricing policy relative to other competitors, and on how climate change mitigation is taken into account in trade policies (NZAGRC, 2012; Stroombergen, 2010; Chapter 5).

Climate change over the next 30 years and beyond will likely not dramatically change the viability of agriculture and forestry in New Zealand. Yet regional shifts in suitable growing conditions will likely put a value on crop diversification that (at the same time) reduces emissions. Shifts in rainfall patterns may also make irrigation more important for horticulture and dairy in some regions.

4.8 Achieving a successful transition

A successful low-emissions transition (where New Zealand meets its targets while increasing incomes and wellbeing) will require a foundation of several key framework policy and institutional elements. Achieving these will not *guarantee* a successful transition, but are the minimum necessary components that will set New Zealand on a trajectory towards achieving its low-emissions goals. The key framework policy and institutional elements are:

- a **stable and credible policy foundation** that provides strong commitment over a sustained period of time (including broad and enduring political support) for the low-emissions transition;
- **price signals** that align social benefits and private benefits, and which are deemed highly credible by investors (ie, they place a low probability on ad hoc intervention);
- a system that **enables innovation** into technologies (products and services) that reduce emissions;
- **good quality information** to enable better decision making (including by private actors, particularly when investments in assets with long lifespans are made);

- avoidance of **abrupt change** wherever possible (which requires foresight and willingness to react in a timely way), to reduce social upheaval, and to enable adequate lead-times for investment in alternative, low-emissions technologies and activities; and
- mobilisation of a more **collective approach** to New Zealand’s transition so that social buy-in for the long-term nature of the low-emissions transition can be fostered (to help to solve investment coordination problems and form a base for enduring action over time).

These components are discussed further in Part 3. Part 4 of this report also outlines mitigation opportunities across all New Zealand’s main emissions sources. The low-emissions transition is very likely to be highly disruptive and costly for some, especially businesses reliant on high-emitting products or services unable to adapt to or remain competitive in the new low-emissions reality. There will be transition pains, and unexpected events may derail the best laid plans. But, with a foundation of stable policy and committed government and private-sector action, opportunities can also be seized and embraced.

The nature of the challenge for New Zealand

The challenge of moving to a low-emissions economy will be different for every country. Current and future governments of New Zealand have a myriad of choices to make along the transition to a low-emissions economy. But there is also opportunity to learn from transitions occurring in other countries and for New Zealand to respond to these parallel transitions (for example through decisions about free allocation of emissions permits, Chapter 5).

Sometimes it may be appropriate for the government to make decisions that mean it moves faster and farther than other countries in certain areas. For example, to stimulate change that aims to capture competitive advantage and set the economy on a manageable transition path (such as by incentivising a low-methane agriculture sector, Chapter 9). In other areas, and at other times of the transition, the government may do better to learn from policy models in other countries, like the concept of emissions budgets, Chapter 8. Yet, no uniform rate of change will be “ideal” – some parts of the economy will be able to adjust more quickly than other parts.

One particularly important consideration is to determine the scope of government responsibility throughout the various phases of the transition. As noted above, the transition to a low-emissions economy is primarily policy-driven (because it is focused on meeting a pre-determined set of (scientifically-linked) policy actions and targets).

Yet, this role throws up a series of political and philosophical choices about the exact nature of government responsibility during the transition. For example, adverse effects arising from domestic policy decisions (such as the effects on certain households due to potentially higher relative costs) may be considered well within the scope of government responsibility to manage (see Chapter 10). But governments may also consider it necessary to develop policies to help address the effects of external disruption. An example of such effects is the potential for significant market disruption in the agricultural sector caused by the offshore development of synthetic food technology. Future governments will need to be clear about the role they intend to play in the transition to provide clarity and direction to the respective decisions of individuals, households and businesses over the coming decades.

The low-emissions transition also represents a whole-of-government challenge. As Chapter 8 discusses, a high level of coherence between overall policy and regulatory frameworks and low-emissions goals will be needed. Identifying and addressing misalignments between core climate policies and other policies outside the climate policy portfolio will be vital. To achieve the transition, every aspect of the government policy and institutional apparatus will to some extent need to be framed with the low-emissions goal in its sights.

F4.4

The scale, nature and complexity of the low-emissions challenge combine to produce a very substantial public-policy challenge. Identifying and addressing misalignments between core climate policies and policies outside the climate policy portfolio will be vital.

Part Three:

Policies and institutions

In transitioning to a low-emissions economy, getting the right mix of policies and institutions in place is critical, not just for achieving sufficient emissions reductions, but also for maximising the benefits of the transition.

Part Three focuses on cross-cutting policies and institutions for New Zealand's transition that are pervasive across the wider economy. These establish a foundation of stable and credible climate policy that can enable the private sector and civil society to plan and take long-term decisions with confidence.

Key elements of this supporting architecture include:

- Effective emissions pricing
- Harnessing the full potential of innovation
- Supporting investment in low-emissions activities and technologies
- Laws and institutions to act as a commitment device
- Targeting short- and long-lived gases differently
- Policies for an inclusive transition

5 Emissions pricing

Key points

- An emissions price is the price emitters pay for each unit of greenhouse gas (GHG) they release to the atmosphere. The price should reflect the costs of emissions arising from their causal link to global warming.
- Emissions pricing can and should be used as the central policy lever to incentivise businesses and individuals to make decisions that lower their GHG emissions.
- Emissions pricing can take several forms: taxes and charges, subsidies, and tradable emissions permit schemes (sometimes called “cap and trade” or “emissions trading” schemes).
- A single emissions price has important benefits: it provides a strong incentive to reduce emissions at least cost; and it decentralises decisions to invest, innovate and consume across the economy to people who have the best information about opportunities to lower emissions given their circumstances.
- The two main forms of emissions pricing – a carbon tax and an emissions trading scheme – have much in common. Yet they also have important differences, such as whether it is better to have certainty in the price or the quantity of emissions, the ease of trading internationally, and the scope for participants to handle risk.
- A good emissions pricing scheme needs to address several important challenges, including carbon leakage and free permit allocation for emissions-intensive and trade exposed firms, policy stability over time, strategic use of government revenue from the scheme, points of obligation, minimising complexity, and rewarding sequestration of carbon through forestry.
- The New Zealand Emissions Trading Scheme (NZ ETS) began in 2008 aspiring to be an all-gases, all-sectors scheme linked to international carbon markets. But biological emissions (mainly methane) remain excluded. The link to international markets led to a sharp and undesirable fall in the effective carbon price, which undermined incentives to reduce net domestic emissions.
- The international link ceased, and the NZ ETS became a domestic-only scheme from 2015. This is desirable for now, and the price has risen to around NZ\$23 a tonne of carbon dioxide equivalent (CO₂e). Despite this, the NZ ETS needs further reform to give the government control over permit supply, a robust process for setting emissions caps, and cross-party agreement on the policy and institutional framework.
- New Zealand should retain the NZ ETS rather than replace it with a carbon tax. Replacement would incur large transition and learning costs for no offsetting gain. Further, an ETS is better for revealing information, setting quantity caps on emissions, managing risk, and international trading.
- Modelling and other available evidence suggest that New Zealand’s emissions price may need to rise to at least NZ\$75 a tonne of CO₂e and possibly over NZ\$200 a tonne over the next few decades for New Zealand to achieve the reductions in domestic emissions to which it aspires under the Paris Agreement.
- Emissions pricing needs a supporting package of low-emissions policies and institutions including legislation, regulations, independent bodies for expert advice and to exercise stewardship over the permit market, a fair distribution of costs and benefits, and widespread understanding and support from business and the wider population.

The purpose of this chapter is to examine emissions pricing as a crucial policy lever to incentivise businesses and individuals to make decisions that lower their greenhouse gas (GHG) emissions.

The chapter will explain the why and how of emissions pricing. It will give a sense of what price levels may be needed to transform New Zealand's economy to achieve a low-emissions future. It will also examine the similarities and differences between the two main forms of emissions pricing: an emissions trading scheme (ETS) (sometimes called a "cap and trade" scheme), and a carbon tax.

The chapter will critique New Zealand's existing policy and arrangements for emissions pricing and make findings and recommendations for how these need to change to achieve outcomes consistent with its transition to a low-emissions economy.

5.1 Emissions pricing corrects a "negative externality"

An emissions price is the price that emitters of GHGs pay for each unit of gas they release to the atmosphere. The price reflects the costs arising from the contribution of emissions to global warming. In the modelling of Chapter 3, the price of emitting GHGs was an important influence on the actions of businesses and households to lower their emissions. Chapter 2 pointed out that New Zealand's main initiative to mitigate climate change to date has been to set up and operate an ETS.

Emissions pricing is an example of using market incentives to correct a "negative externality" – when firms or households, without any direct adverse consequence for themselves, take actions that inflict harm on others. Factories generating air pollution that causes harm to the local population is an example of a negative externality. Putting a price on negative externalities applies the principle of "polluter pays". Making the polluter face the full social cost of their actions is sometimes referred to as "internalising" the external cost.

When negative externalities affect only one or a few other people, the problem is unlikely to require a government to intervene to solve it, particularly if property rights are well defined (Coase, 1960). For example, the neighbours of a farmer who fails to maintain their boundary fence could suffer damage from wandering cattle. The neighbours can expect the farmer either to compensate them, mend the fence, or both. Failing that, they can take the farmer to court.

However, a type of negative externality can occur where many people have rights in common to use property (called a "common property resource"), rather than the exclusive rights of a private owner. In such cases, people typically do not consider any negative impacts that their use may have on the value or productivity of the resource for others. People rationally focus on satisfying their own resource needs first. A collective solution among the community using the resource may develop, but it is by no means assured (Ostrom, 2007).

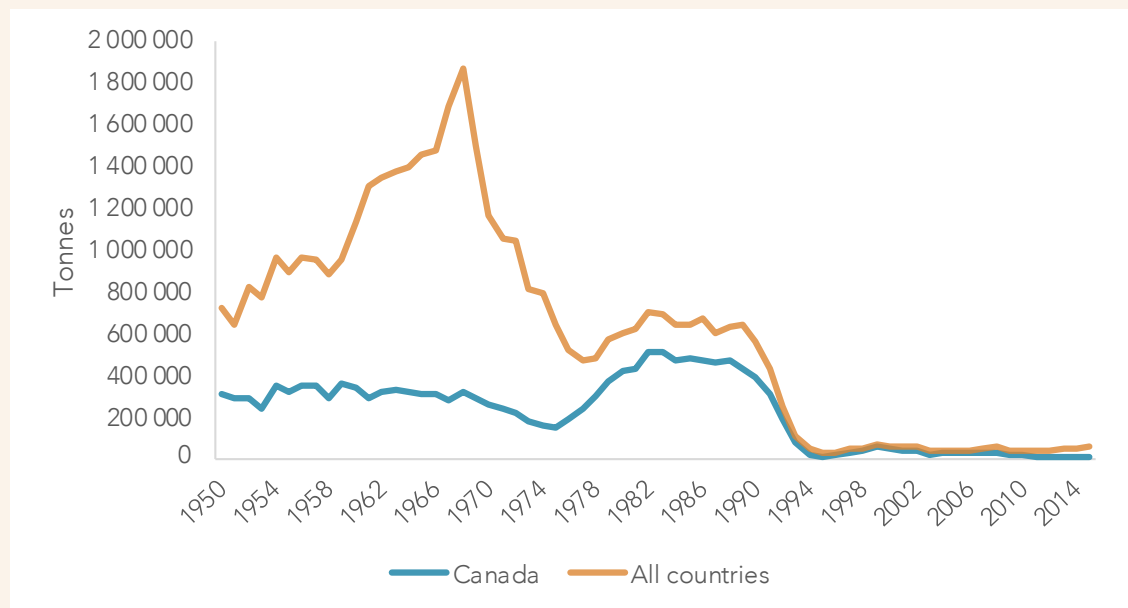
If everyone behaves rationally but individually, the resource will become overused and depleted, even to the point of its productivity falling to zero. This has come to be called the "tragedy of the commons" (Hardin, 1968) (see Box 5.1 for an example). Climate change is a tragedy of the commons on a global scale – where the common property is the earth's atmosphere that everyone shares and depends on.⁴⁸

Box 5.1 A tragedy of the commons: the collapse of the Atlantic cod fishery

For 400 years off the eastern coast of Canada, the Newfoundland Grand Banks cod fishery was one of the most abundant in the world. Colonial settlers recounted stories of lowering baskets into the ocean and pulling them up, teeming with Atlantic cod, *Gadus morhua*.

Between the mid-19th and 20th centuries, yearly catches in the northwest Atlantic were reasonably stable. But by the late 1960s, nearly 2 million tonnes of cod were caught each year. This dramatic peak precipitated a crash in fish populations. By 1992, the fishery had completely collapsed (Figure 5-1).

⁴⁸ Lord Nicholas Stern has described the reality of climate change as the "greatest external effect in human history".

Figure 5-1 *Gadus morhua* capture in the Northwest Atlantic

The collapse of the fishery was the result of several issues (Hutchings & Myers, 1994).

- The imprudent use of new technology: Large trawlers equipped with sonar and other navigation tools caught fish at a rate higher than the fishery's ability to replenish.
- Scientific uncertainty allowing political inertia: Concerns were raised from the 1970s about the reduced number and size of cod. However, uncertainties in the science let regulators avoid making unpopular decisions to limit yearly catch quotas.
- A tragedy of the commons: Governments failed to intervene largely because a transition away from a dependence on fisheries was unpopular, despite growing awareness that it was environmentally unsustainable. This led to individuals seeking short-term profits at the expense of the wider social good.

Source: FAO (2016).

So how can pricing externalities avert the outcomes from a tragedy of the commons? Pricing externalities incentivises people and businesses to take due care and responsibility for the full costs they impose on others. Once faced with the full costs of a product they consume, households may choose to reduce their consumption, or switch to alternative, less-harmful products. Firms face an incentive to look for alternative, less-damaging production methods.

To price harmful GHG emissions, governments can use three main types of instruments: taxes and charges based on emissions volumes, subsidies for avoiding emissions, and tradable permit schemes.

Taxes and charges based on emissions volumes

Volume-based emissions taxes and charges require individual emitters to face the financial cost of each tonne of GHG emitted. Then, each emitter weighs the cost of

emissions control against the cost of emitting and paying the tax; the end result is that polluters undertake to implement those emission reductions that are cheaper than paying the tax, but they do not implement those that are more expensive. (IPCC, 2007, p. 755)

Taxes and charges are also known as price-based approaches; that is, they set an explicit price on a unit of pollution.

Subsidies for avoiding emissions

Subsidies aim to incentivise emissions reductions through rewarding certain behaviours or activities. Types of subsidy include tax exemptions, financial subsidies (such as preferential financing or credit guarantees), and feed-in tariffs.⁴⁹ For instance, the Australian Emissions Reduction Fund provides support to businesses and farmers to adopt new practices and technologies to reduce Australia's GHGs.

Subsidies, such as those for exploring, investing in, or using fossil fuels can work against reducing emissions (Chapman, 2015; OECD, 2017c).⁵⁰ Not putting a price on a negative externality is a subsidy from a social wellbeing viewpoint – that is, by not requiring an emitter to face the full cost of their actions, society is effectively subsidising their actions.

Tradable permit schemes

Transferable permit schemes require emitters to have (and surrender) a permit for each tonne of GHG emitted. On the other hand, those who sequester carbon (such as forest owners) can earn permits (and then sell them if they choose). The scheme works by setting a cap on the net quantity of emissions (ie, by the government issuing that number of permits or allowances), with participants trading emissions permits among themselves. The scheme also has the effect that if

it is less costly for a company to reduce emissions than to buy allowances, the company will reduce its own emissions. Similarly, if a company can reduce emissions below its requirements, so it has excess allowances, those allowances can then be banked for future use or sold in an open market to a firm that finds it more difficult (costly) to reduce emissions. (C2ES, 2015, p. 3)

Permit scarcity through setting a quantity cap is critical because this generates a price on GHG emissions that is high enough to incentivise abatement. These systems are also known as quantity-based approaches, as they work by only allowing a certain quantity of emissions allowances to be distributed (or auctioned).

Efficiency of emissions pricing

Properly designed and implemented, emissions pricing is a powerful, efficient (ie, least-cost) way to reduce emissions. The key is that every emitter or absorber of GHGs across the economy faces the same price for each tonne of CO₂e emitted or absorbed.

The effect of this single price is that emitters are each incentivised to choose all mitigation options that cost less than the price, and to choose none of those that cost more. Conversely, the absorbers are encouraged to invest in all absorption options that cost less than the value of the subsidy or allowance they earn. Collectively, agents are incentivised to find and implement the least costly ways to reduce GHG emissions, invest in their absorption, or both. Figure 5-2 illustrates this for a set of potential projects to reduce emissions.

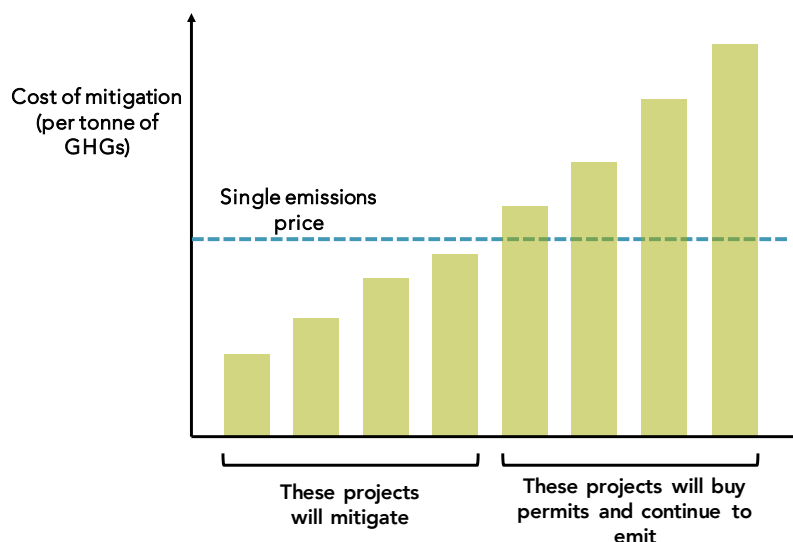
Through exchanging emissions "rights" in this way, emissions pricing can avoid two types of inefficiency.

- Emitter A reduces emissions by one tonne at a higher cost than Emitter B who takes no action but has less costly abatement opportunities (a parallel case could exist for two absorbers).
- An absorber absorbs one tonne of an emitter's emissions at a higher cost than the emitter could have reduced them.

In addition, pricing has another important efficiency property: it can decentralise options and evaluations about the cost of mitigation or absorption to individual agents across the economy. The alternative – gathering all this information at some central point to make decisions about which options to pursue – would be impractical and very expensive.

⁴⁹ Feed-in tariffs aims to accelerate investment in renewable energy by providing a set price (above the retail or wholesale electricity price) to renewable energy producers for each unit of energy produced and exported to the electricity grid.

⁵⁰ See also Chapter 6 for how subsidies that support fossil-fuel production and consumption blunt incentives for low-emissions innovation.

Figure 5-2 The efficiency of a single price in reducing emissions

The level of the emissions price in an economy will strongly influence the overall reduction in emissions. A higher price will incentivise a greater reduction than a lower price.

A government's choice of price instrument will depend on several factors, including deciding whether it is better to specify the price of emissions or their quantity. Taking one example, New Zealand chooses to protect its common-property fisheries using a quantity mechanism: a system of Individual Transferable Quotas (ITQs) that limits fishing catch to keep fish stocks within sustainable limits (Box 5.2).

Another factor to consider is the transaction costs of any scheme of emissions pricing. Transaction costs include the administrative costs of the agency running the scheme, and the compliance costs of businesses and individuals who participate (either voluntarily or compulsorily).

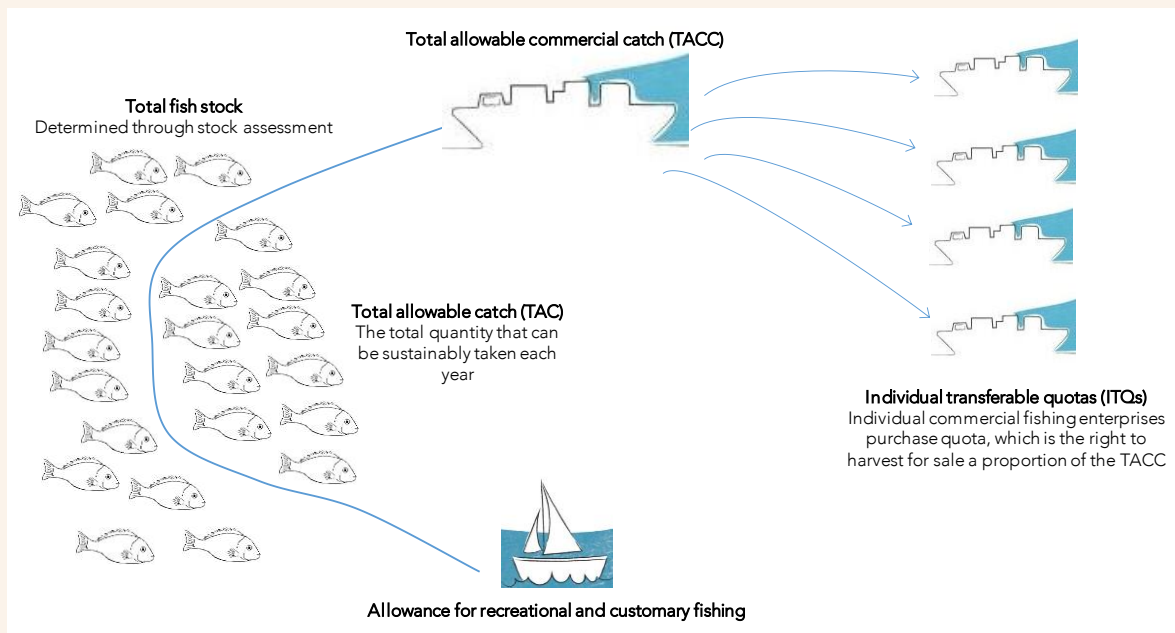
Box 5.2 Fisheries and individual transferable quotas

Established in 1986 by the Fisheries Amendment Act, New Zealand's Quota Management System (QMS) is a market-based approach that aims to ensure the long-term environmental and economic sustainability of New Zealand's fisheries.

The QMS is based on the principle of achieving a maximum sustainable yield (MSY). With reference to environmental, economic and social factors, every year the Minister of Fisheries sets a yearly total allowable catch for each fish species within each fisheries management area of New Zealand's exclusive economic zone. The levels of the total allowable catch are designed to sustain the MSY for each species and are further specified into a total allowable commercial catch: – this is the total allowable catch minus allowances for recreational and Māori customary fishing (Figure 5-3).

Each total allowable commercial catch is divided into Individual Transferable Quotas (ITQs) that individuals or companies may hold, and which entitle them to an associated yearly catch. This entitlement is to a share of the total allowable commercial catch – an amount of the species that the ITQ owner can fish each year. These quotas are property rights and quota holders may trade their quotas for each species (Lock & Leslie, 2007). No centralised trading exchange exists, but quota holders are free to buy and sell quota.

Concerns about certain aspects of the QMS have been raised, such as aggregation of quota by large companies and subsequent exclusion of smaller fishers, with impacts on local communities (Gibbs, 2008). Yet, on balance, analysis suggests that the positives of the system have considerably outweighed any negatives (Mace et al., 2014).

Figure 5-3 Simplified model of the quota management system

Source: MPI (2017b).

Factors for the economic success of the QMS include simple and standardised rules for quota definition and trading, long-term market stability, and low levels of government intervention in the trading process (Kerr et al., 2003). Factors underpinning its environmental success include the development of high-quality technical guidance on achieving MSY, a clear focus on environmental principles and biological diversity, and support for innovative science (Mace et al., 2014).

5.2 Controlling emissions: Permits versus an emissions tax

Most agree that pricing emissions is key to de-carbonising an economy. Among submitters this included Waimakariri District Council, sub. DR192; Graymont, sub. DR201; Chartered Accountants Australia and New Zealand, sub. DR208; Kate McNab, sub. DR219; Northland Regional Council, sub. DR226; Auckland Council, sub. DR273; Wellington City Council, sub. DR276; Genesis Energy Limited, sub. DR301; and Venture Southland, sub. DR336. Yet debates continue about whether quantity permits/allowances or a carbon tax⁵¹ is the better way to implement emissions pricing (Goulder & Schein, 2013; William Hambridge, sub. DR189; Ora Taiao, sub. DR378). This section unpicks that debate to prepare for findings and recommendations later in the chapter.

The “duality” between prices and quantities

The discipline of economics has developed the important insight that a *duality* or equivalence exists between quantities of goods and services and their prices. In 1974, American economist Martin Weitzman published a classic paper called “Prices vs Quantities” (Weitzman, 1974). In the paper he analysed “the question of whether it would be better to control certain forms of pollution by setting emissions standards or by charging the appropriate pollution taxes” (p. 477).

It turns out that, in a world of certainty, duality ensures that it makes very little difference. But uncertainty is real and present and can lead to errors. The answer of whether it is better to set emissions prices or quantities then depends on the relative cost of getting prices or quantities “wrong” when decision makers

⁵¹ This chapter uses the terms “emissions tax” and “carbon tax” interchangeably. The term “carbon tax” is more commonly used, but a large proportion of New Zealand’s GHGs is not carbon dioxide but methane. Therefore, strictly speaking, the broader term “emissions tax” is more accurate.

set one of them and let the market determine the value of the other, and the market's determination turns out quite different to expectations.

Setting quantities gives certainty on the level of emissions, yet creates the risk that the corresponding price (determined by market decisions) will turn out to be a lot higher or lower than expected. Conversely, setting prices gives certainty about the price of emitting a unit of GHGs, yet creates the risk that the corresponding quantities (determined by market decisions) will turn out to be much higher or lower than expected. The answer to the Weitzman question will depend on the relative costs of this uncertainty about the non-control variable (Table 5.1).

Table 5.1 Relative merits of setting prices versus setting quantities of emissions

Control variable for GHG emissions reduction	Cost of "errors" in the non-control variable
Price (eg, set by a carbon tax)	Quantity of reduction is unexpectedly small: the cost is insufficient progress towards meeting a carbon budget or point-in-time GHG target.
	Quantity of reduction is unexpectedly large: emissions reductions are greater than needed, so more mitigation costs than necessary are incurred.
Quantity (eg, set by a cap on emissions)	Emissions price is unexpectedly high: business and households must adjust rapidly or pay the high price, both of which are costly. In effect, the policy caps emissions regardless of cost (McKibbin & Wilcoxon, 2002).
	Emissions price is unexpectedly low: an opportunity is missed to make reductions in emissions more ambitious; and investments in low-emission projects are discouraged.

The answers to two other questions bear on the decision to set quantities or prices.

- How easy or hard is it to reverse an over or under-shoot in the variable that is determined by the market (ie, the price if the quantity is set, or the quantity if the price is set)? For instance, if the reduction in the quantity of pollutant is too small, the damage to the environment could be very large and difficult to reverse (Arrow & Fisher, 1974).
- What information is revealed when the market determines the variable (price or quantity) that is not set? For instance, a small reduction in quantity when price is set, or a high jump in price when quantity is set, suggests emissions reductions are difficult and costly. In turn, this suggests that marginal costs of mitigation are high, or that some other barrier is getting in the way of adjustment.

Comparing carbon taxes and emissions trading schemes

The basic features of carbon taxes and emissions trading (permit) schemes are straightforward. The following description is based on Leining (2017).

Under a carbon tax, obligated parties must pay a specified levy to the government for each tonne of emissions for which they are liable.

Under an ETS, obligated parties must surrender a tradable emissions unit for each tonne of emissions for which they are liable. The government limits the supply of emissions units, which then sets the price based on unit supply and demand. ETS participants can potentially acquire eligible emissions units to meet their obligations by:

- receiving them for free;
- buying them at auction (which generates government revenue);
- buying them from other participants (which creates incentives for others to reduce their emissions and sell surplus units);

- earning them by ETS removal activities (such as forestry); and
- buying them from external (domestic or international) offset projects.

While a carbon tax and an ETS each price emissions by the tonne, the variety of ways that obligated parties can obtain ETS units (ie, permits) – as opposed to the single option of paying a tax – is an obvious difference. Even so, a tax and an ETS are similar and can replicate each other in many ways (Goulder & Schein, 2013). Some similarities are that:

- tax exemptions can have a similar effect to free allocations of emissions units;
- both provide government revenue, if in different ways;
- removal activities (such as forestry) could be rewarded with a subsidy rather than an emissions unit for each tonne removed;
- by offering emissions units at a fixed price, the government can fix a price of emissions similar to a tax;
- agent A purchasing one tonne of emissions from agent B who removes one tonne is similar to A paying the tax and B receiving a subsidy of the same value;
- both require effective measurement, monitoring, and reporting of emissions and enforcement of penalties for non-compliance; and
- both require choices about the point of obligation for surrendering emissions units or paying the tax.

This rather long list reinforces the essential similarity between pricing emissions through a carbon tax or an ETS and is a point to note when considering whether New Zealand should continue with its existing ETS or abandon it for a carbon tax. Yet the choice should focus most on five significant differences that distinguish the two instruments.

- New Zealand already has the legal and institutional machinery for an ETS in place, together with participants and administrators being familiar with how it works. Because of this, New Zealand would not have to incur the cost of investing in this initial machinery and training if it continues with its ETS. New Zealand would need to do so if it built a carbon-tax regime from scratch.
- As noted, a carbon tax and an ETS allow the government to set respectively the price and the quantity of emissions and allow the market to set the other. The costs and benefits of these may differ because of uncertainty and the potential cost of the market-determined variable turning out to have the “wrong” value (Table 5.1).
- A carbon tax cannot incorporate international carbon trading, but an ETS can. An obligated party may be able to buy ETS units outside the regime from a foreign source. The foreign party reduces its emissions on top of what it otherwise would have done, and this offsets the emissions of the obligated party. An offset mechanism of this sort is not available with a carbon tax.⁵² This is a deficiency because carbon trading outside a regime’s boundaries can be an efficient way to reduce global emissions. Further, under an ETS, the market-determined price for emitting one less tonne of CO_{2e} in a country provides important information about the marginal costs of abatement in that country – which can then be compared with abatement costs in other countries. Carbon-tax systems fix prices and do not provide this important information.
- Emissions permits give owners a transferable property right (to emit GHGs), and this right has a value in the marketplace. Carbon taxes do not have this feature. Property rights in permits have several potential benefits:
 - they can enable the holder to hedge risk (eg, by purchasing at today’s price and holding permits to emit later when the permit price may have changed);

⁵² However, government-to-government emissions trading could exist alongside a carbon tax.

- a “thick” market in permits can assist with price discovery, liquidity and incentives to innovate; and
 - the presence of owners of valuable property rights can restrain political tampering and help assure business and others about the stability and longevity of an ETS (Levin et al., 2012; McKibbin & Wilcoxon, 2002).
- Markets for emissions permits have the scope to create futures, forward and derivative markets related to them. A carbon tax does not have the same scope. These related markets can provide additional ways to hedge risk or for the government to signal commitment. In the latter case, by contracting in the futures market to buy a large volume of permits in, say, 10 years’ time at a price higher than the current price, the government can signal its commitment to a high and rising emissions price over time.

In summary, a carbon tax and an ETS are similar instruments in many ways and are aimed at the same objective. Each can be a powerful and effective way to incentivise businesses and households to take actions – investment decisions, consumption decisions, and decisions to innovate – that reduce GHG emissions.

The power of each form of emissions pricing lies in the ability to decentralise decisions across an economy, unlock local knowledge and initiative, be neutral as to the means (eg, choices about technology, sector, and consumption) and achieve the desired emissions reduction at least cost. This power is why an effective form of emissions pricing should be the central prong of a country’s strategy to lower its GHG emissions.

However, a carbon tax and an ETS also differ in ways that are important in any decision about which approach New Zealand should adopt as its centrepiece for driving change towards a low-emissions economy.

F5.1

A carbon tax and an emissions trading scheme (ETS) are different forms of emissions pricing, yet have much in common. Each is a potentially powerful instrument that can act across the economy in a decentralised manner to reduce greenhouse-gas emissions at least economic cost.

Yet, a carbon tax and an ETS also have important differences such as whether the emissions price is fixed and the quantity of emissions is uncertain, or vice versa. These differences bear on the decision about whether New Zealand should adopt a carbon tax or retain an ETS as the centrepiece of its transition to a low-emissions economy.

Should New Zealand replace its ETS with an emissions tax?

As noted, the fact that New Zealand already has a functioning ETS with its supporting laws and other institutional arrangements, as well as familiarity of participants with the system, makes a big difference to whether New Zealand decides to keep the NZ ETS, or replace it with an emissions tax. As these “assets” are sunk investments, their cost should not enter the evaluation of options going forward. Yet, retaining the NZ ETS would not incur such costs again. On the other hand, starting afresh to build an emission-tax system *would incur* the cost of building up a whole new set of supporting assets.

The additional benefits of emissions pricing using a carbon tax rather than an ETS would have to be large to outweigh the significant cost of dismantling the NZ ETS and setting up and becoming familiar with a new system. As noted, differences emerge in the realistic case of uncertainty. The uncertainty that is more damaging depends on the relative costs of different “errors” in the uncertain variable. When the imperative is to reduce the quantity of emissions, the costlier error is likely to be under-shooting the level of emissions reductions. The risk of this error would be present under an emissions tax, but not under an ETS where the emissions reductions can be specified by setting “caps” on the number of units issued.

Two other differences between an emissions tax and an ETS (described above) also point in favour of an ETS – international trading in emissions reductions and the creation of valuable property rights.

The strongest argument for an emissions tax is that, in some respects, it is simpler and easier to understand than an ETS. But this is a more convincing argument when no emissions-pricing system exists, or when a

country lacks the administrative and governance capacities to create and run a sophisticated permit market. Neither of these circumstances applies to New Zealand.

Yet, suppose New Zealand were to transition from the NZ ETS to an emissions tax. To gain a better grasp of just what challenges this transition would involve, Leining (2017) sets out some required key steps and decisions.

NZ ETS participants collectively hold a large volume of “banked” New Zealand Units (NZUs) and NZ Assigned Amount Units (AAUs):⁵³ as of June 2017, the bank of NZUs and NZ AAUs totalled about 128 million units, of which about 82 million were held by individuals or organisations involved in forestry (EPA, 2017). Since 2008, participants have operated under policy settings that enabled them to bank NZUs and NZ AAUs under assurance of their long-term eligibility for surrender in the NZ ETS to legally emit GHGs.

A formidable challenge in a transition to an emissions tax would be how the government would handle these banked NZUs and NZ AAUs. In acquiring and holding banked units, participants have made substantial investment decisions. The government would need to identify a process for running down banked NZUs and NZ AAUs. For example, the government could buy back banked units at a fixed price or accept banked units in place of carbon tax payments.

The government’s transitional process for managing banked NZUs and NZ AAUs would need to be legally, fiscally and politically acceptable. The government would need legal advice on whether its process constituted a taking of private property for which fair compensation was required (Guerin, 2002). At unit prices ranging from NZ\$18 (the NZU price in mid-2017) to NZ\$25 (the government’s price ceiling), this could have a market value ranging from NZ\$2.3 billion to NZ\$3.2 billion. However, banked units are expected to decline over time – particularly from their use to cover liabilities from harvesting forests.

Other challenging steps in a transition would be to:

- set the level of the emissions tax and the process for updating it over time;
- design transitional processes and new regimes for forestry registered under the NZ ETS, and continue with appropriate safeguards against emissions leakage (see next section); and
- ensure continuing effective detection of non-compliance and enforcement.

None of these steps would be straightforward.

Leining (2017) points to further considerations in favour of retaining and reforming the NZ ETS rather than replacing it with a carbon tax.

Decision makers currently face information gaps regarding New Zealand’s technical and economic mitigation potential, sectors’ responsiveness to emission pricing and the relative cost of purchasing international emission reductions. In this context, it would appear to be easier technically and politically for the government to set a quantity cap aligned with our targets and nominate price safeguards against unacceptable extremes than to determine a single efficient carbon price consistent with delivering on our targets and change it over time in response to domestic emission trends. The latter shifts considerable price risk for delivering mitigation to meet national targets from market participants to taxpayers. (p. 29)

F5.2

The additional benefits of emissions pricing using a carbon tax rather than an emissions trading scheme would have to be large to outweigh the significant cost of dismantling the New Zealand Emissions Trading Scheme and setting up and becoming familiar with a new system. While the two instruments are similar in many ways, a reformed NZ ETS is likely to perform better given that New Zealand has an established ETS and has an urgent need for substantial domestic emissions reductions to achieve its targets.

⁵³ New Zealand Units (NZUs) are the main emissions permits within the NZ ETS. Assigned Amount Units are tradable “Kyoto units” under the Kyoto Protocol. From July 2010 to December 2012, the forestry sector could convert NZUs allocated to them for carbon removals into NZ AAUs that could be sold to overseas buyers or surrendered within New Zealand to cover future emissions.

R5.1

The Government should reform the New Zealand Emissions Trading Scheme (NZ ETS) rather than replace it with a carbon tax. The reforms should focus on making the NZ ETS effective in achieving New Zealand's post-Paris commitments to substantially reduce net domestic GHG emissions.

5.3 Specific issues in emissions pricing

Emissions leakage and free allocation

A controversial effect of emissions pricing is raising the costs of domestic firms exposed to international competition from firms in other countries that face either a zero or lower price on their emissions. Possible negative impacts are:

- domestic firms may not be able to compete or even be forced to close;
- over time, production may re-locate and grow in countries without emissions prices; and
- global emissions may stay the same or even increase if production in other countries is more emissions-intensive than the lost New Zealand production. Further, such production shifts could be hard to reverse even after emissions price parity is reached in the other countries.

These effects are called “carbon leakage” or “emissions leakage”. Several New Zealand firms or whole industries claim they are in this position. While relatively few in number, they are significant in scale. Concerns have been raised about aluminium, methanol, urea, dairy, steel, and oil and gas production. For example, New Zealand Steel submitted:

In a similar vein, we ask that New Zealand Steel is only exposed to a carbon cost that is approximately equivalent to our competitors. Any unilateral increase to New Zealand Steel's current net carbon costs would result in the “perfect storm” to our business.New Zealand Steel operates in a challenging, difficult environment where we are often at a disadvantage vis-à-vis many of our trading partners. Put simply, unless our competitors face a similar carbon cost profile then we will be unable to effectively compete in the global steel market place. (sub. 64, pp. 7–8)

In relation to New Zealand's dairy and oil refining industries, Fonterra and Refining NZ submitted:

A global approach must be taken in order to prevent carbon leakage, especially for food production. Due to our efficient pastoral grazing system and healthy cows, New Zealand dairy farmers are amongst the most emission-efficient in the world. We produce less than half the world average (0.9 vs. 2.5 kgCO₂e/kgFPCM) and less than a quarter of the world's least efficient producers (7kgCO₂e/kgFPCM).⁵⁴ There is no global benefit to shifting milk production from New Zealand to (less efficient) milk producers elsewhere. (sub. 88, p. 2)

Overly onerous targets which lead to Refining NZ's closure may result in unintended consequences, such as the production of New Zealand's fuel requirements offshore by less energy efficient, more carbon intensive refineries together with increased CO₂ emissions in longer shipping supply chains. Closure of Refining NZ would, paradoxically, increase GHG emissions globally (carbon leakage). (sub. 129, p. 3)

On the other hand, the evidence to date on the deleterious effects of emissions pricing on competitiveness is weak. See Arlinghaus (2015) for a review of empirical findings.

The problem of emissions leakage would not exist in the presence of a uniform global emissions price. But the world is currently far from that ideal. In the meantime, a common policy response is to award firms in the category of “emissions-intensive, trade-exposed” (EITE) a total exemption from emissions pricing or, within

⁵⁴ FPCM = fat and protein corrected milk.

an ETS, an allocation of free units. New Zealand policy includes instances of exemption (eg, agriculture is outside the ETS) and free allocation (all firms within the ETS that are EITE).⁵⁵

A serious downside to total exemption is that businesses face a zero emissions price and so face no incentive to reduce their emissions. Relative to paying the full social costs of their inputs, these businesses are subsidised. Several submitters have pointed to the adverse consequences of this for forestry (Oji Fibre Solutions, sub. 71; Scion, sub. 67; Waikato Regional Council, sub. 48; NZ Institute of Forestry, sub. 73; and Te Rūnanga o Ngāi Tahu, sub. 83). As Oji Fibre Solutions points out:

Present policies that favour agricultural land use over forestry land use by exempting the former from any cost of emissions have the effect of increasing the cost of land and therefore reducing the profitability of afforestation. Such subsidies are untenable if the Paris Agreement targets are to be met. (sub. 71, p. 2)

Free allocation is a better approach because it gives EITE firms an incentive to reduce their emissions. Several methods of free allocation exist. Each method provides firms with different incentives that are good or bad against the competing objectives of stemming emissions leakage and preserving incentives for cost-effective abatement (PMR & ICAP, 2016). Two methods are grandparenting free allocation and output-based allocation.

- **Grandparenting free allocation on a firm's historical level of emissions.** This “lump-sum” method gives firms a full price incentive to economise on emissions, either by reducing output or the emissions-intensity of output. But since firms incur the full emissions cost of additional output, the method is not good at preserving competitiveness against foreign firms whose emissions are not priced.
- **Output-based allocation with yearly updating.** This method usually defines a benchmark level of *emissions intensity* for a narrowly defined activity such as making steel or smelting aluminium. The benchmark could be based on the historical average for the activity. A firm's free allocation is some proportion of its output multiplied by the benchmark intensity. This method incentivises firms to reduce their emissions intensity through investing in new technology or smarter practices. And it protects the competitiveness of EITE forms. But it does not strongly incentivise a firm to switch to alternative low-emissions products, and it can over-incentivise increases in current output.

New Zealand uses the method of output-based allocation because the main policy objective is protecting the competitiveness of EITE firms. To qualify, firms must trade internationally and meet criteria for emissions intensity. There are two categories: high emissions intensity (which qualifies for free allocation for 90% of output); and moderate intensity (which qualifies for free allocation for 60% of output).⁵⁶ The list of eligible activities is relatively short, yet some eligible firms are large players. The total number of free units allocated in 2016 was 4.3 million – around one-fifth of total units surrendered.

Free allocation of emissions units for EITE firms effectively costs the government revenue. Also, the justification for free allocation will diminish as other countries increasingly impose comparable emissions pricing on their firms in the same industry. As that happens, and given plenty of prior notice, protection for EITE firms should be gradually withdrawn.

F5.3

An emissions trading scheme can be designed to protect emissions-intensive, trade-exposed (EITE) firms from emissions leakage by allocating free emissions units. New Zealand's method of allocating units incentivises firms to reduce their emissions intensity but not reduce emissions through reducing output. Free allocation costs the government revenue. The case is strong to withdraw the free allocation of units to EITE firms over time as competing firms in other countries also face emissions pricing.

⁵⁵ Further information on EITE sectors and their entitlements to free allocation is in the Climate Change Response Act 2002, Part 4, Subpart 2.

⁵⁶ The years for determining the benchmark emissions intensities are the financial years 2006/07 to 2008/09. See MfE (2018).

R5.2

The Government should progressively withdraw free allocation to EITE firms over the next two to three decades to a pre-announced schedule but, subject to an ability to slow the withdrawal rate if, on independent advice, it finds that major competitors are not, actually or imminently, facing comparable emissions prices.

Use of revenue from emissions pricing

Through a carbon tax or auctioning permits (units) in an ETS, governments can raise substantial amounts of revenue. For example, at a carbon price of \$25 a tonne of CO₂e, taxing or selling units to cover 50% of New Zealand's gross GHG emissions in 2015 would raise around \$1 billion. How could and should governments use such revenues to benefit the economy and society more generally? Several possibilities exist, such as the four noted below.

- *Reduce distortionary taxes.* Revenue-raising taxes (such as income taxes and GST) distort incentives to earn, save or invest. A carbon tax or ETS does not distort; rather, it reduces economic inefficiency by putting a price on an unpriced negative externality. So pricing emissions and using the revenue from either of them to reduce a distortionary tax can pay a double dividend.
- *Invest in specific initiatives.* These initiatives could relate to mitigating emissions such as funding research and development (R&D) on new low-emissions technologies, funding schemes to foster the uptake of low-emissions technologies, or investing in public transport and cycleways. Several submitters, such as O-I New Zealand, supported this use of revenue:

O-I sees value in investment in research and development and innovation, and would like to see the government explore the potential for the ETS to generate funds, which could be hypothecated for investment in research into technologies to reduce carbon emissions, particularly in the agricultural sector (sub. 85, p. 6)

- *Support vulnerable households, communities and businesses.* Emissions pricing could cause substantial economic hardship for some households, such as poorer households facing higher heating and transport costs (Chapter 10). Also, as noted above, full emissions pricing can potentially put EITE firms out of business. Providing these firms with tax exemptions or free allocations of ETS units is the most common way to assist them. Effectively, by foregoing the revenue that the government would otherwise have collected, the government spends it.
- *Contribute to general government revenues.* It can be argued that hypothecation – that is, the 'ring fencing' of revenue from a sector or activity for expenditure back into that area – is neither desirable nor common practice in New Zealand. As the Tax Working Group (2018) notes,

hypothecation can ensure that the public understand and support the need for the tax (if they understand and support the need for the spending it funds). But there are some downsides to hypothecation. The government spending may be justified regardless of how much money is raised by the tax – hypothecation might limit worthy spending in the area if the tax revenue falls short. At the same time the level of spending in other areas might be more worth than the hypothecated area – hypothecation might limit worthy spending in other areas if the tax can only fund spending in one particular area (p. 45).

The case for hypothecation needs to take account of these downsides and consider how closely the rationale for revenue raising and the area of spending are linked.

F5.4

Auctioning permits (emissions units) in an emissions trading scheme can enable a government to raise potentially large amounts of revenue. Several legitimate options are available to the government to decide how it spends this revenue. Those options include reducing distortionary taxes, investing in specific initiatives to enable emissions reductions at lower cost, and supporting vulnerable households, communities and businesses adversely affected by emissions pricing.

Stability and predictability

Decisions that help the transition to a low-emissions economy often involve taking a long view. Examples are planting a forest or investing in long-lived assets such as electricity generation plants, vehicles and buildings. An important aspect of these decisions is not just what emissions pricing and rules are in force today, but what businesses and households expect them to be like over the next 10, 20 or 30 years. If the stability of policy settings is uncertain, or confidence in them is lacking, then potential investors will hold back from committing to lowering their emissions. The source of policy instability is often political – lack of consensus across the main political parties, or lack of resolution of current arrangements that are clearly unsustainable (eg, an economic pathway that continues to rely on revenues from fossil fuel). Several submitters expressed the vital need for stability and predictability in emissions pricing and policy.

During the investigation into the UK Climate Change Act, members of my staff met with a number of private sector companies. They found a general frustration with the lack of stability in climate change policy. Without a measure of predictability, companies cannot manage the risks of moving to a low-carbon economy. Nor can they invest with confidence in low-carbon technologies. (Parliamentary Commissioner for the Environment, sub. 54, p. 4)

The most important factor for Todd is that the ETS incorporates clear guidance over future pricing. This will require some predictability on the future supply of NZUs (e.g. eligibility of international units, auctioning, etc.) to enable long term investment decisions to be made. (Todd Corporation, sub. DR373, p. 4)

A mechanism to provide certainty to business and ensure economic stability in relation to climate change controls is essential. Advice and reporting from a Climate Change Committee may help smooth fluctuations in policy and approach of successive governments. (Fertiliser Association, sub. 61, p. 12)

The main uncertainties for investment into a low-emissions future is legislative change. New Zealand's regulatory framework should provide efficient signals, incentives and long-term stability for businesses and consumers to make informed investment and purchasing decisions. (Vector, sub. 63, p. 17)

Business seeks predictability and stability of the conditions and frameworks in which they operate so they can plan with greater confidence, knowing that the assumptions they make about the future are broadly likely to hold. We are mindful that investors in the upstream petroleum sector, and large industrial enterprises, are generally looking at an investment horizon of 5 to 30 years. (PEPANZ, sub 65, p. 4)

Chapter 8 examines the institutional, governance and implementation options for improving policy stability through legislation and accompanying bodies (such as an independent Climate Change Commission) and processes.

F5.5

Because decisions that impact on greenhouse-gas emissions often involve a planning horizon of many years, the stability of policy settings and institutional arrangements for emissions pricing is vital. If the stability of policy settings is uncertain, or confidence in them is lacking, then potential investors will hold back from investing to lower their emissions.

International emissions trading

A key component of New Zealand's past strategy to meet its GHG targets has been to purchase reductions by participating in international carbon markets. In the first Kyoto commitment period (2008–2012), participants in the NZ ETS were free to purchase international credits to offset their emissions. Some purchased large amounts at prices of less than NZ\$1 a tonne of CO₂e, then banked them or exchanged them for emissions units in the NZ ETS (ie, NZUs). Between 2008 and 2012 New Zealand collectively accumulated a large surplus of international credits.

New Zealand plans to meet its 2020 emissions target (covering the 2012–2020 period) partly by relying on this surplus of international credits, despite the source of some credits being from emissions-reduction projects in countries that lacked credibility in reducing emissions beyond business as usual (Young & Simmons, 2016).

New Zealand’s emissions reduction targets for 2021–2030 are specified in its Nationally Determined Contribution (NDC) under the Paris Agreement. The NDC explicitly allows for the use of international market mechanisms and cooperative approaches:

In meeting its target New Zealand intends to use international market mechanisms, cooperative approaches and carbon markets that enable trading and use of a wide variety of units/emission reductions/mitigation outcomes that meet reasonable standards and guidelines to:

- ensure the environmental integrity of emissions reductions generated or purchased
- guard against double-claiming/double-counting, and
- ensure transparency in accounting and governance. (New Zealand Government, 2017c)

The economic logic of allowing trading in emissions reductions internationally is straightforward. The logic is similar to the benefits of free international trade in goods and services: economic efficiency and comparative advantage. If another country can reduce emissions at a lower cost than is possible in New Zealand, it is economically rational to purchase the service from that location. Indeed, having a unified global market for carbon with a single global price has the same logic (but on a broader scale) as having a single emissions price within a country.

While the focus of this inquiry is reducing New Zealand’s domestic emissions, it is desirable for New Zealand to retain the option of purchasing emissions reductions from other countries. This is because of the economic logic just described. Yet any use of this option must consider the following factors.

- The integrity of international units and the institutional arrangements for supporting international emissions trading are paramount. This is because the overall objective is efficient decarbonisation globally. While nations under the United Nations Framework Convention on Climate Change (UNFCCC) are working to develop sound multilateral arrangements, these are unlikely to be in place for some time. An alternative would be for two countries, each with a well-developed ETS, to reach agreement on bilateral trades. Another would be for two or three countries to form a “climate team” in which “investor” countries invest in a “host” country to support the host country to reduce its emissions below its NDC. Payments from investors to the host would be conditional on reductions being achieved and verified (Box 5.3) (Kerr et al., 2018).
- Correctly accounting for the costs and benefits of domestic reductions is important. Measures that reduce domestic emissions may create other environmental benefits, social benefits, or both. These measures may not be considered by New Zealand emitters when they decide either to reduce their emissions or offset them by purchasing international units. The potential environmental and social benefits include better air and water quality, learning-by-doing benefits that lower future costs,⁵⁷ enhancing New Zealand’s reputation, and future economic opportunities from domestic R&D.
- Correctly accounting for large capital costs, such as investing in a new plant to produce low-emissions process heat for many years to come, is important. It is the annualised equivalent of the capital cost that is relevant to compare with the price of international units. Also relevant are expectations about future prices over the lifetime of the investment. Current prices of international units may be modest; but, as other countries restrict their international supply as they strive to reduce their own emissions, prices could be much higher in future years. Thus, international trading may provide only a temporary option. While supporting international trading for agricultural emissions, Fonterra argued that, “New Zealand needs to avoid a long-term reliance on international units to offset emissions from fossil fuels. This is only a short-term solution as carbon dioxide emissions need to reach net zero by the second half of the century.” (sub. DR355, p. 6)

The sums involved in international trading can be very large. As an illustration, The Treasury (2016a) estimated that the potential economic cost of purchasing credits to meet New Zealand’s 2030 target could range from \$14 billion to \$37 billion over 2021–2030. The variation is mainly due to uncertainty about the price of credits.

⁵⁷ This approach has also been described as “building a platform for future domestic reductions at lower cost.”

Even so, it is stated by some that reducing New Zealand's domestic emissions would be much costlier than achieving equivalent reductions in the rest of the world due to the country's national circumstances (MfE, 2015a; Michael Reddell, sub. 111). In New Zealand's first NDC submitted under the Paris Agreement, the Government argued:

The likely cost to the New Zealand economy of meeting the 2030 target in terms of GDP is greater than that implied by other Parties' tabled targets. This is due to a number of factors, such as already achieving a high level of renewable electricity generation, and almost half of New Zealand's emissions originating from agriculture. (New Zealand Government, 2015, p. 5)

Comprehensive analysis of the costs of meeting New Zealand's commitments is limited. Before the Paris negotiations, modelling commissioned by the Ministry for the Environment (MfE) suggested that roughly 65% to 80% of New Zealand's 2030 target should be met through purchasing emissions reductions in other countries, and that an emissions price of up to \$300 would be needed to make meeting the target desirable purely with domestic reductions (Infometrics, 2015). However, caveats to the models used include assumptions of a zero carbon price for forestry and agriculture, no emissions policies beyond pricing, and no consideration of co-benefits, or New Zealand's ability to meet its future commitments domestically. Because of these caveats, the modelling does not provide a definitive assessment of New Zealand's cost-effective mitigation potential through to 2030.⁵⁸

Adrian Macey submitted that the opportunity cost of spending large sums on purchasing international credits would be high. He noted that

the scale of the required purchasing modelled by Treasury would be a severe imposition on the economy, with costs over the period 2020–2030 of the order of 14–20 billion dollars, potentially even more depending on carbon prices. The prospect of spending three times Vote Environment every year for ten years on purchasing units or offsets (or two and a half times New Zealand's annual aid budget) risks being politically and economically unsustainable. (sub. 103, p. 1)

In summary, the choice between abating domestically and through purchasing emissions reductions from other countries needs to be carefully weighed. At one level, the choice is a straightforward matter of choosing the least-cost option. When international credits are of a high integrity, investing in reductions overseas may provide a way to deliver global emissions reductions at lower cost to New Zealand. Even so, accounting for costs must be done correctly in terms of capital costs, reputation costs, co-benefits, and future costs and opportunities.

F5.6

The choice between abating domestically and through purchasing emissions reductions from other countries must be carefully weighed. When international credits are of a high integrity, investing in reductions overseas may provide a way for New Zealand to deliver global emissions reductions for which it is responsible at lower cost to New Zealand. Even so, comparing international and domestic abatement costs must be done correctly in terms of capital costs, reputation costs, co-benefits, and future opportunities.

R5.3

Because international emissions trading could help New Zealand achieve a net greenhouse-gas emissions target at significantly lower economic cost, the Government should:

- support and contribute to UNFCCC efforts to establish rules and an international trading infrastructure with high integrity;
- establish sound guidance for New Zealand public or private purchases of offshore emissions reductions that properly cost such purchases against the alternative of investing in additional domestic reductions – in terms of capital and current costs,

⁵⁸ The Commission's own modelling included agriculture and forestry in the NZ ETS. The modelling estimated that New Zealand could reduce its domestic emissions to reach net-zero emissions by 2050 if those emissions prices were to rise to between \$150 and \$250 a tonne by 2050.

reputation costs, co-benefits and investment in future economic opportunities for New Zealand; and

- make clear decisions, based on expert advice, about how much international purchasing to allow within specified future time periods.

Carbon sequestration

Sequestration of carbon dioxide (CO₂) through growing forests is an important contributor to New Zealand's net emissions of GHGs.⁵⁹ Emissions pricing can incentivise removals of GHGs in a similar way to reductions in emissions: under the NZ ETS, the government provides credits in the form of NZUs to eligible forestry activities that sequester CO₂ (Chapter 2). New Zealand's ETS is the only ETS globally to include full credits for forestry sequestration of CO₂.

Forest owners earn units as their forests grow and sequester carbon, and relinquish units if they harvest, or deforest their land by converting it to, say, farmland. Forest owners can sell units to emitters or bank them in anticipation of harvesting. To date, this feature of the ETS has been largely ineffective at incentivising new forestry planting. Reasons include low unit prices, and little certainty on future unit supply, price management or future forestry accounting rules (Chapter 11) (Leining, 2017).

Carbon sequestration in forests works on a biological cycle – absorbing carbon during growth and releasing carbon when trees are cut down, or decay and die naturally. At harvest time, the use of the wood determines the timing of carbon release. Burning the wood as a biofuel releases CO₂ quickly, but using it for furniture can lock in the carbon for many decades. New forests that are never harvested can act as permanent carbon stores. These variations complicate any emissions pricing scheme for forestry.

The NZ ETS currently assumes that a high proportion of the carbon is released at harvest. But the accounting rules are likely to change in 2021 to allow forest owners the choice of an “averaging” method. When forests are harvested on a regular cycle, this method will allow forest owners to earn credits up to the average that their forests will store over their life-cycles without the need to relinquish units at each harvest and removing the risk that unit prices will have moved against them.

F5.7

An emissions trading scheme is an effective form of emissions pricing to incentivise sequestration of carbon dioxide through forestry. Foresters earn emissions units as trees grow and must relinquish them on harvest. They can bank earned units as a hedge against future price uncertainty. Owners of permanent forests can become “carbon farmers” by earning and selling emissions units.

Chapter 11 explains forestry in more detail, including providing a more integrated treatment of alternative land uses such as plantation forests, permanent forests (carbon farming), animal farming and horticulture.

Points of obligation

The point of obligation in emissions pricing defines the point at which an entity (eg, producer or consumer) is obliged to report emissions information and surrender emissions units under an ETS. The point of obligation should be chosen (as much as possible) to:

- obtain comprehensive coverage of emissions;
- minimise transaction costs (of effective reporting, monitoring and compliance); and
- provide the most clearly targeted incentives to reduce emissions.

As Leining et al. (2017a) note:

⁵⁹ This assumes that net emissions of GHGs are gross emissions into the atmosphere less the removal of GHGs from the atmosphere (see Chapter 2).

An ideal system would have minimal administration costs, a broad coverage of emissions from each included sector with effective transmission of emission price incentives, and effective monitoring, reporting, and compliance systems. (p. 6)

An obvious point of obligation in a supply chain is the point at which emissions actually occur. Yet, a point of obligation that better achieves the three criteria above might lie “upstream” or “downstream” of the emissions point. For example, virtually all petrol will end up being used in internal combustion engines and emitting a highly predictable quantity of CO₂. It will therefore reduce transaction costs – while still achieving comprehensive coverage and the right incentives – to make the point of obligation the importer or the domestic refiner of bulk petrol rather than the many thousands of vehicle users.

Coverage and the right incentives will happen if the business entity at the point of obligation “passes through” the emissions price and this continues through the supply chain to the final consumer. Final consumers then respond to the higher price of the emissions-intensive product or service either by consuming less or switching to a lower-emissions substitute. Alternatively, each business in the supply chain will have an incentive to find lower-emissions options that will give it a competitive advantage. In other words, the point of obligation will not affect the incentives of any party to mitigate. Also, if markets operate effectively, the point of obligation will not affect how the economic burden is shared across parties in the supply chain.

If the government is concerned about who is bearing the economic burden, it is possible under an ETS to use free allocation (Leining et al., 2017a):

If for equity, political, or competition and leakage reasons the government wishes to protect some firms or consumers, free allocation can be used strategically to alter the distribution of costs. The point of obligation also does not need to be the point of free allocation. (p. 7)

Where there are many relatively small upstream producers, the desirable point of obligation may be further downstream (such as with large processing plants). An example is placing the point of obligation with large milk processors after on-farm ruminant livestock emissions are generated. Compared with requiring many individual farmers to be responsible for their own on-farm emissions, placing the point of obligation with such processors will reduce transaction costs. Yet, doing so risks failing to incentivise farmers to produce with lower emissions per unit of output through on-farm mitigation measures such as selective breeding, altering feed mixes, or the use of vaccines. The differences between high- and low-emitting producers of the same products can be considerable (Anastasiadis & Kerr, 2013).

Where a suitable point of obligation does not exist upstream or downstream of many small emitters, a possible solution is to set a size threshold to exclude small emitters. In doing so, a trade-off exists between emissions coverage and administrative/compliance costs. The threshold definition needs to be clear, not able to be manipulated, and not incentivise firms to break into smaller units to avoid emissions obligations (Leining et al., 2017a).

Finally, it is possible, and may make sense, to adopt a hybrid approach to points of obligation.

This would entail setting a default point of obligation in the sectoral supply chain, while allowing for other firms (either upstream or downstream) to opt in (or be required to participate) as a point of obligation accompanied by a carving-out of their emissions from the liabilities assigned to the default point of obligation. (Leining et al., 2017a, p. 11)

Doing this could improve transparency and political acceptability at the cost of increased administrative complexity. An example is that a large energy-using firm could be required to pay for its emissions directly rather than rely on the obligation of the fuel producer or importer.

F5.8

The point of obligation to pay for emissions needs to achieve a good balance between broad coverage, low administration costs, and effective transmission of emissions-price incentives combined with effective monitoring, reporting, and compliance. Placing points of obligation upstream or downstream of actual emissions sources (as well as at source) and using minimum-size thresholds may help to achieve the best balance.

Using a shadow price for emissions

A “shadow price” is the theoretical price of a good or service within an economy that indicates the value or cost of having one more unit of that good or service. If markets are working well (ie, consistent with economic efficiency), then the market price and the shadow price will coincide. If they are not working well, then market prices will give the wrong signals and there is a case for public authorities to use shadow prices rather than market prices when deciding on resource allocations.

The shadow price of one tonne of GHG emissions is the damage to the planet from global warming from having one additional tonne of GHGs in the atmosphere. This whole chapter is about the desirability of making this shadow price a real cost that emitters face. If that is not the case, either because no emissions price exists or it is too low, agents who are concerned about climate change should use the shadow price to guide their decisions.

For example, suppose a public hospital is replacing its heating system: it can choose a coal-fired boiler, a gas-fired boiler or heat pumps powered by clean electricity. Suppose each investment will last 40 years and GHG emissions are not priced. A megawatt hour (MWh) of heat from each source costs \$40, \$50 and \$60 respectively, taking account of both capital and operating costs. This would make investing in a coal-fired boiler the least-cost option. However, if emissions per MWh are 1, 0.5 and 0.1 tonnes of CO₂e respectively, and the correct shadow price of emissions is \$30 a tonne, the costs per MWh become \$70, \$65 and \$63 respectively. This reverses the cost order so that investing in heat pumps becomes the least-cost option.

When emissions prices are absent or too low, governments should consider using a shadow price of emissions in their investment decisions. Examples of such decisions include investments in transport, water and energy infrastructure, buildings, and car fleets. These investments involve not only large resources but, once made, become sunk, irreversible and long-lived. Getting them wrong can lock in high emissions for a long time. The UK Government adopted the use of a shadow price for carbon in 2007.

Explicit carbon pricing can be usefully complemented by shadow pricing in public sector activities and internal pricing in firms. Governments, firms, and institutions often use shadow carbon pricing to help reorient investment decisions, anticipate future pricing or future changes in the carbon price, or account for indirect impacts on emissions (e.g., when public infrastructure investments affect emissions). The United Kingdom adopted the use of a shadow price for carbon in 2007 as the basis for incorporating carbon emissions in cost-benefit analyses and impact assessments. Institutional investors and lenders often incorporate a shadow carbon price into their environmental impact assessments and cost-benefit analyses as well. (Stiglitz & Stern, 2017, p. 12)

The European Investment Bank and the World Bank also use a shadow carbon price when each conducts a cost-benefit analysis (CBA) of a project (Stiglitz & Stern, 2017).

A New Zealand example is KiwiRail’s recent decision to abandon its electric-powered locomotives and invest in an all-diesel fleet. It can be argued that KiwiRail should have used realistic shadow prices for the emissions saved over the life of the investment in its business case analysis of this decision (KiwiRail, 2016a). Auckland Council noted the New Zealand Transport Agency’s recommended use of a shadow carbon price (or “social cost of emissions”) and argued for a standard figure to apply across the public sector.

Developing and/or endorsing a social cost of carbon for use in business cases across the public sector would provide clear guidance and reduce duplication of research across the public sector. At present there is no agreed social cost figure. The NZ Transport Agency Economic Evaluation Manual uses \$40/tonne, although the rationale is not clear. (sub. 97, p. 14)

Elsewhere in this chapter, the Commission recommends a system in which emissions are priced at the level that reflects their harm, and will achieve New Zealand’s emissions-reduction targets. If this happens, government agencies will not need to use shadow prices that differ from the actual emissions prices. If, however and for whatever reason, emissions prices are absent or too low, then a case certainly exists for the government to use a shadow price of emissions to guide its investment decisions.

F5.9

It is preferable to have a system in which emissions are priced at a level that reflects their harm and will achieve New Zealand's emissions reduction targets. If, however, emissions prices are absent or too low, then a convincing case exists for governments to use a shadow price of emissions to guide their investment decisions.

Pricing co-benefits and co-harms

The theory of pricing negative and positive external effects is quite general and applies to any co-benefits (and co-harms) of mitigating emissions – to the extent they are not currently priced. The co-benefits of mitigating emissions can be large – switching away from fossil fuels reduces air pollution and switching land use from dairy to forestry can improve water quality.

The co-benefits of mitigation can be substantial and are therefore often an important element in analyses by policy makers. Observational and modelling studies indicate that 3 million premature deaths are attributable to ambient air pollution and 4.3 million premature deaths to household pollution ... The global average marginal co-benefits of avoided mortality are estimated at US\$50–380/tCO₂ ... In 2011, the United Nations Environment Programme (UNEP) estimated that fast action to reduce emissions could avoid 52 million tons (or 1 to 4 percent) of crop losses per year. (Stiglitz & Stern, 2017, p. 16)

We agree that carbon unit pricing needs to be carefully considered to avoid creating incentives which make it difficult to achieve other government objectives, from a regional council point of view, related to freshwater management, biodiversity and biosecurity, and community wellbeing. (Waikato Regional Council, sub. DR227, pp. 2-3)

Co-benefits generally increase the value of reducing GHG emissions for society. Co-benefits are relevant to setting emissions prices but, because they vary by circumstances (place and type of activity), they cannot be reflected in a single uniform addition to an emissions price. The additional harm of not mitigating could be addressed with either:

- a separate tax or subsidy scheme;
- a separate permit requirement;
- regulation; or
- shadow pricing the co-benefit or co-harm in CBAs.

F5.10

The co-benefits of mitigating greenhouse gas (GHG) emissions can be substantial, such as better air and water quality. The co-benefits increase the value to society of reducing GHG emissions. Policy options that, in addition to emissions pricing, could incentivise businesses and people to consider co-benefits include a separate tax or subsidy scheme, a separate permit scheme, direct regulation, or the use of a shadow price in cost-benefit analysis.

5.4 New Zealand's system of emissions pricing

This section examines New Zealand's current system of emissions pricing and how it got to where it is today. Taking account of recent and proposed reforms, it assesses the extent to which that system is likely to meet the objectives of a good system of emissions pricing. The section then assesses what further reforms are needed to achieve those objectives.

New Zealand's system of emissions pricing: a brief history

Chapter 2 includes a brief description of New Zealand's main current form of emissions pricing – the NZ ETS. This is New Zealand's main policy instrument to reduce emissions and fight climate change. Parliament passed legislation establishing the NZ ETS in September 2008.

New Zealand's consideration of emissions pricing began in the 1990s. In 1999, the government selected emissions trading as the preferred option for the first Kyoto commitment period. In 2002, the Labour-led government introduced a comprehensive climate-change policy package that included a carbon tax on the energy and industry sectors to be implemented from 2008. It was to have a price ceiling of NZ\$25 a tonne to approximate the international price of emissions. Revenue generated by the tax was to be returned to the economy through the tax system. Exemptions were to apply to exposed industrial producers in exchange for entering into "Negotiated Greenhouse Agreements" to achieve world's best practice in emissions intensity (Leining, 2017).

Much of the detailed design for the carbon tax was carried into the later design of the NZ ETS. The carbon tax had been expected to start at NZ\$15 a tonne and rise over time up to the level of the price ceiling. However, after New Zealand's projected emissions against its Kyoto commitment changed from overachievement to underachievement, the government launched a review of its climate-change policies. Then, following the 2005 election, the Labour-led government lost sufficient support for the carbon tax from its coalition partners and it abandoned the tax in December 2005 (Leining & Kerr, 2016a).

On the back of growing interest in emissions trading internationally, the government launched the design of an ETS in April 2007. The scheme was the first in the world to aspire to cover all GHGs and all sectors of the economy. It also innovated in applying an upstream point of obligation in the energy sector. It did not incorporate government auctioning of permits to generate revenue (following the adverse reaction to the carbon tax proposal). Instead, the scheme allowed unlimited buying and selling of units in the international emissions trading market set up under the Kyoto Protocol, which allowed emitters to purchase overseas credits to offset their emissions.

Essentially, rather than New Zealand setting domestic emissions caps and prices, the system allowed New Zealand emitters to observe international emissions prices and choose either to reduce their emissions domestically, or continue to emit and purchase offsetting reductions offshore. The theory was that New Zealand would achieve its Kyoto obligations to reduce global emissions at least cost. The scheme provided for ongoing free allocation to exposed industrial emitters to alleviate competitiveness and carbon-leakage concerns.

The National-led government elected in late 2008 immediately launched a review of the NZ ETS (under its confidence-and-supply agreement with the ACT Party). The review led to the following amendments enacted in 2009 (Leining, 2017):

- a halved obligation to surrender units (one-for-two) to December 2012 that lowered effective prices in non-forestry sectors;
- a price ceiling of NZ\$25 a tonne to December 2012 (so, only \$12.50 under the one-for-two deal);
- free allocation based on current rather than historical output to EITE industrial producers, with a slow yearly phase-out of one percentage point; and
- deferral of the start date for the entry of biological emissions from January 2013 to 2015.

From 2011 to 2017, a further series of government decisions affected the NZ ETS:

- a second review (2011) extended indefinitely the one-for-two measure and the \$25 price ceiling, and deferred indefinitely the phase-out of free allocation and the introduction of biological emissions from agriculture;
- a de-linking of the NZ ETS from the Kyoto market in mid-2015 resulted in international trading in units ceasing. This led to a quite rapid rise in the price of NZUs to around \$21 in early 2018 from a low price of \$1.45 in February 2013 (Leining & Kerr, 2016a; Leining et al., 2017b);
- a phase-out of the one-for-two obligation for non-forestry sectors, with full obligation to apply from January 2019; and

- in-principle decisions in July 2017 on unit supply, price management and international linking (see the next section for more detail).

In October 2017, a new government came into power with an ambitious agenda to reduce New Zealand's domestic GHG emissions.

Over its life to date, the NZ ETS has been ineffective in inducing significant emissions reductions, particularly domestically. Up to 2015, this was not surprising because the scheme's purpose was least-cost fulfilment of New Zealand's Kyoto obligations regardless of the location of the emissions reductions. Even within this purpose, the large drop in international emissions prices from 2011 provided only weak incentives to reduce emissions.

Many submitters to the 2015/16 review of the NZ ETS expressed negative and somewhat cynical views, as the submission of Permanent Forests New Zealand Ltd illustrates:

The NZ ETS has had a 'test run' under CP1 Kyoto rules. It failed to achieve any meaningful emission reductions across our economy (or generate real carbon offsets), but worse has created deep cynicism amongst carbon market players and the financial sector, and expectations are now set that the ETS is a farce, it does no real work, carries no responsibility, and provides for cost avoidance, arbitrage, playing the market, but is too risky for serious investment engagement. (NZ ETS Review, sub. 54, p. 1)

Since the 2015 cessation of access to international trading, the NZ ETS has become a domestic-only scheme and prices have risen. Yet the scheme has still suffered from handicaps to its effectiveness with sector exemptions and several key policy uncertainties, leading to doubt about future rules and prices. As Leining (2017) summarises,

to date the system has had no substantial impact on domestic emissions or business decisions. The causes for this are specific and well-understood. First, under the combination of unlimited access to low-cost overseas units and a half-price unit obligation for non-forestry sectors, the domestic emission price has been too low to incentivise change. Second, since late-2012, participants have had no certainty on future unit supply and price management or on future forestry accounting rules, and therefore no credible long-term price signals to drive transformational low-emission investment. (p. 4)

F5.11

The New Zealand Emissions Trading Scheme began with an impressive all-sectors, all-gases architecture and access to international trading for least-cost mitigation. However, low international prices and various reforms to soften its impact have blunted its effectiveness, particularly in achieving domestic greenhouse-gas reductions. Key policy uncertainties have led to business and investor doubts about future rules and prices, undermining incentives to invest in lower emissions.

NZ ETS reforms announced in July 2017

In July 2017, the then government announced four important in-principle reforms to the NZ ETS. The four reforms, relating to the supply of emissions units, price management and international linking, are to:

- auction emissions units by 2021 under an overall limit (essentially a cap), an option that has been available in legislation since 2012 but not yet implemented;
- allow NZ ETS participants to purchase international units up to a quantity limit to help meet their obligations (offshore purchasing is not possible now, but could become so in the future);
- implement an alternative (higher) price ceiling to replace the current fixed-price option of \$25 a tonne once auctioning or linking is in place; and
- fix and coordinate settings on unit supply, the price ceiling and international linking five years in advance and update them on a rolling basis.

At the same time (July 2017), the government said it would not change the basis of free allocation of units to EITE industrial producers until at least 2021, and that biological emissions from agriculture would remain outside the ETS for the foreseeable future (MfE, 2017k).

The new government's coalition agreement (between the Labour and New Zealand First parties) has just one measure relating to emissions pricing. This is to introduce agriculture into the NZ ETS if recommended by a proposed independent "Climate Commission", with a 95% free allocation to the agriculture sector and revenue recycled to agricultural innovation, mitigation, and forestry planning (New Zealand Labour Party & New Zealand First, 2017).

Sections 5.5 to 5.7 below assess these proposed changes to the NZ ETS as part of a wider assessment of emissions pricing in New Zealand and its desirable future form.

The international environment of the NZ ETS before and after the Paris Agreement

Lack of access to a sound and trustworthy system of multilateral trading is a feature of the current emissions-trading environment after the Paris Agreement. This is unlikely to change for some time and is strikingly at odds with a key assumption behind the original design of the NZ ETS that such access would exist.

The NZ ETS was initially calibrated for a world which no longer exists (if it ever did): one in which New Zealand could rely on the international market to set an appropriate domestic emission price, and allow its domestic emissions to increase as long as they were offset globally. Under the Paris Agreement, all countries must transition to net zero emissions, there is no integrated carbon market governed by internationally agreed rules, and there is no convergence toward a single efficient global emission price. (Leining, 2017, p. 22)

As noted, the ability of New Zealand emitters to purchase international credits explains much of the failure to reduce domestic emissions under the NZ ETS. The ready supply of these credits at low prices and, in some cases, of questionable integrity, enabled New Zealand to meet its first targets for the Kyoto Protocol period with no significant reduction in domestic emissions. In addition, many participants and the government acquired large positive balances of units.

The Government decision in 2012 to take New Zealand's emissions-reduction commitment for 2013–2020 under the UNFCCC rather than the Kyoto Protocol meant that New Zealand lost access to the international Kyoto market from 1 June 2015 (Leining & Kerr, 2016a).

Now that New Zealand's emissions market is essentially domestic, the NZ ETS requires further reform to take control of domestic emissions and emissions prices. Yet some scope for international deals remains. Box 5.3 describes the limited opportunities that exist under the Paris Agreement for countries to meet their emissions obligations offshore, and the ongoing work to develop new multi-party trading arrangements.

Box 5.3 The Paris Agreement and international carbon trading arrangements

Article 6 of the Paris Agreement allows the use of carbon markets to meet nationally determined contributions (NDCs) through "internationally transferred mitigation outcomes." However, currently no top-down framework exists for such transfers: they must be arranged government to government in a way that avoids double counting under the targets of the seller and buyer. Linking different emissions trading schemes (ETSs) qualifies under Article 6, but linking the NZ ETS would present significant challenges. For example:

- ETS linking would reduce New Zealand's sovereignty over domestic emissions and emissions prices;
- the NZ ETS design is not easily compatible with two-way ETS linking given the characteristics of other ETSs currently operating and planned (Leining et al., 2017a); and

- given its 2030 target gap, New Zealand would want to link the NZ ETS with a net seller with a stable and well-established ETS, and an example with such features is yet to emerge.

The Paris Agreement provides for the creation of a new central market mechanism that both governments and private entities could access, but the rules guiding such a mechanism are unlikely to be developed until well into the future. As a result, emissions prices around the globe are likely to remain highly variable in a system where targets and policies are developed from the bottom up.

The other approach of the Paris Agreement for internationally transferred mitigation outcomes is a government-to-government “cooperative” approach that lets countries coordinate trading among themselves, provided they follow accounting principles approved by the UNFCCC. An example of this approach is a voluntary and cooperative “climate team model” that some non-government organisations in New Zealand and Colombia are exploring. New Zealand would “invest in” emissions reductions in Colombia that are on top of Colombia’s NDC. Payments would flow in direct proportion to verified reductions within an agreed price range and maximum budget.

Source: Kerr et al. (2018); Leining (2017).

5.5 Emissions pricing objectives

Any assessment of an emissions pricing system needs to be based on a clear idea of outcomes sought and a set of criteria for a good system. This section sets these out as a prelude to assessing the NZ ETS in its current form and making recommendations for future reform.

Desirable outcomes for a system of emissions pricing

The desirable high-level outcomes for an emissions-pricing system for New Zealand are:

- economically-efficient reductions in emissions that achieve New Zealand’s point-in-time and emissions-budget targets over several decades;
- fair and just distribution of the burden of reducing emissions;
- enough clarity and stability to incentivise innovation and large, irreversible investments in low-emissions infrastructure and other ventures; yet also enough flexibility to adapt to new developments, such as information about technology;
- seamless operation alongside complementary instruments that also help reduce emissions, or aim to achieve co-benefits such as support for public transport; and
- no significant problems in the system’s operation at or beyond the international border.

Criteria for a good emissions pricing scheme

To achieve the outcomes above, an emissions pricing system for New Zealand should be assessed against the following criteria (adapted from the list in (Leining, 2017)). The system should:

- enable control of domestic emissions and reasonable influence over emissions prices;
- raise domestic emissions prices over time in line with New Zealand’s progressively more ambitious international targets and objectives for domestic emissions reductions;
- have substantial policy and price predictability to support efficient low-emissions investment;
- distribute emissions-reduction responsibilities, costs and risks fairly and efficiently across NZ ETS sectors, non-NZ ETS sectors, the government and taxpayers; and
- integrate well with arrangements in place to achieve emissions reductions offshore (assuming those arrangements are robust and trustworthy).

The system should also:

- mitigate potential emissions leakage to other jurisdictions;
- achieve environmental integrity and transparency, and effective compliance and enforcement;
- manage uncertainties and risks (environmental, economic, fiscal and social) and adapt to new information;
- raise and manage revenue strategically; and
- achieve broad and enduring public and cross-party acceptance.

5.6 What changes to emissions pricing in New Zealand are desirable?

How well does the current system of emissions pricing – the NZ ETS – perform against the above desired outcomes and criteria? The analysis below considers the reforms announced (but not yet implemented) in July 2017, and other possible reforms – such as the proposals that came out of an ETS dialogue process led by Motu Economic and Public Policy Research (Kerr et al., 2017).

The current New Zealand ETS has only some of the required features

The NZ ETS has some of the features needed to run a market that prices emissions across the economy in a comprehensive and efficient way. However, decision makers have yet to implement other features. This has led, in part, to New Zealand’s poor record on lowering its emissions (Chapter 2).

As noted, a key problem has been low-emissions prices owing to the government’s one-for-two deal and participants’ undisciplined access to international credits. Figure 5-4 shows the sharp fall in the price of NZUs from 2011 and the price recovery from 2015 following the ending of access to international credits and the NZ ETS becoming essentially a domestic scheme.

Figure 5-4 Price of NZUs, 2009–2017



Source: OM Financial Limited and CarbonMatch (pers. comm, December 2017).

An effective ETS will need to align annual or longer-period caps on unit supply with agreed emissions budgets and domestic emissions-reduction targets. A limit on unit supply is the key mechanism for controlling the quantity of emissions. Such alignment would define credible paths towards New Zealand’s long-term targets to meet its international commitments.

Effectiveness will also require solving the problem of lack of certainty and credibility for ETS participants about future unit supply. Without this, participants will continue to struggle to form expectations about future prices. Certainty and credibility will only come with clear long-term policy direction and cross-party

political buy-in. Topics lacking certainty and credibility for future direction include free allocation of units, the inclusion of agriculture in the NZ ETS, the rules for forestry and mechanisms for updating future unit supply as new information about technology, behavioural responses and climate risks become available. Many submitters agreed that the uncertain policy framework for the ETS has been a serious weakness, including Pacific Aluminium and the Guardians of New Zealand Superannuation:

It is important to have certainty as to the regulatory framework for climate policy. This is not the same as having certainty over the carbon price. ... What matters to decision making is having an understanding of the regulatory framework and that the major parties of Government keep to that framework even while having differing views about the settings for the NZ ETS. (Pacific Aluminium, sub. 21, p. 6)

A stable policy environment on carbon pricing [and] related matters. The policy environment must be sufficiently stable to make investors comfortable with the idea that carbon pricing at economic levels will prevail. It should not be subject to election cycles. (Guardians of NZ Superannuation, sub. 32, p. 9)

Among valuable achievements of the NZ ETS are building the institutional arrangements for NZUs (ownership, responsibilities, points of obligation, systems for measurement, monitoring and verification) and the experience and familiarity of participants in operating the system and trading NZUs. These achievements should not be thrown away – they are valuable assets. As Leining (2017) comments:

If changing instruments mid-course delays implementation of a more ambitious price signal by starting a new complex legislative process, re-opens contentious political debates, disrupts market confidence in government rulemaking, and devalues assets created and investments made under the previous instrument, then the environmental, economic and fiscal costs could outweigh hoped-for gains. (p. 34)

F5.12

Some basic building blocks of an effective ETS are present in the NZ ETS, but lack of others has led to low prices and tepid responses from participants. As a result, the NZ ETS has not reduced domestic emissions or increased domestic removals to the extent needed to achieve a significant reduction in New Zealand's domestic greenhouse-gas emissions. A key problem is lack of certainty and credibility about future unit supply and the pathway to achieving New Zealand's long-term targets to meet its international commitments.

The NZ ETS since international de-linking

The de-linking of the NZ-ETS from international trading provided valuable impetus towards an effective domestic emissions price. The phasing out of the one-for-two arrangement will also support a higher emissions price. But these are partial measures. They fall short of what is needed to provide participants with visibility of how future unit supply will track towards lower net emission. Such visibility is vital to send the right signals to business and others about future emissions prices.

The in-principle reforms to the NZ ETS announced by the previous Government in July 2017 are further steps that, if implemented, will go some way to remedying past deficiencies in the NZ ETS. These reforms will help New Zealand to follow a low-emissions strategy – but only up to a point, as noted below.

- *Government auctioning of units.* Auctioning is important in an ETS because control over the number of units to auction is the best means to implement a quantity cap on net emissions. Yet no government to date has used auctioning in the NZ ETS. Auctioning provides a component of unit supply along with free allocation and credits earned through emissions removals. In addition, auctioning generates revenue for the government that it can use strategically to support New Zealand's overall transition to a low-emissions economy (eg, to cushion adverse impacts on vulnerable groups or to fund R&D).
- *Participants may be able to use international units to partly meet their obligations up to a limit.* This reform recognises the need to limit access to international units. Yet it gives no guidance about how the limits will be set. In any case, no practical and trustworthy means for participant access to international credits exists for now.

- *Implementing a higher price ceiling than the current \$25 for each tonne of CO_{2e}.* This is the right direction of travel, but is too vague about the level of the higher ceiling and how it will be adjusted over time.
- *Fixing and coordinating settings (for unit supply, any price limits and international linking) over a five-year rolling horizon.* Such a clear and coordinated set of signals for the next few years is essential. It needs to be articulated as part of a wider strategy for domestic emissions reduction. Arguably, also, five years is not a sufficient time horizon (relative to what is needed) to make decisions about long-term investments.

Until these reforms are clarified, the NZ ETS will not provide enough information to investors and other participants to make effective decisions for a low-emissions future. Encouragingly, the Government has recently released draft proposals in a consultation document that will help shape future legislative changes (MfE, 2018c). In a message in the document, the Minister for Climate Change said:

The changes proposed in this document will enable us to cap emissions from sectors covered by the NZ ETS and manage that cap over time. They provide the basis for a credible and well-functioning scheme in the 2020s. Your responses will inform the development of this improved framework, a framework that provides a more predictable environment for decision-making, and follows a transparent process when changes need to be made. (p. 5)

The proposals spell out design features about important areas such as setting unit supply, auctioning of units, replacing the current price ceiling, limits on the use of international units, phasing down free allocation, market governance and market information. Yet, many details are not settled and feedback on them is sought.

The overall assessment of the Commission is that while reforms of the NZ ETS have been ongoing, the scheme's current characteristics do not yet meet the criteria for a good system of emissions pricing. The further in-principle reforms announced in July 2017, and the recently released proposals for consultation,⁶⁰ would take the scheme in the right direction. But important details still need to be settled and legislated to provide sufficient information and strong, clear signals to participants, and to households, businesses and investors who are not direct participants. These uncertainties need to be resolved as soon as possible to achieve a robust and well-designed emissions-pricing system.

F5.13

The current features of the New Zealand Emissions Trading Scheme (NZ ETS) do not meet the criteria for a good system of emissions pricing. The further in-principle reforms announced in July 2017 and the recent proposals released for consultation would take the NZ ETS in the right direction, but require important details to be settled to provide strong and sufficiently clear signals to participants, as well as to households, businesses and investors who are not direct participants.

Proposals for reform from Motu's dialogue with others about a low-emissions future

NZ ETS reform proposals emerged from a recent dialogue process on a low-emissions future for New Zealand led by Motu Economic and Public Policy Research (Kerr et al., 2017; Leining & Kerr, 2016b). Motu has undertaken a large amount of research over more than a decade in many aspects of climate-change policy, including the NZ ETS. The dialogue process brought in other experts and organisations to help build common understanding and agreement on proposals for reforming the NZ ETS.

The recommended changes to the NZ ETS from the dialogue process go further and would involve faster action than the four in-principle reforms announced in July 2017. However, the government proposals recently released for consultation mirror them to some extent (MfE, 2018c). Recommended changes proposed through the Motu dialogue aim to make the NZ ETS an effective system of emissions pricing at

⁶⁰ The Government released a consultation document with proposals related to the July 2017 in-principle reforms in early August 2018, see MfE (2018c)

the centre of an overall strategy of emissions reduction. The six recommended changes are described in Box 5.4.

Box 5.4 Additional proposed reforms to the NZ ETS from the Motu dialogue process

1. *Set an initial fixed five-year cap and fix future caps for a full five years in advance.* After one year, and on a rolling basis after that, a cap would be set for year six to support market expectations five years ahead. The capped supply for years one through five would remain fixed.
2. *Add a price floor to be implemented as a reserve price at auction.* Units not sold at auction would be shifted into a unit reserve – an action that would reduce domestic supply and offer a form of government banking. A price floor will maintain a minimum price at auction and adjust market supply downward in the event of unintended over-allocation or unexpected changes in market conditions. A price floor will give greater confidence about returns to low-emissions investors (eg, landowners investing in forestry).
3. *Set a price ceiling by creating and using a unit reserve that would sit within the NZ ETS cap.* When the emissions price hits the ceiling, reserve units are sold holding the price at the ceiling. But if the reserve is exhausted, the price could rise above the ceiling. The NZ ETS market would continue to set the emissions price within the limits of the price floor and the price ceiling. But the floor and ceiling safeguard against downside and upside price risk. The reserve is set within the cap limits and this reduces the fiscal risk from the price ceiling. The price protection is “soft” in the sense that the price relief is limited by the size of the reserve.
4. *Add indicative 10-year trajectories to the cap and price band to guide future extensions.* This addition would impose on government the discipline of forecasting corridors for unit supply and prices, and provide a 15-year horizon to guide NZ ETS participants and investors.
5. *Enlist independent advice.* Decisions on setting emissions caps, price limits and international linking in an ETS require sound technical information, but ultimately are political in nature. Providing for independent expert advice (see Chapter 8) would support evidence-based and transparent decision making, which, in turn, improves the chances of both public and cross-party acceptance and support.
6. *Introduce auctioning and the price band (with a higher ceiling) as soon as possible rather than wait until 2021.* Waiting would extend uncertainty for market participants and investors and increase the risks of stranded assets and fiscal cost. Reducing New Zealand’s domestic emissions in line with its targets will require emissions prices considerably higher than \$25 a tonne. As confidence in the future of the NZ ETS grows, emissions prices could easily pass \$25 a tonne. This increase makes it urgent to raise the price ceiling.

Source: Kerr et al. (2017); Leining (2017).

The recommendations from the Motu dialogue address some clear weaknesses in the NZ ETS that compromise the Scheme’s ability to deliver effective emissions pricing and New Zealand’s emissions targets for 2021 to 2030 and beyond. First, setting caps five years in advance, and auctioning NZUs to achieve the caps would establish transparency and control over unit supply and therefore over New Zealand’s near- and medium-term progress to lower its net emissions. Second, indicating a trajectory for the cap for a further 10 years would provide further stability, transparency and forward guidance to support decision making by investors to lower their net emissions.

Several submitters agreed with reforming the NZ ETS to make it effective with higher emissions prices and, in some cases, extending it to agriculture (Waimakariri District Council, sub. DR192; Kate McNab,

sub. DR219; Northland Regional Council, sub. DR226; Auckland Council, sub. DR273; Wellington City Council, sub. DR 276). But SAFE was more skeptical:

The draft report identifies the shortcomings of the New Zealand ETS but does not provide strong grounds for believing that a reformed ETS would be much more effective. We support the proposal to include agriculture in the ETS but consider it more prudent to see emissions trading as a work in progress and, until proven, put more policy effort into well-designed regulations supported by a suite of targeted environmental levies... While emissions pricing has been credited with moderate success in some countries, in very few, if any, has it been demonstrated to be the main driver of emissions reductions. (sub. DR216, p. 7)

The Commission supports NZ ETS reform to improve its transparency, stability, and control over unit supply consistent with a clear long-term emissions-reduction target. Yet it believes that other aspects also deserve consideration: the institutional architecture for setting quantity caps for the ETS, conducting auctions of NZUs, managing the NZU market and accessing international units. These are covered in the next section.

5.7 The NZU market: reforming the way it operates

Since the NZ ETS began in 2008, a market in NZUs has existed. This market has been relatively self-organised, with several platforms and carbon traders acting as intermediaries to bring together willing buyers and sellers of NZUs (and other international units that were available up to mid-2015). Obligations on emitters to surrender NZUs and related institutional machinery (set in 2008 under amendments to the Climate Change Response Act 2002) created the impetus for the market and continue to underpin its existence and development. Box 5.5 describes the main features of the market as it currently operates.

Box 5.5 How the market for NZUs currently operates

The primary unit of trade in the NZ ETS is a New Zealand Unit (NZU). It is effectively a permit to emit one tonne of CO₂e of GHGs. Emitters must acquire and then surrender NZUs (or other eligible emissions units) to cover their GHG emissions. Foresters earn NZUs in line with the CO₂ they remove from the atmosphere. But, they must surrender units at harvest. The Environmental Protection Authority (EPA) administers the scheme. It operates the NZ Emissions Trading Register where all participants and transactions are recorded. The EPA is also responsible for ensuring that participants comply with their obligations.

So, the demand for NZUs in a specific period comes from obligations to surrender units for emissions of GHGs in covered sectors. The sources of supply of NZUs are the free allocations to EITE firms, banked units, and units earned for sequestration (forestry). Before mid-2015, supply could also come from eligible offshore units. Currently, government does not auction NZUs for supply. But under current settings, the government offers a fixed-price option of \$25 for each NZU to emitters in place of them surrendering units to cover their emissions. The current number of ETS account holders is around 13,500.

Table 5.2 New Zealand Emissions Trading Register: recent statistics

Year	NZUs and NZ AAs held by participants	NZUs issued	NZUs allocated	NZUs surrendered	Number of transactions
2016	135,451,968	432,193	4,270,251	21,137,535	5391
2017	128,496,346	17,009,381	5,809,637	22,482,649	6936

Source: New Zealand Emissions Trading Register, holding and transaction summary (New Zealand Emissions Trading Register, 2018); Environmental Protection Authority information on privately-held units (EPA, 2018b)

Notes:

1. NZ AAs are New Zealand Assigned Amount Units, which are accepted to cover emissions alongside NZUs.
2. Most of the NZUs held by participants are held by foresters to cover future liabilities at harvest.
3. The NZUs surrendered indicate the volume of emissions in the sectors covered by the ETS.

4. NZUs allocated mainly consist of free allocations to EITE firms in line with specified eligibility criteria.

As well as transacting directly with the NZ emissions registry, participants can trade in the secondary market for NZUs. In this secondary market, trading can take place bilaterally through private arrangements or through platforms provided by intermediaries such as Westpac Bank, Carbon Match, and CommTrade (OM Financial Limited).

The NZU secondary market is small relative to the share market or foreign exchange market. It is not highly liquid but is reasonably well developed and stable. The spread between buy and sell spot rates is one measure of market efficiency and is typically less than 1%. One platform has a standard commission rate of 5 cents a unit for each buyer and seller, or around 0.4% in total for a transaction involving units priced at \$25. Participants can bank NZUs (ie, hold them for use in a later period) and buy and sell forward, as well as deal in options. The ability to bank or borrow units helps to stabilise short-term fluctuations and provide greater price certainty for participants. Market aggregators exist and can help participants who trade in relatively small quantities of NZUs.

The market is only lightly regulated. NZUs are not classified as financial products and so are not subject to financial-product regulation. But participants must be registered on the NZ Emissions Trading Register and transactions must comply with Anti-Money Laundering regulations. All movements on the Register are public information.

Institutional architecture for a reformed NZU market

Markets are sophisticated institutions for setting the terms for, and implementing, exchanges of goods and services, usually for money. Markets come in many shapes and sizes. Many are privately run, and buyers and sellers are private agents. Even so, parliament and the courts are important parties because they set and interpret the legal framework and rules for trading and settling disputes. In some instances, the government itself is an active buyer/seller in a market. Examples are the government bond market for borrowing money to fund public investments (and sometimes to fund operating deficits), and the market for money itself (NZ dollars). In each case, the government has delegated authority to agents (respectively the New Zealand Debt Management Office and the Reserve Bank of New Zealand) to act in the market efficiently and effectively. The government gives the agents clear mandates and significant independence to do so.

The government is also very much involved in the NZU market. Indeed, in a purely domestic ETS, the government is the sole initial supplier of NZUs and makes crucial decisions about the quantity it will sell in any given period. In later chapters (Chapters 8, 17) the Commission recommends that the government sets “emissions budgets” for defined multi-year periods – well in advance – and these budgets track down over time to achieve New Zealand’s long-term target for low or zero net emissions. It will be necessary to translate the multi-year emissions budgets to concrete actions within the NZ ETS to achieve the budgets. The main mechanism will be control of the supply of emissions permits (ie, NZUs) into the NZU market.

Careful design of the governance of the NZU market is crucial to ensure this translation works efficiently and effectively. This will be a complex task, just as developing the roles and responsibilities of the New Zealand Debt Management Office and the Reserve Bank of New Zealand, and the features of their respective markets, were complex pieces of institutional design. Fortunately, the existing NZU market and its institutional features (such as laws, regulations, the registry and trading platforms) are sound and can be built on. The Commission makes the following outline proposal for additional features.

- The Government decides multi-year emissions budgets well in advance and after taking advice from an independent climate change commission (Chapter 8).
- The Government also decides the extent, if any, to which New Zealand may use, in each budget period, purchases of foreign GHG reductions to count towards emissions targets where this use is specified either as:

- a maximum proportion of the units that emitters must surrender that can be foreign units;
 - a maximum number of foreign units that the Government may use to help meet New Zealand's responsibility targets; or
 - an NZU price that triggers an ability for either the Government or emitters to purchase foreign units.
- The Government decides the permitted use of foreign units at least five years ahead on a rolling basis.
 - A new agency is set up to act on the Government's behalf in the NZU market. Its mandate and responsibility are an effective and efficient market that controls the supply of units consistent with achieving the Government's emissions budgets over the medium to long term. The agency will have independence to set yearly ETS quantity caps, run auctions, and make interventions that it judges are necessary for an orderly and efficient NZU market. The new agency must make its decisions transparently and with as much advance public notice as is practical and efficient. For example, it could decide to announce ETS quantity caps 5 years in advance on a rolling basis – in line with the July 2017 in-principle reforms and the recommendations that emerged from the Motu dialogue.

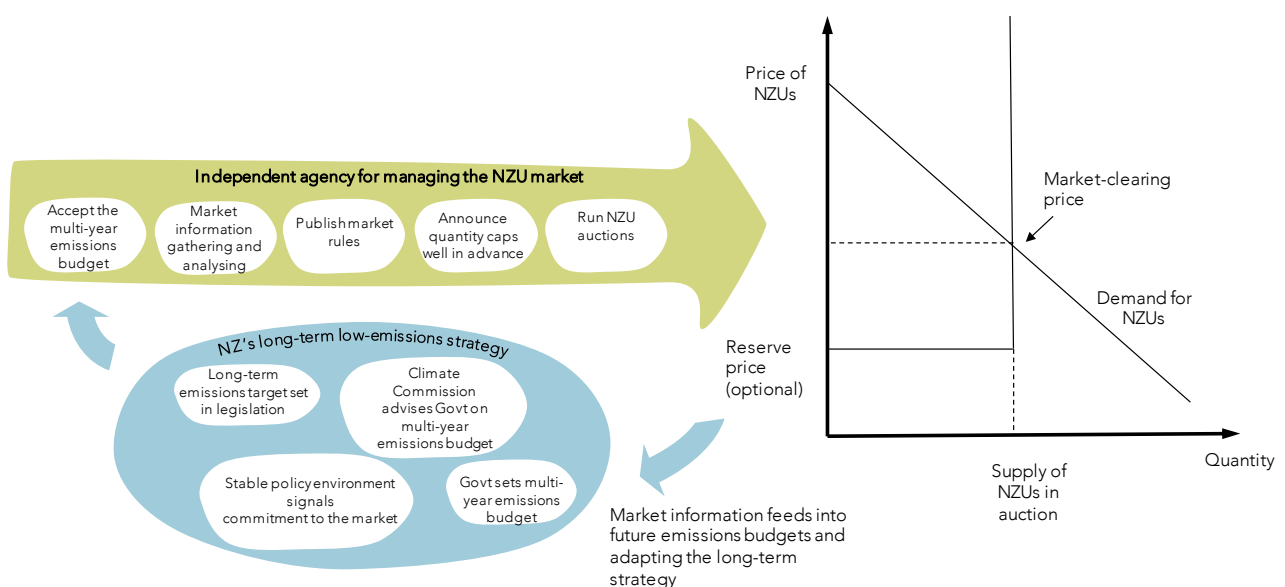
The key features of this proposal are:

- the alignment of the NZ ETS with New Zealand's long-term, low-emissions strategy and targets, including key government decisions such as the balance between domestic and foreign abatement; and
- the independence of the market agency to devolve key operational decisions away from political pressures, yet retain democratic control and accountability for the overarching strategy.

Figure 5-5 illustrates the features of this proposal.

While the current NZU market operates satisfactorily, it needs reform to make possible more deliberate government control over unit supply of NZUs. This is a fundamental change that is crucial to achieving New Zealand's low-emissions targets. In the Commission's view, the reformed institutional architecture should include an independent market steward and operator as described above and, in more detail, below.

Figure 5-5 An independent agency to oversee the NZU market and auction NZUs



R5.4

The government should undertake a well-crafted reform to fix the weaknesses in the New Zealand Emissions Trading Scheme that compromise its ability to deliver effective emissions pricing and New Zealand's emissions targets for 2021 to 2030 and beyond. The reform should establish:

- control over the supply of New Zealand Units (NZUs) that is consistent with New Zealand's long-term, low-emissions strategy;
- clarity over the use of international units for reducing greenhouse gases; and
- a new independent agency to sell NZUs and exercise stewardship of the NZU market. The agency should operate within a clear government mandate and be responsible for market stability, transparency and forward guidance to support efficient decision making by investors to lower their net emissions.

How should the authorities determine the quantities of NZUs to auction?

Under the institutional arrangements that the Commission recommends (as described above), the independent agency for overseeing the NZU market must determine the quantities of NZUs to put into the market in any period for auction. This is an important, yet potentially complex and challenging, task. The agency will need to consider:

- the overall emissions budget set by the government which it is charged to stay within;
- the impact on the market price of NZUs when it announces its quantity caps and its auction programme;
- the possibility of New Zealand achieving faster and greater emissions reductions if that were feasible at a low cost; and
- the need to maintain incentives for long-term investments and innovation in low emissions.

Figure 5-6 uses supply and demand diagrams to illustrate these considerations. The focus is on the quantities of NZUs that are auctioned, keeping in mind that these quantities are key to controlling New Zealand's total GHG emissions in given periods.

The overall emissions budget: the market agency's challenge is to run a series of auctions over the years of the budget (plus previous and later years) to keep emissions within the budget. The agency will have discretion over the timing of auctions and how much to put in the market in each auction. In setting auction quantities to influence overall emissions, it will need to consider within the given period (say a year):

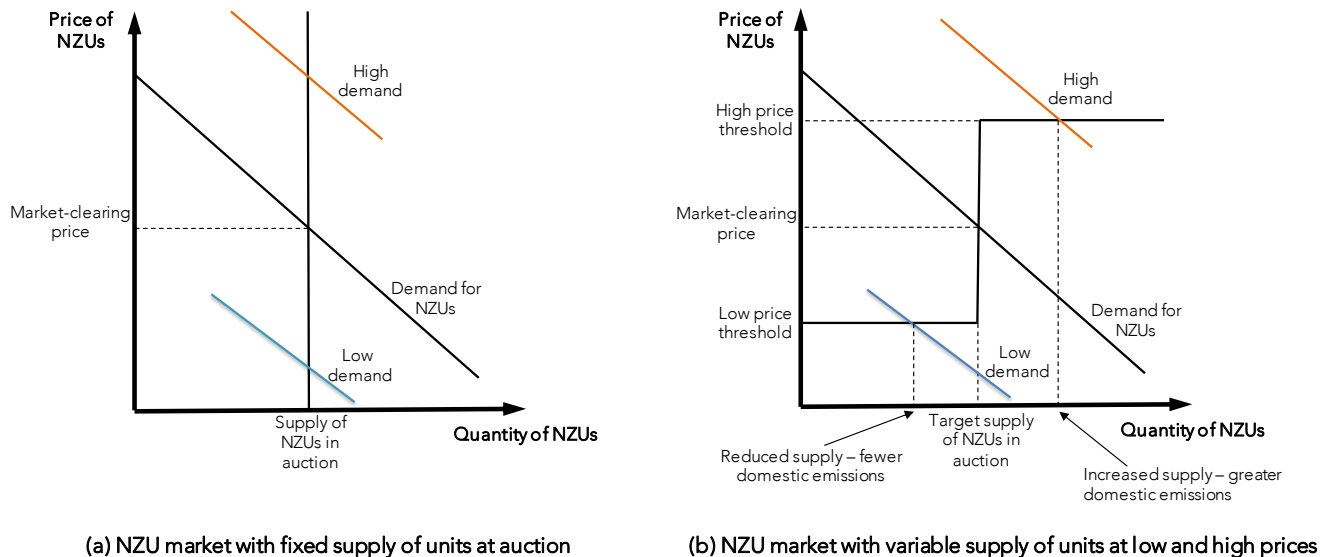
- the NZUs awarded to EITE firms under the free-allocation rules,
- how many freely allocated NZUs will be used in the period by the recipients, or others that buy them from recipients;
- how many previously banked units will be used in the period;
- the net units awarded to foresters and how many of them will be sold to and used by others in the period; and
- the units that will be purchased at auction that will be banked and held for future use.

Only after considering all the above will the agency be able to make a judgement about the quantity of units it should auction to meet a target for net emissions in the period. This quantity is shown in diagram (a) in Figure 5-6 as the "Supply of NZUs in auction".

Impact on the market price of NZUs: supply and demand diagram (a) shows how the demand for NZUs will determine the price when the quantity of units auctioned is fixed at this level. A market-clearing price is shown arising from expected demand. But if demand is unexpectedly high, a high price is needed to ration

demand to the quantity of units on auction. With unexpectedly low demand the market-clearing price must drop to a low level to stimulate enough demand to take all the units on offer in the auction. Because demand is uncertain, if the agency has a preferred range of price variation, it will face a tension between fixing the quantity to meet the overall emissions budget and fixing it at a higher or lower level to head off the risk of prices that lie outside its preferred and expected range. This corresponds to the choice of whether to set the vertical supply curve in diagram (a) further to the right or left.

Figure 5-6 Supply and demand for NZUs with fixed and variable supply



However, diagram (b) depicts another approach to deal with the risk of prices that turn out to be outside the agency's expected range at the time it sets the quantity of units for auction. Threshold prices at which the agency changes its supply of units to lean against prices going outside the range may be in place. For example, at the "high price threshold", the agency would supply additional units to the market.⁶¹ A benefit of this would be to relieve potential domestic political dissatisfaction with the NZ ETS because the additional supply of units stops the price from rising above the threshold. The threshold price would be known to the market in advance.

Achieving faster and greater emissions reductions: if, for example, a major recession were to strike, or the uptake of electric vehicles (EVs) were much faster than expected, then New Zealand's emissions and the demand for NZUs could drop quite dramatically as illustrated by the "Low demand" curves in Figure 5-6. In diagram (a) the market would respond with a sufficiently low price for all NZUs in the auction to still sell. The alternative approach is illustrated in diagram (b). The price is maintained at a "Low price threshold" so that a *quantity* adjustment occurs instead of a *price* adjustment. The quantity of NZUs sold at auction would reduce (as indicated in the diagram). As a result, present or future emissions are lower. In a real sense, lower emissions are not a bad thing. New Zealand's targets are upper bounds that it needs to stay within, not hit exactly. If emissions can be kept below the bound, at low abatement costs, this will benefit the planet.

Maintaining incentives for long-term investment and innovation: another reason exists to keep the price from falling below a low threshold. Large falls in demand for NZUs could happen for a range of reasons (a severe recession and rapid advances in a new technology are just two examples) and persist for several years. But the overall goal is long-term – to decarbonise the economy over at least three decades. It is important to keep on course for that long-term goal by maintaining incentives for long-term investments in low emissions (including forestry planting) and for investing in innovation. A very low emissions price will undermine these incentives. Further, it could directly cause long-term investment decisions in old technology that lock in high emissions for many years to come.

⁶¹ Supplying more units will permit New Zealand to have greater domestic emissions. For this to be consistent with a given target, the authorities could either supply fewer units in the future or, if international rules allow, make up the difference by purchasing emissions reductions offshore.

NZ ETS responsibilities should be shared between the government and the market agency

Overall then, decisions about quantities of NZUs to auction in the market are complex and nuanced. In the default model of a “pure ETS” shown in Figure 5-6 (a), the key decision is to choose the quantity to auction and then the market determines the price, whatever that needs to be, to ensure the demand for NZUs equals that supply.

Yet good reasons appear to exist sometimes to depart from the “pure ETS” model and use a model that works more in line with diagram (b). Which model to use and when will need to be worked out between the government and the market agency. In its *Regulatory institutions and practices: Final report* (NZPC (2014b)), the Commission developed criteria for allocating decision powers between the government and an independent regulator. Table 5.3 lists the criteria that appear to be relevant for the NZU market. The types of decisions in the left column are best suited to the independent market agency, while those in the right column are best suited to the government.

The government is best suited to make decisions about emissions budgets, use of foreign units, and the levels of the high and low threshold prices because these are important decisions about strategy and they may have significant fiscal implications. The government therefore requires a clear political mandate. The decisions could change over time in response to new data that emerges. The government will likely take advice both from the market agency and experts from the proposed Climate Change Commission before making these decisions.

Table 5.3 Features indicating a need for less or more regulatory independence

Features pointing to greater regulatory independence	Features pointing to less regulatory independence
Decisions where the costs are long term and likely to be under-valued due to a focus on electoral cycles	Decisions involving clear value judgements (which are appropriately made by elected representatives)
Decisions requiring a substantial degree of technical expertise, or expert judgement of complex analysis	Decisions with significant fiscal implications, or which are integral to a government’s economic strategy
Decisions where the causal relationship between the policy instrument and the desired outcome is complex and uncertain	Decisions involving the significant exercise of coercive State power (for example, revenue gathering)
Regimes where a consistent approach over a long period of time is needed to create a stable environment	Flexibility is needed to take account of political imperatives
Where public confidence that the regulator is impartial is important	

Source: NZPC (2014b, p. 218).

Once the government has made its decisions, it will be up to the independent market agency to determine the best way to give effect to them. A key responsibility of the agency will be to auction quantities of NZUs over time to hit the Government’s multi-year emissions budgets. The agency will also be judged on its success in contributing to market confidence, liquidity and stability.

ETS schemes in other countries or regions, such as the United Kingdom (as part of the EU ETS), California, South Korea, and the north-eastern United States (with its Regional Greenhouse Gas Initiative), use various devices to adjust quantities or to act on prices directly when specified high or low prices are reached (Goulder & Schein, 2013; PMR & ICAP, 2016). The NZ ETS has operated with a price limit of \$25 per NZU since 2009 (although the limit has never been reached). If the market price reached this limit, the government would allow emitters to settle for \$25 a tonne of CO₂e emissions rather than surrender NZUs.

In making their decisions, the government and the market agency will understand that markets themselves can provide participants with various forms of protection against price volatility. For example, a New Zealand

exporter can purchase a hedge contract that would guarantee them a known amount of New Zealand dollars in payment for a US sale that will be paid for in US dollars in nine months' time. Box 5.5 describes some ways in which the market in NZUs can offer greater certainty to participants who need to buy or sell NZUs in the future when the spot price could be very different from today. A healthy secondary market and the ability to bank and borrow NZUs help reduce price volatility because trading smooths prices, and market makers and intermediaries will provide forward and derivative products.

Yet low or high prices that persist for long periods may not be easy to hedge using private market instruments. Derivative instruments are typically expensive and unlikely to be available for more than a year ahead. Similarly, large-scale banking of units, or forward purchasing may not be enough to buffer a large and persistent unanticipated rise in price. Conversely, the presence of large quantities of banked units in an ETS, purchased when prices were cheap, can create an overhang and depress prices for many years.

Use of foreign emissions reductions

The government may decide to use a certain quantity of foreign emissions reductions to help meet New Zealand's emissions-reduction targets. This will impact the quantity caps on domestic emissions that the market agency will need to apply – consistent with the overall emissions-reduction target. For every foreign unit allowed as an offset to a New Zealand emission, domestic emissions can rise by one tonne of CO₂e without affecting New Zealand's total net emissions for which it is responsible internationally. One way that the Government could specify when the use of foreign units would be permitted is by stipulating that they may be used only when the cost of domestic emissions reductions rises above a threshold.

Use of foreign emissions reductions in this way could have the benefit of enabling New Zealand to achieve its emissions responsibility targets under the Paris Agreement at lower economic cost. One way it could achieve this would be for New Zealand to pay for emissions reductions in other countries that are on top of their responsibility targets, but where the reductions are less costly to achieve than they would be in New Zealand.

Arguments exist then both for and against interventions that try to some degree to “manage the price” of emissions units. On the one hand, intervention in the NZU market may create distortions, have unintended consequences and interfere with its self-regulating responsiveness. Uncertainty about when and how intervention will happen could exacerbate rather than alleviate price volatility. On the other hand, some good reasons exist for the authorities, in pursuit of a long-term decarbonisation of New Zealand, to adjust the quantities of NZUs that they put into the market at certain low or high threshold prices. These adjustments are found in ETSs in other jurisdictions.

F5.14

Arguments exist both for and against interventions that try to influence the price of emissions units from exceeding certain high or low thresholds. On the one hand, interventions may create distortions, have unintended consequences and interfere with the market's self-regulating responsiveness. Uncertainty about when and how interventions will happen could exacerbate rather than alleviate large price swings. On the other hand, by adjusting quantities of New Zealand Units that they put into the market when high or low price thresholds are reached, the authorities may achieve benefits such as:

- the use of qualifying international emissions reductions when those are significantly less costly than further reductions in New Zealand; and
- achieving greater reductions in emissions domestically at low cost, while maintaining a minimum incentive for long-term investments and innovations in low-emissions.

In summary, responsibility for the NZU market to maintain its effectiveness and orderliness should lie with the government and the new ETS market agency. The government is best placed to decide emissions budgets, when international purchases of emissions reductions are justified, and at what low or high price, if any, it would be desirable to maintain the price of NZUs by reducing or increasing the quantity of NZUs

supplied relative to the cap. Over time, the agency will develop deep knowledge about the NZU market and will be in the best position to make judgements about how best to implement these government decisions and regulate the market more generally. The market agency's "constitution" should constrain it to act transparently via public notification of its rules and logic, and any changes in them, well in advance (for example, several years).

R5.5

The Government should be responsible for specifying the New Zealand Unit (NZU) price threshold at which it considers the cost of further domestic emissions reductions would cause net detriment to New Zealand and that other means to achieve its emissions budget (eg, purchasing qualifying international emissions reductions) could be less costly. The Government should also decide at what low price, if any, it would be desirable for the quantity of NZUs supplied to be reduced below the cap and for the price of NZUs to be maintained as a minimum incentive for long-term investments and innovations in low emissions.

The new independent agency set up to auction NZUs and oversee the NZU market should have responsibility for implementing the Government's decisions cost-effectively and for the market's overall stability and efficiency. This will include setting the quantity caps for NZUs to meet the multi-year emissions budgets, and conducting auctions. The agency's "constitution" should require it to act transparently via public notification of its rules and logic, and any changes in them, well in advance.

5.8 Emissions prices to transform to a low-emissions economy

This section indicates the sort of levels of emissions prices likely to be needed to drive the quantity of emissions reductions to achieve the Paris Agreement target of keeping the rise in global temperatures to well below 2°C above pre-Industrial Revolution levels. Because of the many uncertainties about such things as future technology, demand responses, fossil-fuel prices, and climate sensitivity, it is possible to give only a very broad indication of these price levels. The indications are by no means predictions or forecasts.

Some form of emissions pricing currently exists in more than 42 countries or regions of the world. Of the schemes implemented or scheduled as of 2017, half consist of an ETS and half consist of a carbon tax, with the former covering two-thirds of priced emissions. Yet in 2017 these pricing schemes covered only around 15% of global emissions; of these, three quarters were covered by a carbon price of below US\$10 a tonne of CO₂e (Leining, 2017; Stiglitz & Stern, 2017). For certain, current coverage and levels of emissions prices are insufficient to induce emissions reductions consistent with the temperature objective of the Paris Agreement. Future prices will need to be much higher.

Evidence that indicates the level of future prices

Three lines of evidence provide indications of the emissions prices needed to achieve changes that would deliver the Paris Agreement objectives: technology roadmaps, national modelling exercises, and global energy-economy models (called Integrated Assessment Models or IAMs) (Stiglitz & Stern, 2017).

Technology roadmaps

Technology roadmaps seek to identify the carbon price points at which it becomes economic for businesses to invest in new low-emissions technologies in specific sectors or industries (eg, power generation or industrial heat). These prices are called "switching prices". Not surprisingly, they are often uncertain and can vary significantly across countries according to local conditions, and over time when technological change is rapid. Further, a higher switching price is needed to displace existing carbon-intensive assets where capital is sunk, compared to where the two competing choices are both new.

Illustrating these aspects, the International Energy Agency (IEA)'s publication *Energy, Climate Change and Environment: 2016 Insights* (IEA, 2016a) gave indicative switching prices for investment in onshore wind generation of electricity in competition with coal-fired generation (Table 5.4).

Table 5.4 Switching prices for onshore wind in three countries, US\$/tonne CO₂e

	New onshore wind versus existing coal generation	New onshore wind versus new coal generation
United States	10	0
Germany	80	60
China	30	20

Source: IEA (2016a).

Notes:

1. Germany has less favourable wind conditions than China and the United States.
2. The analysis uses 2015 information on fossil-fuel prices and the cost of renewable energy. It is intended to illustrate the policy implications of varying circumstances rather than provide up-to-date information on the cost of switching to a different energy-generation technology.

Another important influence on switching prices is the cost of capital, especially when this cost is higher or lower than for the baseline case of the existing mature technology. In a background note for the High-Level Commission on Carbon Prices, Finon (2017) estimated switching prices for two low-emissions technologies for electricity generation (coal with carbon capture and storage (CCS) and nuclear) to replace two fossil-fuel alternatives (combined-cycle gas turbine (CCGT) and conventional coal) for three capital-cost scenarios for the low-carbon options:

- an 8% "baseline" capital cost, equal to the capital cost for the fossil-fuel generation;
- 12.5%, reflecting risk aversion towards the low-carbon technology; and
- 5%, incorporating a government guarantee on loans for the low-carbon technology.

Assuming each of these capital costs, the switching prices for coal with CCS relative to conventional coal are (in euros⁶²) 35, 54 and 20 a tonne of CO₂e respectively. To displace gas CCGT (a lower-carbon fuel than coal), the switching prices required are higher – 85, 120 and 50 euros respectively.

Stevenson et al. (2018) report likely switching prices to induce investors in electricity generation to replace New Zealand's few remaining fossil-fuelled generation plants. These plants (coal and gas at Huntly and gas CCGT in Taranaki) have a high value because of their ability to supply during dry years, and for seasonal or short-term imbalances between demand and renewably generated supply (Chapter 13). Huntly coal could be retired at an emissions price of around NZ \$40 a tonne of CO₂e and the Taranaki gas CCGT at a price of around \$60 a tonne of CO₂e.

New Zealand also currently relies on open-cycle gas turbines for generation capacity to handle peak demands. Retiring these turbines, while maintaining energy security, would entail investing in greater storage. This would be more expensive and require higher emissions prices to be economic. Two examples, based on current costs and technology, are around \$150 a tonne of CO₂e for producing and storing hydrogen as a reserve feedstock, and \$170-\$280 a tonne of CO₂e to supply and operate a reserve biomass gas plant⁶³ (Stevenson et al., 2018).

Future emissions prices: what does modelling tell us?

Chapter 3 describes the modelling undertaken for this inquiry by the Concept-Motu-Vivid (CMV) consortium. Modelling exercises at a national scale can provide insights on prices needed for an economy to

⁶² A New Zealand dollar is worth approximately 60 euro cents, so the switching prices in NZ dollars are approximately 58, 90 and 33 for coal with CCS to replace conventional coal, and 142, 200 and 83 for coal with CCS to replace gas CCGT.

⁶³ Renewable energy technologies are developing fast, with unit costs falling as new technologies come on stream and are scaled up. So it is likely that switching prices for these or alternative technologies will be lower in the future.

decarbonise and transition to low emissions. Those exercises can deal with some of the limitations of technology roadmaps (for instance, by considering interactions between sectors).

The CMV modelling suggests that emissions prices will need to rise several times above the current level of \$24 a tonne of CO₂e if New Zealand is to reach targets for low emissions by 2050. To reach a target of 25 megatonnes of CO₂e by 2050 (around 60% below 1990 levels) will likely require emissions prices to rise to between \$75 and \$152 a tonne by 2050, according to the modelling. The lower price occurs along a pathway in which emissions-reducing technologies develop more rapidly.

The more ambitious target of reaching net zero emissions by 2050 will require significantly higher prices. According to the modelling, prices may need to rise, even with rapid technology change, to \$157 a tonne of CO₂e by 2050. Without slower technology change, prices may need to rise up to \$250 a tonne by 2050. Even so, all but one of these emissions prices are in the range of estimates of what will be required in other developed countries to meet the Paris Agreement to keep temperature rise to below 2°C.

In earlier work on New Zealand low-emissions scenarios for Globe NZ, Vivid Economics (2017b) grouped options for change in the economy into three categories: those induced at low, medium and high emissions prices where:

- low was under NZ\$50 a tonne of CO₂e;
- medium ranged between \$50 and \$100 a tonne of CO₂e; and
- high was above \$100 a tonne of CO₂e.

Options that would be cost-effective at a low (or even zero) emissions price include afforestation, many forms of improved energy efficiency, and, increasingly as their price falls, EVs. Economic options in the medium-cost range are likely to include electric heating for mid-level industrial heat and EVs for freight. Technology options in the high-cost range include CCS and the electrification of high-temperature heat.

IAMs produce global scenarios of future socio-economic and technical development that are consistent with global temperature targets such as below 2°C in the Paris Agreement. Differing model assumptions and structural features produce a wide range of results as indicated in the following quote from Stiglitz and Stern (2017):

While there is a consensus across models on the technical changes that are needed to maintain climate change below 2°C, models fail to agree on the carbon price required to trigger those changes. Based on the assessment provided in IPCC (2014c) [the IPCC's report *Mitigation of Climate Change* (2014)], scenarios that limit warming to below 2°C with a greater than 66 percent probability imply carbon prices increasing throughout the 21st century, but with prices ranging from US\$15 to US\$360 (in 2005 United States dollars) per tCO₂e in 2030, and from US\$45 to US\$1,000 (in 2005 United States dollars) per tCO₂e in 2050. (p. 32)

Some causes of the variation in emissions prices make intuitive sense and are worth noting. In general, emissions prices required to meet the 2°C target are lower:

- *in baseline scenarios with faster per capita economic growth, more expensive fossil fuels, or preferences for low-energy consumption patterns* (eg, regarding diets);
- *the higher the credibility of signals about future emissions prices*. In models where emissions reductions in the short term are based only on knowledge of current prices and costs, higher prices are required over the short term. Near-term emissions prices therefore must be assessed in the context of the credibility of signals about long-term prices;
- *the better the potential for low-carbon technologies*. The availability, costs and penetration of new technologies are difficult to model or forecast because they are driven by many factors such as innovation and learning, and institutional and financial constraints (Acemoglu et al., 2012); and

- *the higher the ability to re-allocate resources across the economy.* IAMs vary in their constraints on technology penetration, on whether they allow installed capital to be scrapped early, or in their limits on the re-allocation of workers across sectors (Stiglitz & Stern, 2017).

F5.15

Substantial modelling and other evidence indicate that emissions prices will need to rise far above their current levels if New Zealand is to decarbonise its economy over the next several decades. Even so, it is notable that emissions prices required to achieve a given emissions-reduction target will generally be lower:

- the better the potential for deploying innovative technologies to reduce emissions;
- the higher the credibility of signals about future emissions prices; and
- the greater the flexibility in the economy to re-allocate resources from high- to low-emitting activities and sectors.

5.9 Complementary measures to emissions pricing

A key message of this report is that an effective system of emissions pricing should be at the centre of a strategy to reduce emissions. But the strategy needs other elements to back up pricing and even take the lead in situations where pricing is not powerful enough because of market or government failures, or distributional considerations. An effective package of complementary measures can also lower the emissions price that would otherwise be needed. This section briefly examines these other measures and situations, and indicates where later chapters in this draft report deal with them in greater depth.

Institutions and laws

Markets invariably sit and operate within an institutional infrastructure and work well, or not so well, according to the quality of that infrastructure. In the case of the NZ ETS, the basic transaction unit is the NZU – the legal right to emit one tonne of CO₂e. To make the market work, a register for ownership and its transfer, and a means of linking physical emissions to the surrender of units (or the physical removal of tonnes of CO₂e from the atmosphere with the earning of units) are needed. Fortunately, the NZ ETS already has these basic underpinnings in place.

Strong and sound legal and institutional foundations that enshrine a clear, long-term, emissions-reduction goal are needed to provide credibility and confidence to businesses and households about the direction of policy and emissions prices. Agreed and understood arrangements are needed for choosing and implementing the size of emissions budgets, free allocations of units, auctioning, price thresholds, guidance on future prices and quantity caps, and possibilities for international trading in emissions reductions. Chapter 8 examines institutions and laws and proposes an independent expert body – a Climate Change Commission – that would make recommendations on climate policy to the government of the day, based on best evidence.

Infrastructure and planning

Land-use plans, transport infrastructure and city design have a significant influence on how people live and work, and therefore on emissions. Decisions in these areas are not purely market based – and there are spatial and network externalities to consider. It is important that large, long-lived, city-shaping investments fully internalise the social costs of emissions (Chapter 16). To align decisions about investment in infrastructure with a low-emissions future will require business cases and project appraisals to use appropriate emissions prices over the expected lifetimes of investment options.

Other infrastructure areas for attention are supporting infrastructure for electrified transportation (Chapter 12) and a low-emissions electricity system (Chapter 13).

Performance standards and direct regulation

In some situations, price signals are known to be relatively ineffective in changing behaviour. Evidence of this is the existence of investments that would lower emissions and deliver attractive returns (even in the absence of an emissions price), yet nothing is invested. For instance, landlords may fail to invest in better insulation for their rental properties because tenants pay the energy bills for heating, and landlords perceive they would not recoup the cost through higher rents. Also, most tenants are unwilling to invest owing to a lack of long-term, secure tenure.

In these situations, minimum standards may be a more effective solution. Another example is a car owner who has weak incentives from the emissions-price component of fuel prices to demand a car with high fuel efficiency. A solution may be to set fuel-efficiency standards. New Zealand is one of a small number of developed countries without such standards (Barton & Schütte, 2015) (Chapter 12).

Innovation and dissemination

While emissions pricing encourages emitters to seek out new technologies that reduce their emissions, investing in innovation remains subject to another sort of market failure – insufficient reward for new knowledge that spills over and benefits others. Support for innovation should operate alongside emissions pricing. Chapter 6 examines policies to support innovations that mitigate or remove GHGs, and their demonstration, dissemination and deployment. An important result to note, as mentioned above, is that the greater the potential for, and actual use of, innovative technologies that reduce emissions cost-effectively, the lower the emissions prices that will be needed to reach a given emissions target.

Distributional impacts

Applying an emissions price at moderate or high levels across the economy could have significant adverse impacts on some businesses and households. Gradually bringing in increases in emission prices, and signalling those increases well in advance, will provide most of those affected with time to adjust. And, as noted, the free allocation of NZUs is a way to combine emissions pricing with transitional protection for New Zealand's EITE firms.

Broadly speaking, it is vital for emissions pricing to remain credible, sustainable and the centrepiece of a low-emissions strategy. To achieve this, emissions pricing must be based on sound market institutions and remain socially and politically acceptable. Attending to the distributional impacts of emissions pricing is also necessary to achieving this outcome. Chapter 10 covers distributional issues and policies.

The importance of policy coherence

Policies other than emissions pricing that influence emitters of GHGs should mutually reinforce emissions pricing. But some policies can be counterproductive or duplicative. In the mutually reinforcing category are policies that remove non-price barriers to behaviour change, such as providing information or access to finance. Two examples in the counterproductive category are hidden or explicit subsidies to fossil-fuel exploration and use, and regulations that dictate very high-cost ways to reduce emissions.

Any area that has co-benefits from reducing GHGs calls for policy coherence. For example, the electrification of transport will reduce emissions and improve air quality – with benefits to human health. Reducing stocking rates on dairy farms or planting trees will reduce emissions and improve water quality in streams, rivers and lakes. In theory, emitters could be rewarded for both benefits through two separate pricing schemes. In practice, the additional benefit of cleaner air or water is more likely to be encouraged through regulation, a grant scheme or the use of a positive shadow price in public CBA.

Complementing emissions pricing with other, well-designed policies, then, is both theoretically sound and needed in practice (Stern, 2015; Stiglitz, 2013).

F5.16

An effective system of emissions pricing should form the centrepiece of a strategy to reduce emissions. Yet the strategy needs other elements to back up pricing and take the lead in some situations where pricing is not powerful enough because of market or government failures, or distributional considerations.

5.10 Conclusion

Emissions pricing should be a central policy lever to incentivise businesses and individuals to lower their GHG emissions. It is a powerful lever because it sets a single emissions price across the whole economy and provides a strong incentive to reduce emissions at least cost. Emissions pricing also decentralises decisions to invest, innovate and consume across the economy to people who have the best information about opportunities to lower emissions given their circumstances.

The two main forms of emissions pricing – an emissions tax and an ETS – have much in common. The choice between them is less important than the need to give a strong signal that the emissions target is real, and the Government is committed to achieving it. The chosen scheme needs to be credible and stable over time through being well-designed, well-implemented and founded on broad cross-party and social support.

However, a carbon tax and an ETS also have differences that raise the issues of:

- whether it is better to have certainty in the price or the quantity of emissions;
- the ease of trading internationally; and
- the scope for participants to handle risk.

An ETS is better at achieving certainty in the quantity of emissions reductions, and allowing trading between emitters and removers of GHGs. As New Zealand already has an ETS that is functional and well-understood by participants, it should keep the NZ ETS and not replace it with an emissions tax. But the NZ ETS needs to be reformed to improve control over unit supply (ie, effective caps on emissions) and have an institutional architecture to underpin a credible and efficient market in emissions units. The reforms should also improve forward transparency and policy stability to incentivise long-term investments in lower emissions.

New Zealand's emissions prices have been too low to incentivise meaningful reductions in emissions. All evidence points to the prospect that emissions prices may need to rise to at least \$75 a tonne, and possibly, if new emissions-reducing technologies are slow to emerge, to more than \$200 a tonne, over the next three decades. Prices at these sorts of levels will flow naturally from the government setting effective emissions budgets which then translate to emissions caps that control the supply of NZUs into the market.

An overall strategy to reduce emissions needs to be a coherent package. It would have an effective system of emissions pricing at its centre and other policies to complement pricing. These other policies would take the lead in situations where pricing is not powerful enough because of market or government failures, or distributional considerations.

6 Innovation

Key points

- Innovation can and should play a central role in New Zealand's transition to a low-emissions economy. It is the closest thing to a "silver bullet" to enable humanity to meet the challenge of avoiding damaging climate change.
- Innovation also holds out the opportunity to combine the transition to low emissions with dynamic and creative improvements in the economy and national wellbeing.
- While the form, timing and impact of innovation are highly uncertain, a country's policies and institutions significantly affect its innovation performance. They need to enable and encourage researchers and business organisations to both create new low-emissions technologies and deploy existing low-emissions technologies.
- The processes of innovation and economic change are strongly path-dependent. This can make it difficult to shift an economy from polluting to clean technologies. Delay in making the transition can increase the productivity gap between the polluting and clean technologies and make the transition longer and costlier in terms of slower growth during the transition.
- A strategy to support low-emissions innovation needs to combine an effective emissions price with direct support for research, deployment and adoption of low-emissions innovations. Stronger emissions pricing will incentivise more innovation in clean technologies. But relying on pricing and direct regulation alone – without subsidising innovation – would be sub-optimal.
- New Zealand's record as an innovative economy is mixed. Lacklustre productivity growth in the economy partly reflects low investment in research and development as well as other issues in its innovation ecosystem, including a patchy record at commercialising research and skill shortages. Yet within this broad picture, pockets of successful innovation exist.
- Transitioning to a low-emissions economy calls for directed technical change in New Zealand's energy and transport systems, land use, buildings and industrial processes. In many areas New Zealand will be a technology taker. This requires capacities and resourcing to identify, absorb, adapt and deploy technologies from offshore. Yet in certain areas, New Zealand should invest in the full menu of basic and applied research, commercialisation, infrastructure and skills.
- In New Zealand's transition to low-emissions economy, innovation should have priority alongside emissions pricing, targets and budgets, and the laws and institutions supporting them. Given the imperative to reduce emissions, the Government should devote significantly more resources to low-emissions innovation than the modest and inadequate current allocation.
- Well-designed and implemented support for low-emissions innovation is likely to have payoffs for New Zealand's wider economic performance and its international reputation. Another payoff is making a material contribution to combatting dangerous climate change at a global level.
- The right climate policies are likely to trigger new waves of global investment, innovation, and discovery. If a country designs its policies to foster learning and flexibility, then new opportunities will arise. The transition to low emissions may represent a very attractive path that could, if economic history is a guide, stimulate dynamic, innovative and creative growth.

Interestingly once innovation is taken seriously ...a whole new set of policy conclusions emerge, most of which are related to ...knowledge spillovers and complementarities. (Aghion et al., 2014, p. 5)

Innovation can and should play a central role in New Zealand's transition to a low-emissions economy. New technologies can enable production of existing products with reduced emissions (eg, a vaccine that reduces methane emissions from dairy cows), or can spawn new low-emissions industries that disrupt and replace emission-intensive industries (eg, synthetic meat replacing animal farming). While innovation comes in many forms and is unpredictable, it is the closest thing to a "silver bullet" that will enable humanity to meet the challenge of avoiding damaging climate change.

This chapter will:

- indicate the power of existing and future innovations to reduce greenhouse gas (GHG) emissions;
- explain the modern understanding of the sources of innovation and its uptake in an economy in terms of path dependence and the concept of an "innovation system";
- show that, in the face of New Zealand's challenge to transition to a low-emissions economy, supporting innovation in clean technologies has a key role to play in addition to emissions pricing;
- note the evidence that New Zealand's poor productivity performance relates to weaknesses in its innovation system, and argue for using the imperative to transition to low emissions as an opportunity to boost innovation and achieve better economic performance and higher incomes more generally;
- consider New Zealand's position as a small, developed country with an unusual economic structure and emissions profile (eg, high export dependence on its primary sector, predominantly a technology taker, high proportion of agricultural GHGs) and what this structure and profile imply for an optimal innovation strategy to lower emissions; and
- make findings and recommendations for how the government can best exploit the "engine of innovation" and the "technology diffusion machine" to lower New Zealand's GHG emissions.

6.1 Innovation for a low-emissions future

The transforming power of innovation

Technological and institutional innovations – arising from applied science, persistent trial and error by gifted entrepreneurs, cultural factors, and political, economic and financial reforms – have been the main driver of the remarkable economic growth and increasing living standards that many nations have experienced since the dawn of the Industrial Revolution (Mokyr, 2016). Existing innovations already make possible large reductions in emissions from many economic activities. The challenge is to turn these known low-emissions technologies into daily realities. Future innovations will also be key to the transition to a low-emissions economy. Box 6.1 describes some examples of existing and likely future innovations that can lower GHG emissions.

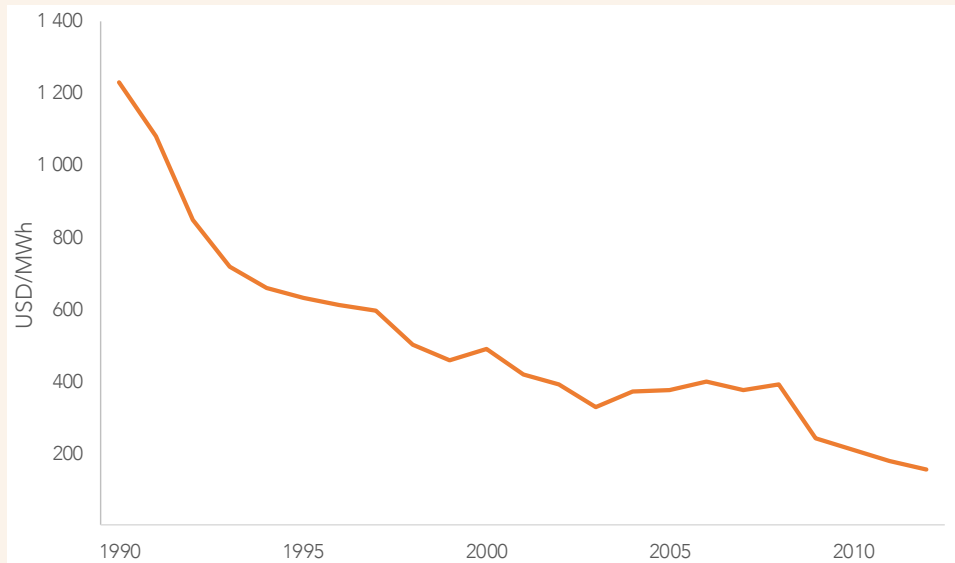
Box 6.1 Examples of the power of innovation to lower emissions

Example 1: the dramatic falls in the cost of solar and wind generation

Continuous technology improvements and scale economies have seen the cost of generating one megawatt hour (MWh) of electricity from solar photovoltaic panels drop from over US\$1 200 to around US\$150 in 2013 and the cost is still falling (Figure 6-1). Solar power is emissions free in its operation, and even over its life-cycle curtails 94% of the carbon emissions of equivalent coal-powered generation. It also eliminates the emissions of sulphur and nitrous oxides, mercury and particulates that come from burning coal – major contributors to nearly 4 million premature deaths from outdoor air pollution in 2012 (New Climate Economy, 2014, p. 14).

Solar-generated electricity can be deployed on rooftops in towns and cities, in remote locations or in giant solar farms occupying many hectares and with capacities up to one gigawatt.

Figure 6-1 Delivered price of electricity from solar photovoltaic panels, 1990–2013



Source: New Climate Economy (2014, p. 39).

New Zealand is particularly well endowed with wind energy. Ongoing cost reductions are likely to make generating electricity from wind the least expensive source of installed electricity capacity within a decade. Current costs (in US currency) in the United States in 2016 were:

- 2.9 cents per kilowatt hour for wind;
- 3.8 cents per kilowatt hour for natural gas combined-cycle plants; and
- 5.7 cents per kilowatt hour for utility-scale solar.

Example 2: innovation lowers emissions from air travel

Air travel for both passengers and freight is growing faster than any other transport mode. Upwards of 50 000 planes are expected to be flying by 2040 – up from around the 20 000 in service today. Emissions from aircraft fuel combustion constitute 2.5% of global GHG emissions.

Innovations that lower emissions from aircraft fall into the categories of incremental and radical. Incremental improvements in aircraft and engine design continue to deliver significant improvements in fuel efficiency. For example, the engine maker Pratt & Whitney improved fuel use by 16% by adding a gear to its turbofan engine design. Another engine maker, Rolls Royce, is using strong, light carbon fibre for its newest generation of lightweight engines.

More radical changes may come with hybrid and battery-powered engines. Airbus, Rolls Royce and Siemens are collaborating to develop hybrid-electric propulsion for commercial aircraft with test flights anticipated in 2020. Intermediate options include the use of biofuels. The Carbon War Room has noted sustainable aviation fuels as having “the greatest potential for achieving carbon-neutral growth in aviation”.

Behavioural innovations include flying less at low altitudes (where fuel efficiency is lowest) and not using aircraft engines to move planes on the ground (where they spend 10% to 30% of their transit time).

Source: Airbus (2017); Hawken (2017).

Given the importance of innovation to a low-emissions future, it is vital that policies and institutions are conducive to the uptake of existing innovations, and to stimulating new low-emissions innovations. The next section examines the most important ways that policies and institutions can help deliver these outcomes.

Incentives to innovate for low emissions

Positive incentives

Putting a price on GHG emissions creates incentives for businesses to innovate – to find different ways to produce the same good or service with lower emissions, or to find a substitute product that can be produced with clean technology. Every tonne of emissions avoided is worth the price of an emissions permit or not having to pay an emissions tax. The higher the price or the tax, the stronger the incentive. Entrepreneurs that come up with new and cost-effective ways to reduce emissions will make profits. Yet, with low emissions prices to date in New Zealand and elsewhere, the incentives have been quite weak.

Despite weak pricing, much innovation in areas such as wind and solar power, green supply chains and electric vehicles (EVs) has already occurred. Some entrepreneurs strive to fulfil a social need, some believe they can satisfy wants better with clean rather than polluting technology, and some see future, if not current, profits as attractive because they foresee emissions prices rising over time.

But the process of innovation is subject to its own market failure that is quite distinct from emissions causing climate damage. This failure arises because useful new ideas or inventions tend to lead to “knowledge spillovers”. These spillovers potentially benefit numerous other people and businesses who pick up the new idea or practice and copy it. The beneficiaries may include people far in the future because knowledge is cumulative – new knowledge builds on past knowledge. These beneficiaries do not have to pay for these benefits and, conversely, the knowledge creator is not rewarded for providing them. This outcome is sub-optimal. Because the marginal social benefit of an additional innovation will often exceed its marginal private benefit (to the innovator), too little innovation will happen relative to what is desirable for society.

Over a long period, societies have developed different means to tackle this market failure. These mechanisms support and incentivise innovation and knowledge creation as well as spreading the benefits of knowledge widely (Box 6.2).

Box 6.2 Institutions and policies that support knowledge creation and use

A variety of institutions and policies exist to support innovation and innovators. None is a perfect solution because of a tension between incentivising knowledge creation on the one hand and knowledge diffusion and use on the other. Typically, countries adopt a mixture: the challenge is to choose the best level of each and the balance between them.

Intellectual property rights

Intellectual property rights include patents, copyright and trademarks. They establish property rights for intellectual goods somewhat like property rights that exist for ordinary goods and services. A problem with intellectual property rights is that they give monopoly power over the use of something that requires no resources for another firm or consumer to use (because knowledge is “non-rival”⁶⁴). Given this, and the cumulative nature of knowledge, unlimited monopoly power could have very high social costs. Therefore, intellectual property rights are generally limited. For example, patents are time limited, require the applicant to publicly disclose the nature of the invention, and allow others to use the knowledge to conduct further research.

Subsidising open science

Open science involves communities of scholars with commitment to high standards of research judged largely by peers. This requires laying out research results in a very open way. The incentive for individual scientists is mostly the recognition for being the first to make a discovery, rather than any

⁶⁴ A good or service is “non-rival” if providing it to one person effectively provides it to many people at no extra cost. Examples include street lighting, uncongested roads and codified pieces of knowledge such as Pythagoras’s theorem. Mitigating climate change is also a non-rival good.

monetary reward. The culture of the community entails great respect for originality and disapproval of any form of plagiarism or lack of acknowledgement of the intellectual precedents of a person's research. Through this powerful reward system, open science encourages the creation and dissemination of knowledge. One downside is that open science can be expensive for taxpayers. Also, because science is often isolated from market signals, few incentives may exist to make research relevant to society's needs.

Public subsidies for private research and development

Public subsidies for private research and development (R&D) come in the form of either tax credits or grants to firms that undertake spending on R&D.

Direct government purchase of research

The government purchases research directly, either by choosing among offers from potential research providers or through direct funding of research organisations (such as government research institutes and universities).

Facilitating links to internalise spillovers

Formal and informal networks and other links between researchers and users of research encourage knowledge creation, dissemination and use. Such networks can be described as part of a "national innovation system". The system generally works better when flows are two-way, with feedback loops from users to researchers and vice versa.

Prizes

Governments or private benefactors can offer large inducement prizes for the first person or organisation that develops a solution to a serious problem. A famous example is the British Admiralty's offer in 1714 of a large prize to the first solution to determining longitude – critical for accurate marine navigation. The prize offer stimulated much ingenious research and building of devices, and the prize was eventually awarded to clockmaker John Harrison. He worked along quite different lines to the scientific orthodoxy of the day by inventing an extremely accurate ship's clock or chronometer.

Source: Blakeley et al. (2005).

In climate change, the world faces an extremely serious and complex challenge. Reducing emissions is likely to require many, varied innovations. Even where technologies already exist to reduce emissions to very low or zero levels, this may be costly. Incentivising innovation has the potential to speed up emission reductions and lower their costs. As such, incentives to innovate have a very important role to play in the transition to low emissions while continuing to grow incomes and wellbeing.

Regulatory incentives and disincentives to innovation

Regulations can incentivise innovation, but they can also discourage or even prevent it. Policymakers should consider this when designing regulations, yet they often do not (Blind, 2012). For example, technology standards can force the use of a specific technique or practice to reduce emissions, such as using scrubbers on industrial smokestacks (Asafu-Adjaye, 2005). On the one hand, this stipulation can prompt firms to adopt new methods; on the other, it can inhibit the development of superior, lower-cost solutions, or even the use of an existing lower-cost solution.

A better approach is to design regulations to be technology neutral. For instance, regulations could specify minimum performance standards (such as for vehicle exhausts or energy efficiency) and leave it to manufacturers to find the best means to achieve these standards. Yet, even this poses a risk of not incentivising the optimal level of performance – a level that could be higher or lower than the standard.

Regulations designed to achieve objectives other than lower emissions (eg, product safety) also pose risks. Such regulations can have the effect of inadvertently inhibiting low-emissions innovations. For example, safety regulations that require approvals of new products create a high barrier to radical innovations that

carry some, as yet unquantified, risks. Chapters in Part 4 describe cases where existing regulations are barriers to new, low-emissions technologies in sectors such as electricity, agriculture and transport.

Subsidies to emissions-intensive activities discourage innovation

While emissions pricing incentivises low-emissions innovation, subsidies to high-emissions activities dis-incentivise it. This is because private decisions about where to direct innovation effort and resources depend on relative payoffs, and subsidies for emitting activities reduce the relative payoff to lowering emissions. One striking example consists of the extremely large subsidies around the world for fossil-fuel exploration, development and use. These subsidies were estimated to be worth between US\$55 billion and US\$90 billion every year between 2005 and 2010 across the 34 OECD countries (OECD, 2015a). Across a wider group of 76 countries, the OECD and the International Energy Agency found the subsidies totalled at least \$373 billion in 2015 (Carbon Brief, 2018). UN Secretary-General António Guterres has stated that by subsidising fossil fuels, humanity is “investing in its own doom” (Guterres, 2017).

New Zealand campaigns globally for reform of fossil-fuel subsidies. Yet the Government provides no official figures on fossil fuel subsidies in New Zealand. The OECD calculated New Zealand fossil-fuel support at \$78 million in 2016 (including budgetary transfers and tax expenditures) (OECD, 2018d). Another estimate suggested a higher figure of \$88 million a year of total government support to the oil and gas industry in 2016/17 (Loomis, 2017). However, these figures are large overestimates of New Zealand’s subsidies. A big component (\$58.7 million in 2016) is a rebate of fuel excise duty to off-road fuel consumers. The excise is essentially a user payment for road construction and maintenance. Smaller components include favourable tax depreciation rules for petroleum mining and funding for public-good, petroleum-related R&D. In total these “support measures” totalled less \$4 million in 2016/17 (MBIE, 2018a).

F6.1

Innovation in clean technologies is a key enabler of transitioning to a low-emissions economy while growing incomes and wellbeing. Innovation is positively influenced by pricing emissions, by direct government support for research and development into low emissions, and support for the deployment and adoption of innovation. Innovation is discouraged by subsidies to emissions-intensive activities.

F6.2

Subsidies for fossil fuels act in direct opposition to the world’s transition to low greenhouse gas emissions. They reduce the payoffs to innovation in clean energy. New Zealand should continue to campaign for their removal. New Zealand provides only minor (less than \$4 million a year) government support to activities with some relationship to fossil-fuel production and consumption.

Transitioning from polluting to clean technologies: Theory and evidence

The transition to low emissions has, at its heart, a transition from an initial economic structure dominated by polluting technologies to an economic structure dominated by clean technologies. This change is profound and challenging, not least because of the powerful path dependencies that exist in much economic life (Zenghelis, 2016). These path dependencies have several causes such as economies of scale, network effects, lock-in to existing assets and infrastructure, vested interests in the status quo, and (importantly for technological progress) the cumulative nature of knowledge. The National Energy Research Institute (sub. 53), for instance, notes that “[o]ne significant barrier to innovation is the extent of commitment to current technologies – for example replacing dirty plant early incurs both a write-off and a new investment” (p. 8).

Favourable conditions for new clean technologies depend strongly on learning and experimentation from R&D and deployment (ie, learning by doing). They can also depend on complementarities between a new technology, new networks (such as smart electricity grids), new institutional arrangements, new financial models to secure investment, and the development of new skills in the labour force (Aghion et al., 2014).

Theory

Shifting an economy from its current high-emissions trajectory requires leaning against these path dependencies. Acemoglu et al. (2012) apply modern economic thinking about growth, productivity and innovation to the technology aspects of this challenge (Box 6.3).

Box 6.3 The environment and directed technical change

A seminal paper by the Massachusetts Institute of Technology, Harvard University, and University of California authors Acemoglu, Aghion, Bursztyn, and Hémous (AABH) appeared in the *American Economic Review* in 2012. The paper illuminated the role of policy in shifting an economy from “dirty” to “clean” technology.

The model described in the paper analyses a highly stylised economy – it has one final good that can be produced with either a dirty input or a clean input. Effectively the economy has two sectors – dirty and clean. Use of the dirty input has a negative external effect and degrades the environment which, in turn, lowers the wellbeing of every citizen. The environment has a capacity to renew, but it can also suffer a “catastrophe” if its condition degrades beyond a certain point.

An important feature was to model the determinants of technical progress in each sector – unlike in most climate-economics models that assume external factors determine technological progress. AABH noted that technical change flows from the directed research of scientists in the dirty or clean sectors according to the relative private returns to the research. These returns will be higher when:

- the market share of a sector is larger: this reflects that knowledge (the product of research) has high fixed costs and low marginal costs when it is applied. So there are increasing returns to sector scale; and
- the technology of a sector is more advanced: this reflects the “standing on the shoulders of giants” character of knowledge that occurs because earlier discoveries lay a platform for later discoveries.

Clearly, the effects of both market share and technology development contribute to path dependence.

AABH used the model to investigate several important questions, starting from an initial state in which the dirty sector is much larger than the clean sector. The model generated the following results.

- Under free-market conditions where no policy interventions address either the environmental damage from the dirty input or positive knowledge spillovers, the growth path of the economy always leads to environmental disaster (because cumulative pollution from the dirty sector reaches a tipping point).
- If the clean and dirty inputs are sufficiently substitutable for each other, a temporary research subsidy to the clean sector can turn the downward path of the economy around. The subsidy redirects technical change to clean technologies to the point where they are dominant enough for clean-technology research to continue without the subsidy. The shift to the use of clean technology is also enough to make growth sustainable and avoid environmental disaster. The following quote describes the contrast between the free-market and research-subsidy paths.

No firm has an incentive to produce clean research because it can neither pay the best scientists nor overcome the network effect of the incumbent dirty technology to deploy its innovation. The economic system stays locked in fossil fuels. In an alternative path, the system is given enough of a ‘push’ to overcome initial switching costs so that cleaner technologies are fully developed and adopted, eventually displacing fossil fuels. (Aghion et al., 2014, p. 7)

- Delay in implementing the subsidy for clean research is costly because of (i) the increase in environmental degradation, (ii) the bigger the intervention needed when it does happen, and (iii) a longer period of slower growth during the transition (the last two are both because technology in the dirty sector has moved further “ahead” during the delay).

- Optimal policy requires *both* emissions pricing and research subsidies (ie, a policy aimed at each market failure).
- Use of emissions pricing (ie, a carbon tax or an ETS) alone is a “second-best” option and would be distortionary. This distortion is because only using emissions pricing would require a much higher emissions price than under optimal settings and impose a substantially greater cost (in lower consumption) than using emissions pricing and research subsidies.
- Numerical simulations of the model suggest optimal environmental regulation should include an immediate switch of R&D resources to clean technology, followed by a gradual switch of all production to clean inputs. The simulations suggest the costs of delay could be substantial – equivalent to a decline in consumption of 8.5% for a 10-year delay.

Source: Acemoglu et al. (2012).

Perhaps the most important insight of Acemoglu et al. (2012) is for policy to support the creation and adoption of new technology *in addition to* an effective emissions price. Failure to support clean technology to overcome the path dependence on the old (polluting) technology will reduce the effectiveness of emissions pricing. It will require higher emissions prices and higher costs than otherwise needed, in turn heightening the risks of political resistance.

The AABH model has a possible scenario in which the clean sector is supported and develops so effectively that it completely supplants dirty technology because clean technology becomes cheaper and better. At that point, an emission price becomes unnecessary. This situation of old inferior technologies dying out is quite common. Some are predicting this change will happen with the internal combustion engine regardless of carbon pricing (Arbib & Seba, 2017). Yet, an optimal policy always includes a carbon price for any emissions in AABH’s model.

Another important insight from the model is the need for an immediate start on support for clean technology. Delay is costly because it further widens the gap between the stages of development and uses of the old and new technologies⁶⁵.

If delay causes a larger gap between polluting and clean technologies, society risks bearing the cost of a longer and harder transition period. While innovation re-focuses from the more-advanced polluting sector to the less-advanced clean sector, the growth of final output is likely to be slow. Yet, as Aghion et al. (2014) note, while the transition will divert resources, it will not do so permanently:

[T]he tying up of additional resources necessary to trigger the transition may also inhibit the endogenous drivers of growth, especially if the transition is protracted. It will take a certain period of time before there is higher and cleaner growth, powered by a “clean innovation machine”. But once the clean technology has gained sufficient productivity advantage, the clean innovation machine can be left on its own. (p. 8)

Traditionally, public support for R&D is called for to support development of technologies that are further from market (which clean technologies generally are) yet have long-term potential (Dechezleprêtre et al., 2016).

A striking illustration of a firm trying to counter powerful network effects and other causes of path dependence exerted by an “old technology” industry is Tesla, the EV company. Tesla is giving away its intellectual property. It has granted public access to all its EV patents to speed up development of EVs by other firms and create broad pressure for investment in EV infrastructure (Zenghelis, 2016). Of course, vested interests may still resist – car dealers have acted to block the sale of Tesla cars in some US states.

⁶⁵ Not all new technologies will be disruptive to old technologies. Some may serve to reduce the emissions intensity of old technologies and help keep them in use, such as a vaccine for reducing methane emissions from cattle and sheep.

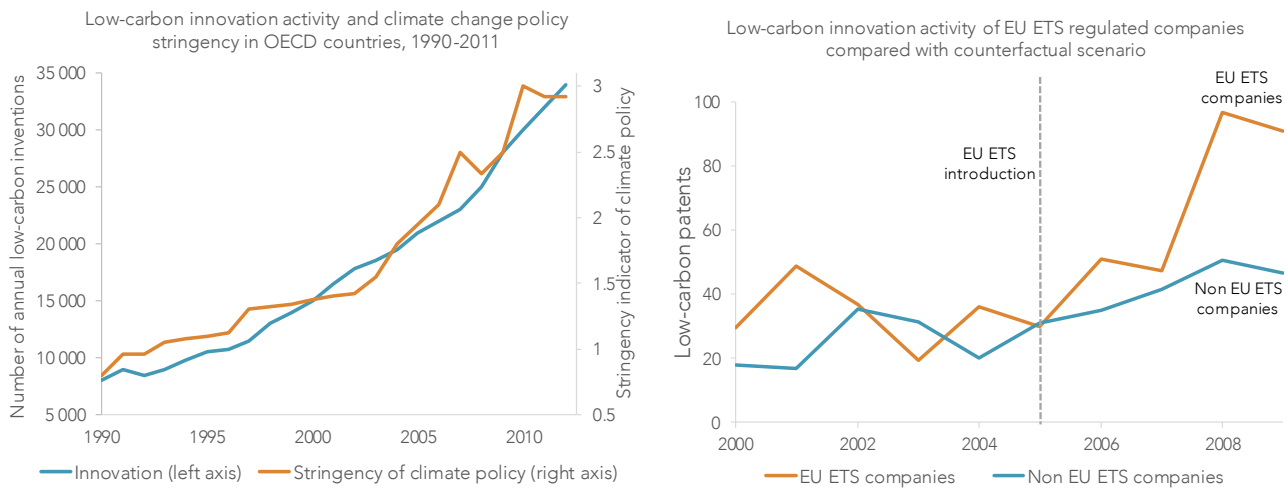
Evidence of the effectiveness of public policy support for clean technologies

Considerable evidence shows the effectiveness of, public-policy support for new, clean technologies.

Evidence for path dependence exists in the form of firms directing their innovation efforts to areas where they already excel. One example comes from cross-country patenting data in the auto industry (Aghion et al., 2012). The research showed that clean innovation is path dependent at the firm and industry levels – those that start with a greater stock of clean technology patents innovate in clean technology at a faster rate in the future.

Evidence also exists that climate-change policies induce innovation in low-carbon technologies. One example is a strong positive relationship found in OECD countries from 1990 to 2012 between the number of low-carbon inventions (measured by patent filings) and the stringency of climate policy in the country (Dechezleprêtre et al., 2016). Another study compared the number of patents in low-carbon technologies produced by firms covered by the European Union’s ETS with firms not covered. Before the ETS was in place, the two groups of firms exhibited roughly similar innovation activity (as measured by the patents). After the policy was in place, the innovation activity of the group within it quickly began to diverge upwards (Calel & Dechezleprêtre, 2016) (Figure 6-2).

Figure 6-2 Responses of low-emissions innovation to climate-change policies



Source: Dechezleprêtre et al. (2016).

Evidence indicates that the impacts of policies to incentivise low-carbon innovation are generally both large and rapid. They can therefore help economies break from their existing high-carbon trajectories to low-carbon trajectories.

In addition, knowledge spillovers from innovation in clean technologies can have wider economic benefits and stimulate growth and higher productivity. As might be expected, spillovers from R&D in a relatively unexplored area of technology tend to be larger than from an area of mature technology. Using patent citation data, Dechezleprêtre et al. (2017) consistently found up to 40% higher spillovers from clean technologies than from conventional technologies associated with GHG pollution. They also used firm-level financial data and found a greater positive impact of knowledge spillovers from clean technologies on the market values of firms.

F6.3

The transition to a low-emissions economy will require policies that lean against path dependencies that can lock in polluting technologies and patterns of production. These dependencies arise from market size, scale economies, the cumulative nature of knowledge, network effects, sunk investments and political pressures from vested interests.

F6.4

A good low-emissions strategy needs both an effective emission price and support for innovation that creates, disseminates and deploys low-emissions technologies. Relying on emissions pricing alone will require higher prices than otherwise needed, which, in turn, will likely impose unnecessary economic and social costs.

F6.5

Delay in supporting clean technologies is undesirable. The productivity gap between polluting and clean technologies will increase during the delay period and make the transition longer and costlier in terms of slower economic growth during the transition.

F6.6

Evidence indicates that policies to incentivise the development and uptake of clean technologies may be highly effective. Impacts can be both large and rapid and, as such, can help economies break from their existing high-emissions trajectories to low-emissions trajectories. Evidence also indicates that low-emissions innovations induce greater economic benefits through larger knowledge spillovers compared to innovations in mature high-emissions industries.

Key elements of a good innovation system

If, as argued above, government support for clean innovation is a critical plank of an overall strategy to transition to a low-emissions economy, what form should that support take, and what are the broader, system features of economies that successfully innovate? Box 6.2 earlier described different forms of policy support. Different features and how they each play a part and complement each other are sometimes described as making up a “national innovation system” (Box 6.4).

Box 6.4 A national innovation system

Successful business innovation involves more than narrowly defined R&D. It can include such dimensions as:

- identification of opportunities;
- fostering research-business links;
- testing and demonstration;
- adaptation to local conditions;
- investment in technology, deployment, training and skills;
- funding and finance; and
- market research and marketing.

Typically, only a minority of firms have capabilities across all these dimensions.

At a national level, K. Smith (2006) argues that successful innovation systems are characterised by institutional arrangements (which may differ significantly across countries) that take care of five broad problems:

- **Identification of innovation opportunities** – opportunities are rarely obvious and often emerge from a complex interplay between government, businesses, financial systems and research infrastructures. Exploiting opportunities is not usually an automatic market process, but an action an innovation system may perform well or badly.

- **The creation and distribution of knowledge capabilities** – this is much broader than R&D. It includes non-R&D inputs to innovation and the distribution of knowledge through relationships, intermediaries, people mobility, and education and skills.
- **Business finance and development** – commercial success depends on far more than a good idea. The ability to develop and finance a business idea rests on complementary assets such as management capability, a conducive financial system (Chapter 6), and logistical and marketing capabilities.
- **Risk and uncertainty management** – risk and uncertainty are inherent in innovation. A basic problem is the mismatch between the shorter time horizon of profit-seeking firms and their investors, and the longer time horizon of most research endeavours. The system needs mechanisms to bridge this gap.
- **Infrastructure provision** – much innovation is infrastructure-dependent. Infrastructure for innovation is either physical (eg, a broadband network) or knowledge-based (eg, public research institutes and universities). Items of infrastructures are typically expensive to create and operate. They also tend to pose financing, governance and regulatory challenges no matter which sector (private or public) provides them.

A typical successful modern economy is innovative in specialised areas where the above capabilities have built up and evolved over long time periods. Examples include Denmark in wind technology, Taiwan in laptop computers and Germany in machine tools. The challenge of transitioning to low GHG emissions faces all economies. It is pervasive and not confined to particular sectors. Using innovation to meet the challenge will require, to varying extents, addressing these five broad problems. Along the way, the challenge may also provide both business and the country with new opportunities to prosper by innovating in particular clean technologies.

Source: K. Smith (2006); The Treasury (2008).

How far should governments direct research and innovation to specific areas?

Section 6.2 will examine New Zealand's innovation system and how well it performs. Before doing that, it is important to consider how far a government should direct an innovation system to specific areas and ends rather than leaving scientists, innovators and entrepreneurs to pursue their own interests and dreams (so-called investigator-led research). Further, could a specific area ever be so important to command exceptional treatment?

At one end of a spectrum, the government or another research funder may take no view on what the goal is, other than research excellence. The topic may have no apparent connection to improving human lives. Sometimes, but not often, such research does lead to breakthroughs in understanding that eventually make huge contributions to economic, environmental or social progress.

Most government support for research and innovation carries an expectation that it will improve society, the economy or the environment. Yet, in many cases, the government does not decree the specific projects to which research funding is to be applied, or the precise outcomes sought. Respecting university autonomy and academic freedom, much support for university research falls in this category.

A third category of government funding for research and innovation is more directive. The funding is to achieve desirable outcomes within distinct areas such as agricultural productivity, medical devices, pharmaceuticals, space exploration or saving endangered species. This type of directive research funding is common in OECD and other economies. Areas are usually chosen for their perceived economic, social or environmental importance to the country. Yet the total funding, and the absolute and proportional funding that each area receives, is a product of many forces and is ultimately political. This outcome reflects multiple pressures on a limited government budget.

That said, the planet faces grave risks from harmful climate change. Innovations in energy and transport systems, agriculture and other industries hold out the best hope for substantially eliminating GHG emissions and saving the planet for humans and other species to enjoy, while maintaining and improving living standards. Further, this is a “one-shot” challenge – climate change will not wait for humans to get around to changing their economies (Chapter 1). A failure by the global community to stop or severely curb emissions would have potentially grave and irreversible consequences. So the case to direct substantial public resources towards science and innovation to help solve the problem is convincing.

Many submitters agreed with this assessment and that New Zealand must act in this regard (including SRD Consulting, sub. DR173; AgResearch Ltd, sub. 191; Resilienz, sub. DR206; Pure Advantage, sub. DR239; Engineering Leadership Forum, sub. DR280; National Energy Research Institute, sub. DR337; and Nu Capital Works, sub. DR350). The view of Resilienz (sub. DR206) was quite typical:

We strongly endorse the PC Report’s comments about the centrality of innovation to a transition to a low-emissions economy and, indeed, to effective climate change responses generally.

We find it hard to imagine a more important investment, or one with a better long-term payback, than a prompt, maximum possible commitment to climate change innovation, including that related to transitioning to a low-emissions economy. (p. 18)

Of course, New Zealand acting alone cannot solve the problem, but it should make its fair contribution as a developed country.

F6.7

The risks of harmful climate change are very serious. The application of research and knowledge offers the prospect of substantially cutting GHG emissions. A convincing case therefore exists for government resources to target low-emissions innovation as an exceptionally important part of a country’s public funding for science and innovation.

Absorbing knowledge from other countries

For a small country like New Zealand, the majority of global knowledge is created overseas – for example, less than 0.2% of OECD R&D expenditure occurs within New Zealand. New Zealand is more of a knowledge taker rather than a knowledge maker. But being good at taking does not happen automatically. It requires similar capabilities to creating knowledge – technical and management skills, and the ability to tailor innovation to local conditions. New clean technologies can flow from overseas to New Zealand firms through several channels including collaborations between New Zealand and overseas researchers, international trade, investment and people flows, and as “embodied” knowledge in imported capital equipment (Scion, sub. DR366; Nu Capital Works, sub. DR350; De Long & Summers, 1991).

Notably, a firm’s ability to absorb and apply knowledge from leading-edge firms to itself is significantly improved if the firm itself invests in R&D (Griffith et al., 2000).

Skills

The substantial change and disruption in the transition to a low-emissions economy also implies that, alongside the new technologies themselves, a parallel evolution is needed in skills to use them and in shifts in the labour force (Chapters 4 and 10).

One of the preconditions for a smooth decarbonisation of the overall economy is that the vocational education and training system adapt in a timely way to changing skill demands. Another is that labour market institutions and policies support the necessary reallocation of labour from shrinking to growing firms and activities. This is all the more important as there are concerns about job destructions related to the shift to a low-carbon economy connected to threats of carbon leakage. (OECD, 2015a, p. 107)

The key overall message

The key overall message is the need for an innovation system geared to the objective of transitioning the economy to low emissions, and for the various complementary parts of that system to be in tune and working well together. That means not only adequate R&D support for clean technologies, but also that finance, skills, knowledge sharing, infrastructure, market conditions and regulatory regimes are aligned to

support the widespread changes needed across the economy to achieve low emissions. The Morgan Foundation sums this up:

Strong carbon prices and national policy direction combined with meaningful, broad-based support for research and development (for example through tax credits) would hopefully go a long way to encouraging low carbon innovation. (sub. 127, p. 22)

Further, as Andy Reisinger (sub. 28) argues, a successful transition also requires policy certainty across these complementary areas that sends a consistent signal to potential investors in new technology (see also Chapters 5 and 8).

F6.8

The effective creation and application of low-emissions knowledge and technologies depend on different facets of the national innovation system being present and working well together. The facets include:

- clear objectives;
- identification of innovation opportunities;
- domestic and international links between firms, investors, researchers and governments;
- timely provision of complementary infrastructure;
- adequate risk capital, management capability, skills and training; and
- flexible markets for resource reallocation from shrinking to growing firms and activities.

F6.9

Both the government and the private sector have important roles to play in a national innovation system geared to achieving a low-emissions transition. The government's role includes setting credible and transparent goals and policies, and enabling market forces to mobilise businesses to redirect resources from dirty technologies towards clean technologies. This role facilitates but does not substitute for private-sector market activities.

6.2 Current support for low-emissions innovation in New Zealand

This section examines New Zealand's innovation system at present – both generally and in relation to the goal of transitioning to low emissions. The Commission's assessment is that some current features are positive for that goal, but considerable scope exists for improved resourcing and design. Further, the proposed changes are likely to be beneficial not only for decarbonising New Zealand's economy, but also for enhancing its performance more generally.

Description of current support

Government support for science and innovation

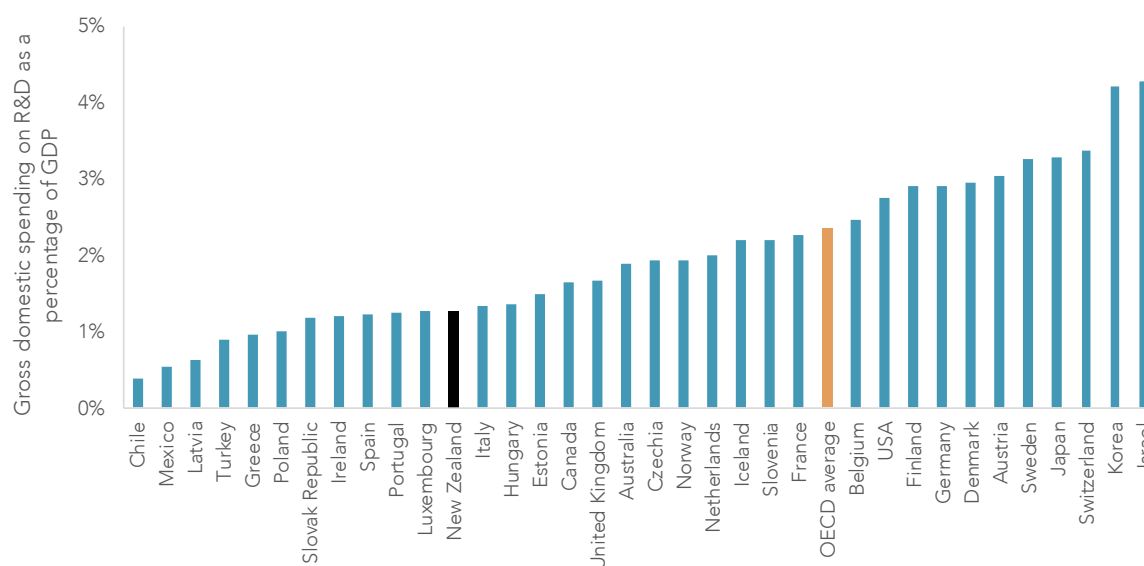
The New Zealand Government spent \$1.32 billion in 2015 on support for science and innovation. It plans to lift this to around \$1.66 billion by 2021 (MBIE, 2017c). The current spend is around 0.4% of Gross Domestic Product (GDP) and 1.7% of total government spending. The proportion of spending aimed at climate change is small – according to the 2016 R&D survey the proportion of total R&D in the broad category of "Environment" is 10% (Stats NZ, 2017c) and this category includes many other areas than climate-change mitigation.

Both New Zealand's public- and private-sector investment in R&D as a share of GDP is well below the OECD average (Figure 6-3). New Zealand is also unusual in that the business sector funds less than 40% of total R&D; the average proportion in the OECD that the business sector funds is close to 70%.

Government funding support for R&D and innovation more broadly flows through two main channels.

- **Research funding to tertiary education institutions.** This funding includes specialist research centres and networks, such as Centres of Research Excellence. But a large proportion of the funding is non-directive and flows to universities through the Performance Based Research Fund (Ministry of Education, n.d.). These funds are administered through the Tertiary Education Commission with policy advice from the Ministry of Education.
- **Support for public-good research and business R&D.** This is administered through the Science and Innovation Directorate of the Ministry of Business, Innovation and Employment (MBIE). Recipients include Crown Research Institutes, businesses, universities, and other private- and public-sector researchers.

Figure 6-3 Public and private R&D spending as a percentage of GDP, 2015



Source: OECD (2018b).

Research organisations that undertake low-emissions R&D in New Zealand sometimes with private-sector partners include:

- universities that carry out “blue sky” and/or targeted research, such as through the MacDiarmid Institute for Advanced Materials and Nanotechnology and the Electric Power Engineering Centre;
- Crown Research Institutes which, with dedicated interests in agriculture (AgResearch), horticulture (Plant & Food), land care (Landcare Research), forestry (Scion), and geothermal and carbon capture and sequestration (GNS) undertake applied research into ways to reduce or absorb emissions;
- the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) and the Pastoral Greenhouse Gas Research Consortium (PGgRc), which research ways to curb agricultural GHGs; and
- Motu Economic and Public Policy Research, which is a non-government trust that has a programme of research on climate-change impacts and mitigation in New Zealand including forestry, agriculture and emissions pricing.

Most of the research carried out by these organisations is funded directly or indirectly by government. Only the NZAGRC and the PGgRc focus exclusively on climate-mitigation research. Only the university institutes,

the Crown Research Institutes, the NZAGRC and the PGgRc research and develop low-emissions technologies.

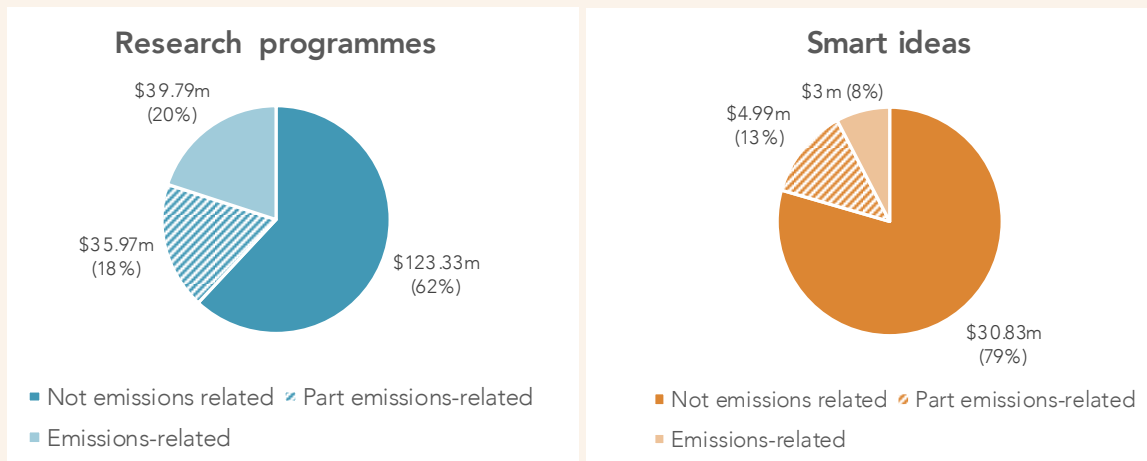
Research organisation such as these may receive their own dedicated funding, but can also seek funds from sources that offer pools of contestable funding. One source is the Endeavour Fund (Box 6.5).

Box 6.5 The Endeavour Fund and low-emissions research

The Endeavour Fund, administered by MBIE, invests around \$200 million each year in projects and programmes chosen for their potential for long-term transformational impact for New Zealand including its economic performance, a stronger society, and the sustainability and integrity of the environment. The two selection criteria are research excellence and impact. The two categories for applications are *smart ideas* (specific projects) and *research programmes*.

MBIE announced decisions on the 2017 round of the Endeavour Fund late in 2017. Figure 6-4 shows the funding in the two categories of research programmes and smart ideas that went to research related to a low-emissions transition, to research partly related to a low-emissions transition, and to research in unrelated areas.⁶⁶ The proportions of funding going to research relating partly or more fully to lowering emissions are significant. For a single outcome area, they are relatively high. It suggests that the funders believed a high number of quality applications had the potential to make an impact in transitioning to low emissions. Yet, in terms of the Commission's conclusion in the previous section, reducing emissions is not just another (important) outcome area. It is an imperative that should be treated with urgency and high priority.

Figure 6-4 Endeavour Fund 2017 Research Funding Allocations



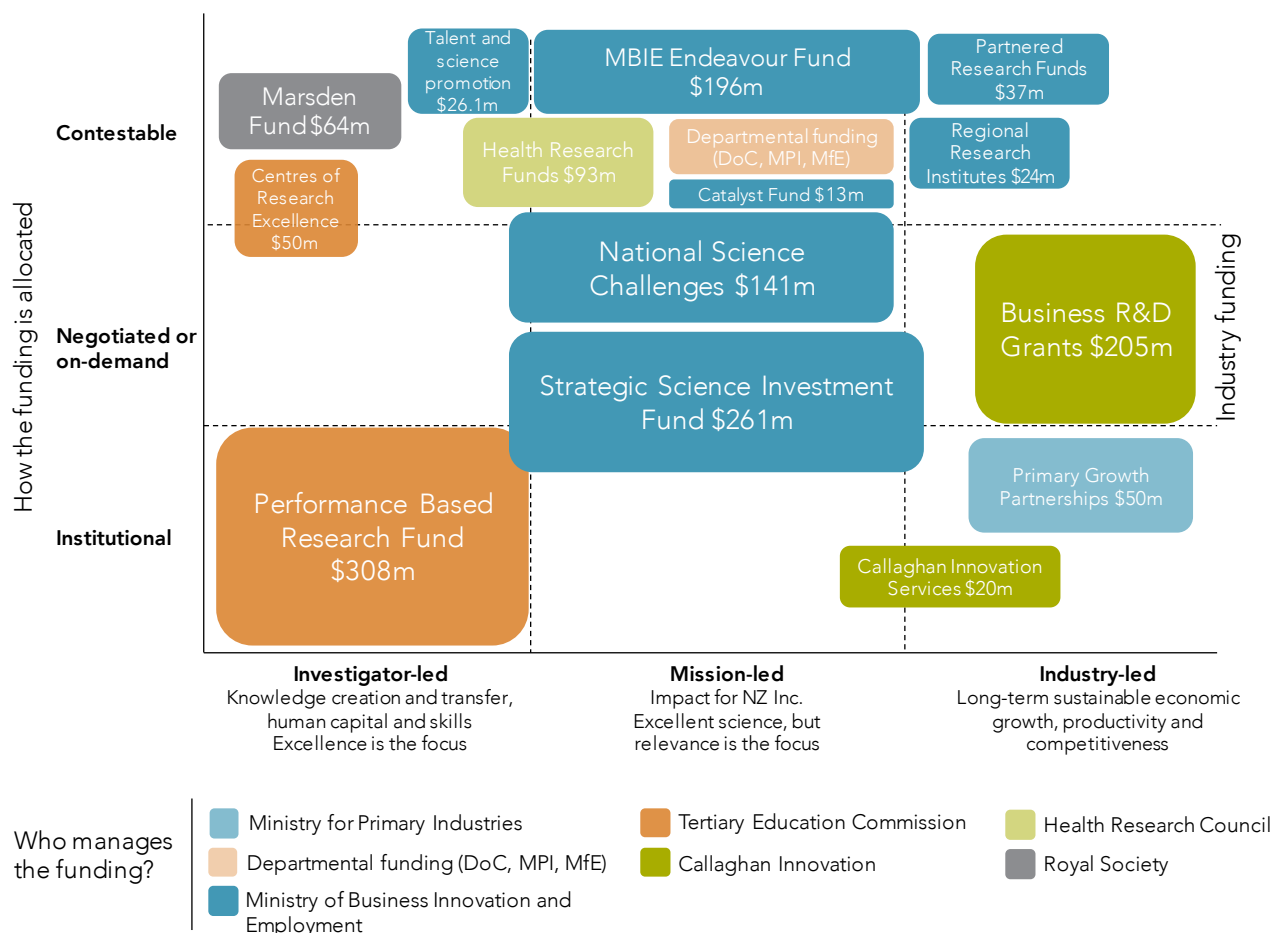
Source: NZ Productivity Commission analysis of MBIE information.

The wider public-funding landscape for science and innovation

The Endeavour Fund sits within a wider landscape for science and innovation funding in New Zealand. The landscape is shown in Figure 6-5. Directive funding programmes (ie, mission-led) sit in the centre of the figure. It is through these programmes that the government has the most influence on the purposes of the research that it funds. It also has some influence through its contributions to the industry-led programmes in the right column.

⁶⁶ Classified by the Commission based on the brief descriptions of the projects and programmes on MBIE's website.

Figure 6-5 New Zealand's science and innovation public funding landscape, 2017/18



Source: MBIE (2017c).

Note: The Government intends to implement a new R&D tax credit scheme by 1 April 2019 to contribute to increasing R&D expenditure to two percent of GDP over 10 years. It will close its Growth Grant scheme to new applicants on 31 March 2019.

Table 6.1 describes three of the schemes (apart from the Endeavour Fund) that have large budgets – the Strategic Science Research Fund, the National Science Challenges and business R&D grants awarded by Callaghan Innovation – plus several of the more specialised funding streams.

The government has the potential – through its funding and objective-setting – to influence the extent to which these schemes focus on research and innovation relevant to a low-emissions economy. The table describes the extent to which they do.

Table 6.1 Mission-led and industry-led research support schemes funded or co-funded by government

Scheme	Purpose	Annual funding (mostly 2017/18) and degree of focus on low emissions
Strategic Science Investment Fund	Funding for investment in mission-led research programmes and research infrastructure that are of enduring importance to the economy, environment and wellbeing. The Fund also provides funding for the seven Crown Research Institutes.	Over \$260m. Priorities are defined in the Fund's investment plan 2017–2024. Low-emissions innovation is not identified as a priority.
National Science Challenges	Eleven big challenges that, if successfully met, will have major and enduring benefits to New Zealand. Crown Research	\$141m. No challenge is specifically focused on lowering GHG emissions (<i>The Deep South</i> challenge focuses on aspects of climate change and adapting to it).

Scheme	Purpose	Annual funding (mostly 2017/18) and degree of focus on low emissions
	Institutes must strategically align some of their R&D with the challenges.	
Callaghan Innovation and business R&D grants	Several different grant schemes aimed at stimulating New Zealand businesses to invest more in R&D. A Global Expert scheme to put New Zealand firms in touch with international experts. The Government is committed to increasing business R&D and intends to implement an R&D tax credit on 1 April 2019.	\$205m for grants. A focus on low emissions is not a priority – little sign of firms being awarded grants with a focus on lowering emissions. The Global Expert scheme is driven by business demand. A scanning role to find potential low-emissions technologies from overseas is not part of the scheme.
Primary Growth Partnership (PGP)	A joint venture between government and primary industry that invests in innovation to increase the market success of primary industries. Programmes include R&D, education and skills, and technology transfer.	\$39m government contribution (2016/17), with matching co-funding from industry. \$235m total investment by government over the life of 22 PGP programmes (to mid-2017). Around 5 programmes have some focus on lower emissions – often as a co-benefit with improved water quality.
NZ Agriculture Greenhouse Gas Research Centre (NZAGRC)	A partnership between New Zealand researchers and industry bodies in the agricultural GHG area. The partnership aims to bring cost-effective, simple solutions to New Zealand farms, and contribute world-leading mitigation solutions to the international science community.	Average of \$4.8m a year over 2009–2019 (funded from the PGP). Fully focused on reducing agricultural emissions.
Pastoral Greenhouse Gas Research Consortium (PGgRc)	A consortium that aims to deliver knowledge and economically viable mitigation practices and products that help New Zealand farmers manage their GHG emissions. The pastoral farming sector leads the consortium in partnership with government and the NZAGRC.	Government funding average of \$3.1m a year over 2013–2019, matched by the sector. Fully focused on reducing on-farm emissions.
Global Research Alliance on Agricultural Greenhouse Gases	An alliance of 49 countries focused on R&D and deployment of technologies and practices to help grow more food without growing GHG emissions. New Zealand hosts the Secretariat.	Contribution by New Zealand Government of around \$6m a year over 2010–2020. Reducing emissions from livestock farming is a strong focus.

Source: MBIE, PGP, NZAGRC, PGgRc and Global Research Alliance on Agricultural GHG websites.

Current government support for other aspects of the innovation system

Finance

The government encourages the private venture capital market to supply adequate risk capital to early-stage business innovators through the New Zealand Venture Investment Fund (NZVIF). The Fund's policy is to be sector neutral in its allocation decisions. In fact, most investment decisions are taken by private-sector partners. A small number of the 267 investee companies have a focus on innovations to lower emissions. These companies include, for example, CNano, Ray Power Systems, and SolarBright. Chapter 7 has further information on finance for low-emissions investments.

Public procurement

Public procurement is recognised as an important instrument of innovation policy. Across OECD countries, public procurement expenditures average 13% of GDP. Smart government purchasing can demonstrate low-

emissions technologies and help to develop the supply side of the market. Government can be influential in sectors where its expenditures are large (such as transport and construction). Public procurement can promote low emissions through life-cycle costing that includes the social cost of emissions, and by market dialogues with potential suppliers to encourage innovative tenders and new business models (Baron, 2016).

Leadership and guidance on best practice in public procurement rests with New Zealand Government Procurement within MBIE. While dedicated to raising standards for procurement across government, its focus is on commercial best practice and conventional value for money, rather than fostering innovation in priority areas such as low-emissions investments and technologies.

Prizes

As noted above, prizes for developing innovative solutions to difficult problems can be an effective way to incentivise knowledge creation, follow-on development, and subsequent knowledge sharing. Callaghan Innovation awards a biennial “C-prize” of \$100 000 in a competition that challenges entrants to come up with technologies that deliver solutions to real industry problems. The 2017 challenge stipulated solutions delivered by the “next generation of wearable technology”.

The Prime Minister’s Science Prizes are awarded each year. The five prizes have a combined value of \$1 million. The top prize is awarded to “an individual or team for a transformative scientific discovery or achievement, which has had a significant economic, health, social and/or environmental impact on New Zealand or internationally”. The 2017 MacDiarmid Emerging Scientist Prize of \$200 000 went to University of Otago scientist Dr Carla Meledandri applying nanotechnology to two very different areas: reducing tooth decay, and gas capture and storage with the potential to mitigate GHG emissions. In a radio interview, Dr Meledandri said the prize money would make a huge difference to paying for additional staff, travel and collaboration, and equipment (Meledandri, 2018).

Assessment of New Zealand’s support for low-emissions innovation

By OECD standards, the public and private resources devoted to research, science and innovation in New Zealand are modest. Even for these investments, New Zealand struggles to leverage them to raise its productivity and incomes (Conway, 2016; Wakeman & Conway, 2017).

Funding either does not give priority to low-emissions innovation or it is minor

New Zealand’s numerous programmes for supporting science and innovation could fund R&D in low-emissions technologies. But many of the programmes either base their funding decisions on research excellence and impact regardless of the sector (which are good criteria), or they have priorities that do not include reducing GHG emissions. As noted, the sector-neutral Endeavour Fund has awarded funding to research related to, or partly related to, reducing GHG emissions in significant amounts for a single topic area. But the absolute amounts for each programme or project are relatively small.

Some programmes are dedicated to lowering GHG emissions, especially in animal agriculture. This is appropriate given New Zealand’s economic specialisation in animal agriculture and the unusually high proportion of its total GHGs that come from that sector. But the amounts devoted to these specialist programmes are small – a few million dollars each a year. Other primary industry areas also receive some emphasis – for example, forestry and horticulture through the CRIs Scion and Plant and Food respectively. Yet again, these efforts are modest relative to the potential and probable need for these sectors to expand and make a significant contribution to reducing emissions.

New Zealand also has strength in some forms of energy research. Yet these do not appear to be strongly or systematically supported (Martin Atkins, sub. DR361; Fonterra, sub. DR355; Chapter 14). New Zealand has nothing comparable to Scottish research into tidal power or the huge investments in developing wind power in Denmark and more recently in the United Kingdom. As the former Parliamentary Commissioner for the Environment, Jan Wright, has remarked, New Zealand has some of the best wind in the world, and trains many engineers; yet it has had to import Danish expertise and engineers to build its wind farms.

Research strengths exist in materials science in centres such as the MacDiarmid Institute for Advanced Materials and Nanotechnology, GNS Science, and Scion (biomaterials), but they are relatively small

operations (eg, the MacDiarmid Institute received only around \$6 million in government funding in 2015). Again, no systematic slant exists to favour research and innovation for low emissions.

Relatively small prizes seem to be effective in motivating research and innovation to solve practical problems. Potential therefore exists to make greater use of this approach to drive innovation that searches for low-emissions solutions.

Government agencies' use of other levers to support low-emissions innovation is patchy

No serious attempt has been made to use government procurement as a lever to encourage low-emissions innovation. Likewise, investment to date in research infrastructure to support low-emissions innovation (eg, in tidal power or distributed energy) has been minimal. This is even though the Strategic Science Investment Fund provides for strategic investments in "infrastructure projects that have high national benefits that will not emerge in the course of usual business because of the public nature of the benefits, and the scale, complexity, long duration and multi-user nature of the investment".⁶⁷

NZVIF, the government institution for improving flows of risk capital to innovative start-ups, has no special focus on low-emissions technologies (see Chapter 7). Auckland Council (sub. 97) notes that "[s]tart-ups that are supported by government and who lead in the innovation space are not currently supported to scale..." (p. 55).

Some parts of government (eg, in the transport area) have appreciated the need to help fund investments in complementary infrastructure and to support reforms of regulations to encourage low-emissions innovation and new technologies. Yet the thinking and efforts have been sporadic and not part of an overarching theme or strategy for a transition to a low-emissions economy.

Strategic fit and conclusions

This assessment needs to consider New Zealand's status as a small, developed country with a distinctive emissions profile and then ask: what does this status imply for a publicly-supported innovation strategy? Should New Zealand, for example, focus its innovation strategy on a few niche areas of high importance given its emissions, and focus on being a smart follower for the remaining areas? This approach has a convincing logic. New Zealand will continue to be a technology taker in many instances, including within low-emissions innovation. New Zealand's public investments in the science of agricultural GHG emissions and in seeking innovative ways to reduce them make sense because of the importance of agriculture in the economy and its high emissions. Yet efforts to date appear to fall short in depth and scope if New Zealand is serious about its GHG-reduction targets.

Several conclusions follow from the above examination and assessment of how well New Zealand's innovation system measures up in supporting the transition to a low-emissions economy.

- The investments in the NZAGRC, the PGgRc, and the Global Research Alliance on Agricultural Greenhouse Gases are limited in size and scope.
- New Zealand should be giving significantly more support to other existing areas of research strength in its innovation ecosystem that relate to reducing emissions. such as materials science and energy. The National Energy Research Institute, for instance, points to improving geothermal energy use as worthy of attention (sub. 53). Nu Capital Works draws attention to missed opportunities because New Zealand has not supported young, clean-tech companies who then either fail or move offshore (a notable example in the latter category is Lanzatech, now based in the US) (sub. DR350). Arguably, increased support in these areas would open up export opportunities and reap broader economic returns.
- Opportunities exist to raise the profile of low-emissions innovation in several large science and innovation programmes, and in financing early-stage development by making low-emissions innovation a strategic priority. Auckland Council (sub. 97) and The Morgan Foundation (sub. 127) each argued for a National Science Challenge focused on the deployment of low-emissions technologies and the transition

⁶⁷ Strategic Science Investment Fund, Investment Plan 2017–2024, p. 8.

to a low-emissions economy. The Manufacturers' Network thinks that supporting climate change mitigation research could be made a core part of Callaghan Innovation's mandate (sub. 52).

- Even if many new low-emissions technologies that can assist New Zealand to reach its low-emissions targets come from overseas, the identification, dissemination and uptake of them by New Zealand firms can be very slow (Conway, 2016). Information and coordination failures, path dependence and returns to early adopters not commensurate to their risks can all play a role in causing this.

New Zealand has no institution that scans internationally for new low-emissions technologies to import and adapt to help New Zealand transition to low emissions. BusinessNZ (sub. 89) noted:

As a technology-taker, with the right diffusion policies, New Zealand can benefit from the rapidly falling costs of new technology especially in the energy sector, and in turn minimise any efficiency losses that might be associated with the early adoption of higher-cost, lower-emissions technology. Currently there is no efficient way for business to peer inside the global new knowledge, research and development 'cupboard'. The Commission might want to look at knowledge and technology transfer tools and approaches that business and universities use to monitor and access knowledge, research and development related to transitioning to a low-emissions economy... (p. 8)

Some institutions could be tasked with actively scanning international developments in low-emissions technologies, conducting due diligence and feeding relevant information to New Zealand firms and industry associations (NERI sub. DR337, p. 9). One possibility would be to expand the role of the Global Expert service in Callaghan Innovation. Another potential location for the function would be the unit within New Zealand Trade and Enterprise that promotes foreign investment into New Zealand.

An example of a technology developed offshore (by researchers at MIT in Cambridge, Massachusetts) that could be relevant to New Zealand is a new "air breathing" battery that can potentially store large amounts of electricity for months for about a fifth of the cost of current storage technologies (Matheson, 2017). New Zealand's growing dependence on wind and other renewable generation that is intermittent could make this new technology useful. However, its usefulness would need to be assessed and tested along with other energy-storage technologies that are emerging.

A possible model for a national agency that scans globally for domestically relevant technologies is Fundación Chile. This Chilean non-profit corporation has "a national purpose of delivering high-impact technological solutions through transference, adaptation, research, and development. This demanding task has required [links] with more than 160 international organisations, companies, governments and technological centres, among others, in 35 countries" (World Bank, 2014).

Overall, the current suite of government programmes lacks the strong strategic focus on low-emissions innovation needed for New Zealand to transition to a low-emissions economy with the greatest net benefit. Making the most of available technologies and investing in innovative new technologies can not only reduce the emissions price required for the transition; but also open new economic opportunities for business investments with good returns, high-skill jobs, and profitable export opportunities.

Some of the best opportunities in New Zealand are likely to lie in agriculture. Chapter 11 has an example illustrating the high potential returns – some hundreds of millions of dollars a year – if investment in R&D led to a vaccine that lowered methane emissions from farm animals by 30%.

Strong support for low-emissions innovations may only need to be temporary. The rationale for public support is technological path dependence and knowledge spillovers. These reduce private returns to investments in new clean technologies relative to their returns to society and are most present when the economy is dominated, as it currently is, by high-emission technologies, skills and infrastructures.

F6.10

Current government investment in science and innovation to support a low-emissions transition lacks a clear strategic focus and priority commensurate with the imperative to succeed in achieving the objective, and to taking bold action. Current investments are inadequate in size and scope.

Strong support for innovation as part of an overall low-emissions strategy would be likely to:

- make more emission reductions possible at lower cost;
- lower the emissions price necessary for achieving target emission reductions;
- create economic opportunities in the form of attractive business investments, high-skill jobs, and the potential for profitable export opportunities; and
- enhance New Zealand's reputation internationally through developing innovative, low-emissions technologies that help the world as well as New Zealand to reduce GHG emissions.

F6.11

In many areas New Zealand will be a technology taker. From this follows the need for a capacity and resourcing to identify, absorb, adapt and deploy a wide range of technologies from offshore. At the same time, in areas relevant to New Zealand's emissions profile, and areas of existing research strength relevant to lowering emissions, the country should invest in the full menu of basic and applied research, commercialisation, infrastructure and skills.

6.3 Harnessing the full potential of innovation

The twin themes of this chapter are:

- concerted government support for innovation is key to achieving the imperative of low emissions and is required to break the forces of path dependence from the old emissions-intensive economy; and
- an opportunity exists in so doing to boost New Zealand's existing tepid productivity performance to become a more innovative economy with higher productivity growth.

The first theme flows from the analysis by Acemoglu et al. (2012) about technological path dependence and the insufficiently strong private incentives to invest in knowledge and innovation. Innovators need additional support and rewards for the positive spillovers they create. The analysis points to the need for concerted policy support, at least for a transitional period, until the "clean innovation machine" is self-sustaining in continuing the shift from the existing trajectory.

The second theme flows from innovation being a key driver of productivity growth in advanced economies. New Zealand's innovation and productivity growth performance has been disappointingly low for decades. Part of the explanation is geographic – the combination of New Zealand's small market size and its distance from other markets. This combination limits the intensity of competition and weakens international connections – both of which are important for firms' performance. However, other important parts of the explanation are firms' low levels of investment in knowledge assets (crucial to their ability to benefit from technological diffusion of national and global best practice) and the limited flexibility of the economy to reallocate people, physical resources and finance from lagging to leading firms (Conway, 2016; de Serres et al., 2014).

Absorptive capacity of firms

The above conclusions emerge from the Commission’s research in recent years about the causes of New Zealand’s slow productivity growth. This research uses comprehensive data on individual New Zealand firms and their characteristics. Harris and Le (2018) have written a recent paper in this research programme. Their paper examines the “absorptive capacity” of New Zealand firms, which refers to the capacity of firms to learn – usually by using knowledge from their external environment – to improve their productivity.

A focus on the innovative capacity of firms is a necessary counterpart to the government’s role in developing an effective national innovation system. Without enough firms with sufficient capacity, good research will not translate to commercial uptake and effective solutions.

An important part of the story about innovation and low emissions is the absorptive capacity of firms to learn about and use clean technologies. Making the most of new technologies is a major challenge for firms. The research indicates that those firms that actively develop their capacity to adapt and learn are much better placed to benefit from the opportunities that new technologies bring. Three key dimensions of absorptive capacity in firms are “use of external knowledge”, “links with national researchers” and “international cooperation with business”. Markers associated with high levels of absorptive capacity in firms are:

- firms having overseas interests and links (eg, New Zealand multinationals);
- firms that undertake R&D;
- firms that innovate and/or export;
- larger firms; and
- firms employing greater relative numbers of professionals, managers and technicians.

The research concludes that scope exists for policy to improve the absorptive capacity of firms. To the extent this succeeds, these firms are highly likely to innovate more, undertake more R&D, and export more – three “drivers of productivity”. Fonterra (sub. 88) notes that limited capability and “knowledge-transfer” resources hinder the widespread adoption of best practice on farms. This is one example where policy – perhaps in the form of revived farm-advisory extension services could – could play a useful role.

When these insights about the absorptive capacity of firms are applied to the challenge of adopting new clean technologies, they suggest the possibility of a double benefit: reduced emissions and improved productivity performance. A corollary is that simply providing external knowledge about clean technologies is unlikely to be enough for firms to adopt them – unless these firms have sufficient absorptive capacity.

F6.12

“Absorptive capacity” is the capacity of firms to learn by using knowledge from their external environment. It appears to be a key driver of a firm’s ability to accumulate knowledge assets and raise its productivity. Absorptive capacity is therefore likely to be important for learning about, and investing in, clean technologies. This suggests a double benefit from better absorptive capacity – reduced emissions and improved productivity.

Focusing the national innovation system on results

The analysis in this chapter points to two key outcome failures of New Zealand’s innovation system. One – the failure of innovation in New Zealand to drive stronger economic performance and productivity growth – is longstanding. The other – failure to put sufficient priority and resources into low-emissions innovation – is recent and emergent. A potential cause of both outcome failures is that the innovation system is highly fragmented and weighted too heavily to investigator-led research (Bentley, 2017; MSI, 2011)

The high weighting given to investigator preferences in the design of the system and in how funds are allocated has an upside – the high quality and achievements of New Zealand science, scientists and other researchers by global standards (as measured by research-paper output and citations). The downside,

however, is the underweighting to high-quality, mission-led and industry-led research, the weak incentives for university and CRI researchers to engage with industry, and the barriers for industry in accessing scientific and research expertise in publicly funded research institutions (MSI, 2011).

The Engineering Leadership Forum (ELF) in its submission described the Product Accelerator programme that it felt should be built on to encourage more industry-led research and influence, and greater research-industry collaboration (NZ Product Accelerator, 2018).

The University of Auckland based and led Accelerator programme is a good example of how these collaborations can be achieved. This programme has a core focus on material science for business development and involves most NZ research organisations in a collaborative environment. The programme format is centred on weekly and monthly multi-firm briefing and innovation sessions, now involving over 300 firms. These are excellent environments for sectors to work together on industry development.

As the focus shifts to low emission technology development, new funds will be needed that sit alongside the existing science funding programmes. The Accelerator programme provides a framework to deliver this technology development with its proven management, its streamlined innovation development processes, and its business-based culture. (sub. DR280, p. 4)

Programmes such as this are likely to be effective in improving firms' absorptive capacity. Another possibility is through Callaghan Innovation. It has recently launched a new strategy that puts more emphasis on helping New Zealand firms to innovate in the technology space and to accelerate its commercialisation. Partly this will be through improving the innovation eco-system – fostering connections through local and global networks, making firms aware of opportunities and “empowering innovators” (Rotherham, 2018).

SRD Consulting and ELF (sub. DR173 and sub. DR280) point at the Australian Renewable Energy Agency (ARENA) as an example of an institution set up to support directed technical change in low-emissions innovation. The Australian Government set up ARENA to “improve the competitiveness of renewable energy technologies and increase the supply of renewable energy in Australia”. ARENA describes its role in the following terms:

We provide **funding** to researchers, developers and businesses that have demonstrated the feasibility and potential commercialisation of their project. Our funding helps find a good renewable energy idea and get it to market.

We build and support **networks**, and share the **knowledge**, insights and data from our funded projects to help us all learn from each other's experiences. (ARENA, 2018)

The bolded words (as replicated from the website) are key parts of an effective innovation system.

If the Government, as the steward of the public funding of New Zealand's innovation system, takes the Commission's advice to give greater priority and resources to low-emissions innovation, what criteria should it use to prioritise and choose topic areas? The National Energy Research Institute (NERI) has argued for criteria very similar to some earlier suggestions in this chapter. Box 6.6 describes the NERI version of these criteria and some of the topics that NERI and other submitters suggest would fit them.

Box 6.6 **Criteria for choosing focus areas for low-emissions innovation**

NERI (sub. DR337) proposes the following framework for New Zealand to analyse where it might invest in innovation to reduce emissions. The framework has three key categories.

Innovation where there is something unique to New Zealand about the problem that means the innovation needs to be done in New Zealand

The common suggestion in this category is research to tackle the problem of agricultural GHGs (Chapter 11). Other examples in the primary sector are forests, soil and wetlands as carbon sinks, wood as a sustainable resource, and innovative horticulture and cropping. Yet, submitters' suggestions were not confined to the primary sector. Finding cost-effective ways to replace fossil-fuel process heat with renewable sources in areas such as milk drying, other food processing and cement was argued to offer

high potential returns to R&D (NERI, sub. DR337; ELF, sub. DR173; Dr Martin Atkins, sub. DR361; see also Chapter 14). NERI argued the need for New Zealand-specific research on options to decarbonise the heavy transport fleet. SRD Consulting and several other submitters argued the need for research on the best ways (including through regulatory and institutional innovation) to exploit distributed energy resources, demand response and the smart grid – to make the most of New Zealand’s high levels of low-emissions electricity generation (Chapter 13). First Gas (sub. DR316) suggested a contestible fund to support innovation by regulated network industries – similar to Ofgem’s fund in the United Kingdom. Scion (sub. DR366) proposed research to discover higher-end uses of methane to encourage more methane capture. One opportunity may be to use gas-phase biotechnology to convert methane to products such as bioplastics.

Innovation that New Zealand should do because it is internationally strong in that area

Examples in this category include strength in certain aspects of materials science; energy storage and photonics (the MacDiarmid Institute and Dodd-Walls Centre); geothermal (GNS, sub. DR390; ELF, sub. DR280); and carbon capture, storage and use (Kevin Rolfe, sub. DR187; GNS, sub. DR390). David Geraghty makes this broad comment:

There is great scope within the national science system – across investigator-led, mission-led and industry-led science – for the Government to prioritise investment into low emissions research. New Zealand universities have broad, deep research expertise across the many discipline areas that could feed into this. (sub. DR313, p. 2)

Imported innovations that will need innovation capability for adaptation and to support uptake under New Zealand conditions

This will be a dominant and important category. It will sometimes require government support because adaptation to New Zealand conditions could have strong public benefits, or research may be needed to overcome skill/learning or social barriers to adoption.

In some cases, worthwhile innovation investments may exist that integrate two or even all three categories. For example, New Zealand, as a small, distant country with a long, thin domestic geography, faces long-haul and short-haul transport challenges. Air travel is emissions intensive. New Zealand would therefore benefit disproportionately from more high-quality virtual meetings in place of face-to-face meetings. New Zealand also has advanced gaming, virtual reality / augmented reality and other capability in information, communications and technology, as well as a high-speed broadband network, and it can easily import a wide range of hardware.

Putting these attributes with a Kiwi capability to adopt different business norms could yield high travel and emissions savings. (NERI, 2017).

Another integration opportunity could lie in exploiting the digital economy.

There are many parts of society that are hard to move, or at least require disproportionate effort to trigger the momentum in order to reduce emissions. Globally every country faces similar complex issues – climate change impact, inequality, infrastructure development and broader wellbeing – all of these are positioned for focus by the next generation digital economy. Digital technology is not only necessary for measurement but also for behavioural change. In many ways it is equivalent to the original switch from analogue to digital but with greater potential to empower individuals to take control. Taking control also means being responsible and this might be the most dramatic outcome. Any country can lead this. The question for sectors like transport, manufacturing, agriculture and energy is whether to wait until it happens or respond and engage now. The impact of digitalisation will be ubiquitous across the entire economy. (BusinessNZ sub. DR347, p. 15)

A final aspect of focus is timing. Three important insights from the Commission’s modelling of uncertainty (Chapter 3) are that (1) early action can greatly lower the future costs of emissions reductions; (2) the advent of low-emitting technologies is a powerful means to lower these costs, and (3) investing in “optionality” will create valuable choices as future uncertainties resolve themselves. Investing in low-emissions research and

innovation *early* hits the mark with each of these insights. The long lead time required for effective R&D also points to the need for investing early. Even if a hoped-for technology breakthrough from a research investment does not occur, the increased knowledge and understanding places society in a better position to act in the future.

F6.13

New Zealand needs a framework for prioritising its investments in low-emissions innovation. Three important categories are (1) the problem has something unique to New Zealand; (2) New Zealand is internationally strong in that area; and (3) imported innovations need identification and tailoring for uptake in New Zealand. In addition to greater focus through topic prioritisation, early investment in innovation will likely reap high benefits in the face of inevitable uncertainties about future events and developments.

Policy implications

This chapter emphasises six strands of policy.

- Get emissions pricing right (Chapter 5).
- Place a high priority on government support for creating and adopting clean technologies to change from the path dependence on polluting technologies to a path dependence on clean technologies. In addition, have a good framework for prioritising investments in low-emissions innovation.
- Strengthen the weaker parts of the national innovation system so that the various parts are aligned and work well together in the transition to a low-emissions economy.
- Help firms improve their absorptive capacity.
- Create and maintain clear and stable policy settings.
- Keep the market environment flexible to allow “creative destruction” to take place, so that resources can flow from firms that lag in adopting clean technologies to firms that lead.

The need for an innovation system geared to transitioning the economy to low emissions and for the complementary parts of the system to be in tune and working well together is urgent. Achieving the objective requires not only adequate R&D support for clean technologies, but also finance, skills, knowledge sharing, infrastructure, market conditions and regulatory regimes that are aligned to support the widespread changes needed across the economy to achieve low emissions.

These policy strands lead to the following four recommendations:

R6.1

New Zealand should establish the goal of transitioning to a low-emissions economy as a high priority within its national innovation system. It should also recognise that achieving it will require extensive economic transformation and restructuring. The Government should provide major public backing and funding support for innovation so that innovation can play a central role in the transition, alongside effective emissions pricing.

R6.2

The Government should take steps to:

- strengthen the national innovation system by clarifying its low-emissions objectives, improving links, identifying relevant innovation priorities, and fostering knowledge transfer and sharing; and
- align the various complementary parts so they work well together in the transition to a low-emissions economy.

The scope should include not only science and research, but broader innovation, knowledge dissemination and learning, skills, infrastructure, regulation and finance.

R6.3

The Government should investigate and implement any cost-effective institutional models that:

- scan new low-emissions technologies around the world to identify ones with promise for New Zealand but that may need adapting to suit local conditions; and
- help firms to improve their absorptive capacity for external knowledge, including new low-emissions technologies.

R6.4

Policy should keep the market environment competitive and flexible to allow “creative destruction” to take place, so that resources can flow from firms that lag in adopting low-emissions technologies to firms that lead.

Lord Nicholas Stern, the author of *The Stern Review* (Stern, 2007) on the economics of climate change and a world-leading thinker in public economics, has written a more recent volume *Why are we waiting? The logic, urgency and promise of tackling climate change* (Stern, 2015). Stern is a technological optimist but emphasises that countries must grasp the opportunities that lie before them.

Stern’s thesis is that the right climate policies are likely to trigger new waves of global investment, innovation, and discovery. If countries design their policies to foster learning and flexibility, then new opportunities will arise. Perhaps, he argues, the urgency of tackling climate change calls for something like the dedicated R&D that occurred to achieve major national goals such as the US Project Apollo for landing a person on the moon, or the Manhattan Project for developing the atomic bomb partly to allay fears that Nazi Germany would develop it first. The Sustainable Business Council (sub. 31) cites the view that “climate change [is] the largest economic disruption in our lifetimes, as well as the greatest driver of innovation since World War Two” (p. 2).

However, the challenge of reducing GHG emissions also differs in important ways from these types of projects. The challenge is global and requires major economic transformation involving billions of individuals and organisations. Stern points to the need for a new Industrial Revolution with energy at its core, to achieve the required reduction in GHG emissions. Yet the transition to low-emissions growth may represent a very attractive path that could, if economic history is a guide, stimulate dynamic, innovative and creative growth. Stern has in mind a new economic era of innovation based on clean technologies that could be like earlier waves of innovation such as steam and railways; oil, automobiles and mass production; and information and communications technology (Chapter 4). The new wave could see great opportunities emerge from rapid and innovative developments in, and combinations of, digital, materials, biological and energy technologies.

But, as Stern warns, opportunity is not destiny – dangers exist of lock-in to, and path dependence on, high-emissions technologies and infrastructure.

6.4 Conclusion

Innovation can and should play a central role in New Zealand's transition to a low-emissions economy. It is the closest thing to a "silver bullet" to enable humanity to meet the challenge of avoiding harmful climate change. It also holds out the opportunity for New Zealand to combine the transition to low emissions with dynamic and creative improvements in national wellbeing.

While the form, timing and impact of innovation are highly uncertain, a country's policies and institutions significantly affect its innovation performance. They need to enable and encourage researchers and business organisations to both create new low-emissions technologies and deploy existing low-emissions technologies.

It will be important to align all parts of the innovation system, so they work well together in the transition to a low-emissions economy. Some parts are currently weak. The following parts of the system are priorities.

- The seriousness of the climate-change threat justifies all developed countries devoting serious attention and resources to it within the publicly funded parts of their national innovation systems. New Zealand can and should do more in this regard.
- The Government should take cost-effective actions to improve the absorptive capacity of firms, provide skills training to complement new technologies, and establish a mechanism to scan for emission-reducing technologies around the world that are suitable for New Zealand to adapt and deploy.
- Policy should maintain a flexible and adaptable economy to facilitate resources moving from high-emissions activities to low-emissions activities.

The upside of a transition to low emissions is that it likely represents a very attractive path that could, if economic history is a guide, stimulate dynamic and creative economic growth. Well-designed climate policies can unleash a new wave of innovation and create an era of economic opportunity and wellbeing.

7 Investment

Key points

- Transitioning to a low-emissions economy requires a major re-orientation of public and private investment away from emissions-intensive activities and towards those that support and catalyse low-emissions energy, land use and other activities.
- Sufficient capital is available to meet low-emissions goals. The issue is *redirecting* that capital to investments consistent with the transition. Investors will be motivated to respond to the challenge of climate change to avoid risk, pursue profit opportunities, and achieve goals related to socially responsible investment.
- Stable and credible climate policy, underpinned by enduring institutional arrangements such as effective emissions pricing, provides a critical basis for a well-functioning investment system that will take advantage of emissions-reductions opportunities. This will likely be enough to enable certain types of investment financing, such as green bonds and commercial equity.
- Yet additional barriers to low-emissions investments exist and require attention. These include information and inertia barriers, coordination failures, technology and market risks, and scale-of-investment barriers. Stable and credible climate policy will partly resolve these barriers but is unlikely to be sufficient. This is because of a lack of alignment between standard commercial decision making and the public interest in avoiding dangerous climate change. In addition, the need for government to provide direct financial support for low-emissions investment is likely to be higher at the beginning of the transition while other policies (such as emissions pricing) take effect.
- Introducing mandatory climate-related financial disclosures is an important action the Government can take to encourage investment that supports the transition to a low-emissions economy. These disclosures help overcome information and inertia barriers inhibiting entities from adequately addressing climate risk and capitalising on low-emissions opportunities. They can help investors to correctly value assets and investment opportunities, and avoid misdirected finance or stranded assets.
- Other relevant actions for Government include targeted grants and loans which can play an important catalytic role in reducing market risk for the development and deployment of low-emissions technology. The proposed Green Investment Fund has potential to stimulate some of the technology and infrastructure needed to achieve a low-emissions transition in New Zealand.
- Finally, the Commission identifies the need for a more aligned and strategic view across public-sector interventions targeting low-emissions activities.

This chapter examines, and makes findings and recommendations about, the risks and opportunities of investments that support a transition to a low-emissions economy. It investigates types of instruments that can facilitate these investment opportunities, such as equity and debt finance, government initiatives (such as government-backed investment banks and funds), and climate-related financial disclosure requirements. It also examines the role of other supportive actors for the transition (such as institutional and Māori investors). The chapter concludes by identifying the need for a more aligned and strategic view across public-sector interventions targeting low-emissions activities.

7.1 Mobilising the investment needed for the transition

Transitioning to a low-emissions economy requires a re-orientation of public and private investment away from emissions-intensive activities and towards those that support and catalyse low-emissions energy, land use and other activities.

Transitioning to a low-carbon and climate-resilient economy will require clear and stable climate policies, targeted public climate finance and well structured financial instruments to catalyse a major shift of private capital investment. Limited public funds need to be used efficiently to overcome barriers and to mobilise the power of market forces to support climate action. Domestic policy reform is essential to level the playing field, expand low-carbon and climate-resilient investment opportunities, and to help to manage the risks and increase the returns for investors. (OECD, 2012a, p. 1)

Financial flows can stimulate the transition by supporting investment into low-emissions activities or infrastructure (eg, networks for charging electric vehicles). They can also promote innovation, and research and development (R&D), by firms into technologies that are too risky a proposition for traditional investors. The latter is particularly relevant given the core role of innovation as a driver of a low-emissions economy (Chapter 6). Box 7.1 explains what is meant by climate finance in the context of this report.

Box 7.1 **Climate finance**

Climate finance broadly refers to the “flow of funds used to help countries to cut their emissions and adapt to climate change” (Curran, 2016).⁶⁸ These funds may originate from public or private-sector sources, or a mix of both (also known as blended finance). Climate finance can be understood as a subset of green finance. Although “green finance” has no commonly agreed definition (Lindenberg, 2014), it also includes finance supportive of other environmental goals such as biodiversity preservation.

The Organisation for Economic Co-operation and Development (OECD) identifies two main investment challenges for the transition to a low-emissions future:

- scaling up finance for long-term investment in infrastructure; and
- shifting investments towards low-emissions alternatives (OECD, 2015a).

The scale of the challenge

Globally, the investment required to address climate change is immense. The International Energy Agency (IEA, 2016d) estimates that to have a 50–50 chance of limiting warming to 2°C, investments of US\$40 trillion to meet energy needs, and US\$35 trillion in energy efficiency, will be required globally by 2040. The IEA also estimates that fossil fuels will need to drop from three-quarters of the world’s energy mix to one-third by 2040. This represents a major movement of investment away from fossil fuel generation that will also have substantial flow-on implications for all other sectors of the economy (Chapter 4).

Sufficient capital exists to achieve mitigation goals. It is fundamentally about *redirecting* that capital to investments consistent with the transition to a low-emissions economy. For example, Geoffrey Heal (2018) calculates that the investment required to transition the entire United States electricity generation market away from fossil fuels (approximately \$US37.6 billion a year) is less than the existing capital expenditure on electricity capacity (US\$42 billion a year). The OECD (2015c) notes that

[t]here is no shortage of available capital. The challenge for governments is to ensure that public policies and investment conditions facilitate a re-allocation of investment from high-carbon to low-carbon and climate-resilient (LCR) options. It is only by such a re-allocation that we can get on a global emissions trajectory to meet the 2°C target. (p. 5)

Despite New Zealand’s high proportion of renewable electricity and the associated need for significant new low-emissions energy infrastructure, other types of infrastructure will be needed for the transition, such as the transport and logistics networks of a greatly expanded forestry sector (Chapter 11). Investment must also be available to enable New Zealand to respond to trends in shifting global markets, and to develop new, low-emissions goods and services to replace those that are no longer feasible as consumer preferences, costs and types of inputs change.

⁶⁸ Because of the focus of this inquiry is on New Zealand’s domestic transition to a low-emissions economy, this chapter does not discuss international climate finance (funds from developed to developing countries, as required under Article 9 of the Paris Agreement).

It is important to direct investment away from high-emissions activities

Investment contrary to the transition to a low-emissions economy is problematic because it serves to slow the transition's speed and effectiveness. While the amount of climate-aligned investment is large and growing, it is still far outpaced by fossil fuel-intensive investment (Amin et al., 2014). This is due to market forces and regulations collectively favouring such investments, though often unintentionally (OECD, 2015a). The UK's Environment Audit Committee (2014, p. 3) notes that stock markets are "currently over-valuing companies that produce and use carbon", creating substantial risk for the transition (section 7.2).

Large investments in fossil-fuel exploration, or major pieces of equipment that require fossil-fuel energy (such as coal-fired boilers or diesel trains) have long lifespans and are particularly important to discourage so as to minimise the risk of high-emissions lock-in and stranded assets. These are risks facing individual companies, but they also have consequences for the whole of the economy (EY, 2018a). For example, Adrian Orr, the former Chief Executive of the New Zealand Super Fund (NZ Super Fund) contended that carbon is "mis-priced globally", and continuing to invest in emissions-intensive activities would expose the Fund to "undue risk" (Orr in Coughlan, 2018). But, perceptions about the value of carbon are important – it may be mis-priced in the context of achieving the 2°C target of the Paris Agreement, but may not be mis-priced based on companies' perceptions about the likely implementation of mitigation policies (such as emissions pricing). This is why stable and credible climate policy is so important.

Taken together, the myriad smaller investments by individuals via channels such as pension funds are also relevant and worth considering. For example, over \$40 billion was invested in KiwiSaver in 2017 alone (FMA, 2017). Moving even 1% of this amount away from high-emissions to low-emissions investment could make a substantial difference towards the amount of finance available for the transition.

7.2 Why are investors interested in a low-emissions economy?

The transition to a low-emissions economy requires a major shift of capital. Three main reasons explain why investors may be motivated to change their decisions: risk, opportunities, and social conscience.

Risk

Silk (2017) argues that "climate-related risk is a real financial risk". Two main risks are particularly relevant to the relationship between investment and climate change: physical risk and transition risk (TCFD, 2017).

Physical risk

In New Zealand, as in the rest of the world, climate change will increase the costs relating to weather events (ICNZ, 2014). For example, the observed 20cm rise in sea level since 1950 directly increased losses caused by Hurricane Sandy by 30% in New York alone (Lloyds, 2014).

Physical risk can have diffuse economic impact. Insurance premiums will rise where climate change is expected to increase risk, with insurance companies possibly no longer insuring high-risk assets, such as coastal property where flood risk is elevated (Storey et al., 2017). Subsequent asset devaluation related to weather-related damage, or uninsurable property, influences household wealth or firm profitability. Banks that lose such assets as loan collateral may also restrict future lending (Bank of England, 2017).

Transition risk

Transition risk refers to the risks arising from the adjustment process towards a low-emissions economy (Bank of England, 2017). Two key transition risks are apparent. First, as noted above, is the risk of stranded assets. This includes the subsequent risk to overarching financial stability objectives if large-scale asset revaluation occurs more quickly than firms or industries are able to adjust (Carney, 2016).

A key issue relating to stranded assets and transition risk is what is known as "unburnable carbon" or the "carbon bubble". This is the amount of fossil-fuel reserves unable to be used if countries' emissions targets are met. Globally, between 60% and 80% of the coal, oil and gas reserves of publicly listed companies cannot be used to have an 80% chance of limiting peak warming to 2°C (Carbon Tracker, 2013). Despite its relatively high proportion of renewable electricity, this is still a substantial issue for New Zealand for two main reasons. First, many public-sector activities and investments currently include or rely on fossil fuels. This has

implications for the ability of the public sector to help finance the transition. Second, as outlined above, fossil fuels are ubiquitous across society. Any firm or organisation whose business model relies upon fossil fuels, or products manufactured out of fossil fuels, will be impacted.

The second transition risk is “liability risk”, where those suffering losses due to climate change (either from its physical effects, or decisions made about the transition to a low-emissions economy) seek financial compensation. Climate-related litigation has increased sharply in the last decade (Nachmany et al., 2017). A recent example is that of New York City which has filed a claim against several major fossil-fuel companies such as BP and Exxon Mobil. The claim argues that despite these firms having “full knowledge that fossil fuels would cause catastrophic harm”, each firm “decided to continue its conduct and commit itself to massive fossil fuel production” (New York City v BP plc et al., 2018, p. 34).

Another issue relating to liability risk is disclosure of activities or assets. If an investor considers that a business or entity did not provide adequate information regarding its exposure to climate change risk, it may also make a claim (see section 7.5 for more on disclosure). In Australia, a superannuation fund is being sued for failing to provide information about how it is managing climate risk, argued to be necessary information for fund members to make informed decisions about their investment (Slezak, 2018).

The key factors driving transition risk are the speed and scale of the transition. A stable, long-term transition is likely to reduce transition risk. This is because it allows investors to make more informed decisions that better consider factors such as anticipated emissions price trajectories. Avoiding an abrupt transition is vital to ensuring financial stability (Bank of England, 2017) and ensuring an inclusive transition (Chapter 10).

Opportunities

Realising a low-emissions economy offers the potential to create new business opportunities. For example, the International Finance Corporation (IFC, 2016) estimates that approximately US\$23 trillion worth of climate investment opportunities are possible in emerging markets from 2016 to 2030. Capturing competitive advantage, particularly in higher-value areas where customers may be willing to pay a price premium for climate-friendly products or services, or which will not incur emissions penalties, may well offer substantial investment returns. Already, businesses actively engaged with climate change show superior profitability. Research by the charity CDP (2014) found such companies achieved a 67% higher return on equity and higher shareholder dividends than non-engaged companies.

Socially responsible investment

Finally, social responsibility and altruism can drive low-emissions investment. An approach based on socially responsible investment (SRI) involves individual, firm or institutional investors, for ethical reasons, being unwilling to invest in, or divesting from, activities contributing to climate change. This is similar to avoiding investment in or to divest from tobacco or munitions, as practised by the Accident Compensation Corporation (ACC) and the NZ Super Fund (ACC, 2017; NZ Super Fund, 2017).

While divestment from fossil fuels is argued by some to be necessary (Auckland Council, sub. 97; NZ Church Climate Network, sub. 121), new types of SRI also involve a more proactive approach known as environmental, social and governance (ESG) investing. This involves investors employing shareholder influence to, for example, work with firms to help them move away from reliance on fossil fuels or other high-emitting inputs. Yet the threat of divestment remains a relevant lever, particularly for ethically-aligned investors. For example, the Church of England recently voted that their £12 billion endowment and investment funds would sell shares in any fossil fuel companies that are slow to tackle climate change from 2023 (Mooney, 2018).

Recent research shows that firms that consider ESG issues are important are more profitable and trade at a premium compared to rivals that do not (BCG, 2017). This type of SRI is increasingly seen in New Zealand. For example, the NZ Super Fund (2018) states that it considers engagement as “a key tool for managing carbon emissions and risk exposure” in its passive portfolio. Engagement also forms the basis of what is known as impact investing, which has been described as “the point where capital meets purpose” (New Zealand National Advisory Board for Impact Investing, sub. DR203, p. 2). Government can engage in impact investing by acting as a market participant, builder or steward, and by supporting impact-investing

vehicles, such as social enterprises, to flourish. An Impact Investment Network has been established in New Zealand, as has an impact investing fund (the Impact Enterprise Fund) (Esperance Capital, sub. DR184).

7.3 A well-functioning investment system

Private investors cannot be *forced* to choose low-emissions investments or activities over high-emitting ones. The role of government is to establish the conditions that provide incentives for the market (including private investors) to *prefer* low-emissions investments. To mobilise this investment, and provide an overarching framework of climate policy that is “coherent, consistent and credible” (Matikainen, 2017a, p. 9), two elements are critical:

- institutional arrangements to act as an enduring commitment device for decision making (Chapter 8); and
- effective emissions pricing (Chapter 5).

A foundation of stable and credible climate policy is vital (Chapter 1). It enables investors to confidently expect that emissions reductions policies will actually be implemented as planned (Amin et al., 2014), and steers investments away from path-dependent, high-emissions lock-in (Chris Livesey, sub. DR247).

Enduring institutions help by providing clear information on the direction of travel, and fostering greater awareness of, and investment into, low-emissions activities (NZ Carbon Farming, sub. 95). Long-term commitment devices are particularly important as a signalling mechanism for investment decisions (NZ Super Fund, sub. DR334). In a nutshell, “any actions that Government can take to remove instability and risk, and increase certainty about rewards will assist investors” (Environment Audit Committee, 2014, p. 8).

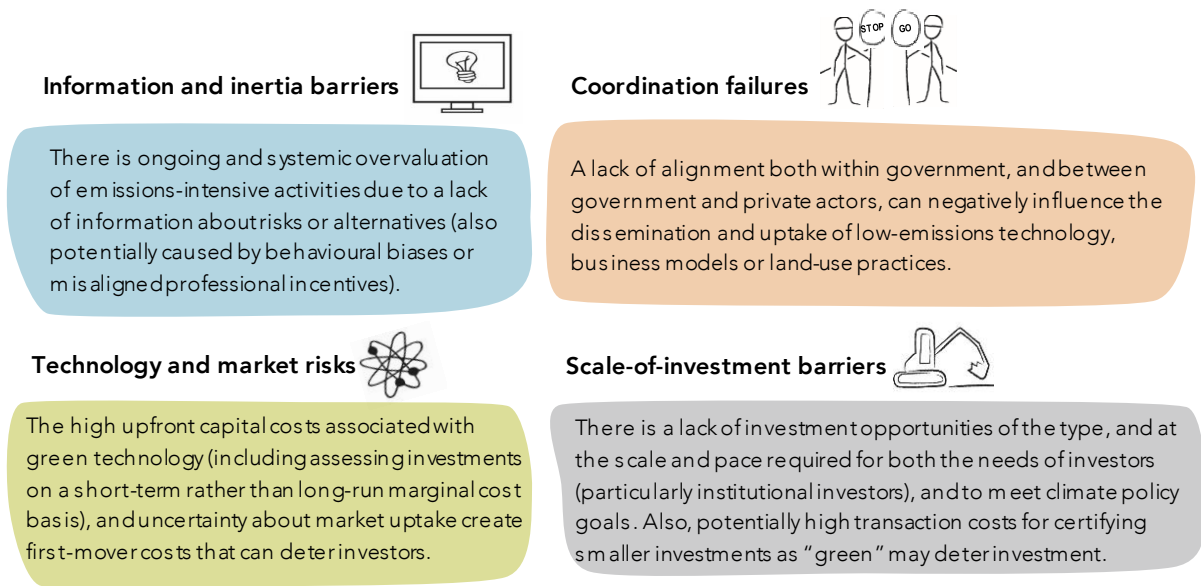
An effective emissions price is also needed to divert investment flows towards low-emissions activities (Guardians of NZ Superannuation, sub. 32). Without a price for the negative emissions externality, the risk-return profile is unattractive for low-emissions activities as compared to high-emissions activities (that are not facing the true cost of their actions). An effective emissions price therefore provides a strong incentive to shift towards investments that do not incur an emissions penalty, and clearly signals to the investor community which activities are likely to remain viable (or not) over time (Chapter 5). In essence, emissions pricing is necessary to provide a financial system that correctly values climate risk.

These core elements are vital to help offset the nature of climate change as a “tragedy of the horizon” (Carney, 2016, p. 2). Capital markets have significantly shorter time horizons than necessary for the transition to a low-emissions economy. This includes the short-term focus of financial analysis not shedding adequate light on long-term risks, and a lack of a long-term time horizon when making corporate disclosures (2° Investing Initiative, 2017a, 2017b). Enduring commitment devices, and an effective emissions price, help to signal where investment may be most effectively directed over the longer term. They can help create a new path dependency centred on low-emissions activities and technologies, as well as foster investment in social and natural capital to achieve long-term goals (Te Rūnanga o Ngāi Tahu, pers. comm. 26 March 2018).

In general, New Zealand benefits from a positive macroeconomic and regulatory environment. However, uncertainty about climate policy settings – as well as policy decisions that have resulted in an ineffective emissions price – have not been conducive to encouraging private investment into low-emissions firms and activities at the scale required.

7.4 Additional barriers to low-emissions investments

The OECD (2015a, 2017c) argues that while coherent climate policy (including effective emissions pricing) provides a necessary foundation, it is not sufficient to effectively transition to a low-emissions economy. Figure 7-1 describes additional barriers to the investment required to support New Zealand’s transition. These do not represent a failure of business, but rather illustrate a disconnect between standard commercial decision-making and the public interest of avoiding dangerous climate change.

Figure 7-1 Barriers to investment required to support New Zealand's transition

Some of these barriers are not unique to low-emissions investments. Many high-technology investments are riskier than existing technologies, and misaligned policy objectives can serve to discourage investment in numerous sectors, not just in relation to climate change. It will be important that any government intervention does not unnecessarily duplicate activities with different mandates. Thinking strategically across the economy also offers an opportunity to enable a decision-making framework which, in turn, enables social, cultural, environmental and economic benefits to be quantified or comparatively assessed (Te Rūnanga o Ngāi Tahu, pers. comm. 26 March 2018).

Barriers may also change over time. Investors may be hesitant to invest if they are uncertain about the durability of newly enacted climate laws or institutions. Equally, emissions prices will take time to increase to a level effective for driving significant investment change. Therefore, a justification exists for additional government support in the short term to stimulate the investment in certain areas.

Public interventions in support of green investments should ideally be designed to plug gaps within the private sector financial market. However, whilst determining the exact size of these gaps is important it is difficult to do as the maturity and capacity of financial markets change. If levels of support are set too high, they can lead to moral hazard. If not closely managed both in terms of objectives as well as appropriate phasing out, public interventions can also lead to broader market distortions. (Amin et al., 2014, p. 22)

A question for governments is how to respond to these barriers, given that the transition to a low-emissions economy is a priority public-policy issue. Governments must focus on the investment gap that stable policy, supported by enduring institutional arrangements and effective emissions pricing, is unlikely to meet. Governments have two main options. They can create policy to provide clearer signals or a more supportive underlying framework (eg, via regulations that encourage better understanding of climate risk), or use their own funds to directly support the transition to a low-emissions economy (Environment Audit Committee, 2014).

The following section examines four types of financial or investment instruments relevant to the transition to a low-emissions economy and assesses their potential in the New Zealand context.

F7.1

To ensure adequate investment for the transition to a low-emissions economy, the government needs to provide a stable and credible climate policy underpinned by enduring institutional arrangements, and effective emissions pricing. However, while necessary, these may not be sufficient. To enable an effective transition, these credible and consistent settings need to be complemented by other interventions that specifically focus on information and inertia barriers, coordination failures, technology and market risks, and scale-of-investment barriers.

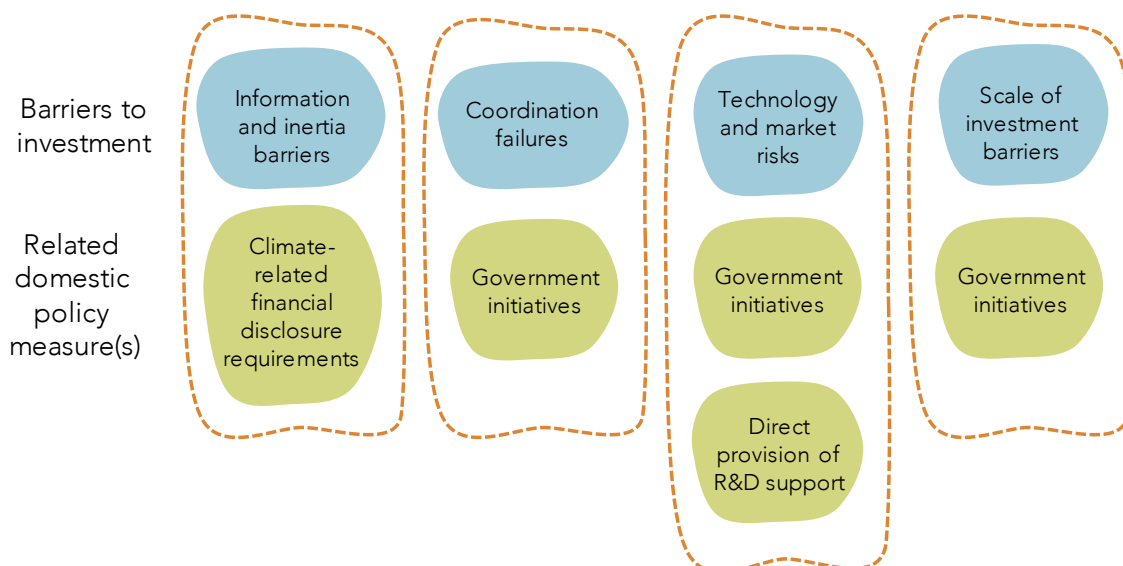
7.5 Investment opportunities

In response to the identified barriers to low-emissions investment, complementary measures will be required to mobilise finance at the scale and speed to stimulate the transition. The international literature identifies four broad categories of financial instrument or policy as having the greatest potential to encourage low-emissions investment. The four categories are:

- equity finance;
- debt finance (including green bonds);
- government initiatives (eg, early-stage equity financing or green banks); and
- climate-related financial disclosure requirements.

The subsequent sub-parts of this section examine these four main categories in the New Zealand context. Figure 7-2 summarises the policy measures likely to be the most effective in catalysing necessary levels of investment in New Zealand (R&D support is examined in Chapter 6, and so is not discussed further here).

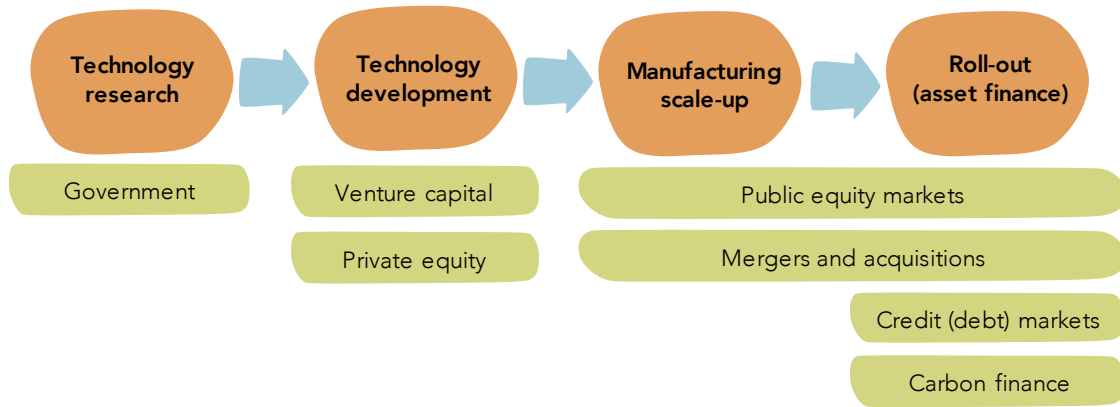
Figure 7-2 Barriers to low-emissions investment and related domestic policy measures



Equity finance

Equity finance is where a permanent share in the ownership of a firm or a project is offered for sale to raise funds to carry out an activity, with investors sharing in the future profits of the firm or project. Two channels to raise equity finance are privately raised funding (such as venture or angel capital) and publicly raised funding (such as a listing on the stock market).

Equity investors offering climate finance often invest in what is known as junior equity, which is riskier than other types of equity (such as preferred stock) because it is the last to be paid out in the event of liquidation. The intent of this choice is to lower the overall level of risk for other investors who can buy less risky types of equity (such as preferred stock) (UNEP, 2014). Equity finance is also particularly important for developing and deploying low-emissions technologies. Figure 7-3 shows the prevalence of equity finance at nearly all stages of the technology development process (noting that this linear model is highly stylised).

Figure 7-3 Mapping sources of finance to stages of low-emissions technology development

Source: Patel (n.d.).

In New Zealand, an estimated \$88.6 billion worth of equity assets taking an ESG approach was under management by the end of 2016 (D. Hall & Lindsay, 2017). Barriers to firms being able to secure adequate levels of equity finance for low-emissions investments throughout their lifecycle include “the scale of New Zealand’s investment community, its priorities and/or appetite for risk, or a combination of both” (D. Hall & Lindsay, 2017, p. 42). Further climate-aligned equity investment in New Zealand will be driven by:

- more climate-aligned firms emerging and seeking equity finance in response to economy-wide climate policy (ie, an effective emissions price and enduring institutional arrangements);
- banks or other entities making ESG-aligned funds invested in New Zealand equities increasingly available (largely for profit-making reasons and, again, as a result of stable climate policy settings);
- disclosure requirements (see the section on climate-related financial disclosure below); and
- public-sector equity funding incorporating a low-emissions focus into their funding decisions, particularly at the early stage of the equity financing process. The aim of which is to overcome technology and market risks, as well as coordination failures between investors and low-emissions technology development (see the section on government initiatives below).

Debt finance

Debt financing refers to funds that a public or private sector organisation borrows to carry out an activity, and is repaid to the lender with interest. As with equity finance, different levels of risk are available if the organisation defaults (ie, is unable to pay back its creditors). For example, “senior” debt is paid out before “subordinated” debt, and climate-focused investors can target subordinated debt to lower the overall level of risk so that other investors are more likely to invest. Similar to equity finance, debt financing may be raised through private or public channels. Privately raised debt financing generally takes the form of loans (eg, from a commercial bank); publicly raised debt financing most commonly occurs as issued bonds.

Green bonds

So-called “green bonds” are an increasingly prevalent type of debt financing where proceeds go towards financing projects relating to climate change or other environmental activities (OECD, 2017d) (see Box 7.2 for a discussion of what makes a bond “green”). Green bonds are most commonly issued as a full recourse debt security, but can take other forms – such as non-recourse revenue bonds, project bonds or securitised bonds (Russell McVeagh, 2017).⁶⁹

⁶⁹ Full recourse means that no matter what happens, the borrower will repay the debt. Revenue bonds are backed by revenues from specific projects or sources. Non-recourse means that if the revenues cease, bondholders do not have a claim to the underlying source of the revenue. Securitised bonds are pools of financial assets created by intermediaries such as banks.

Box 7.2 What makes a bond “green”?

Defining a bond as “green” signals to investors its legitimacy in contributing towards the transition to a low-emissions future. While “green bond” has no agreed legal definition (Russell McVeagh, 2017), the investor community currently has two options to decide whether to label a bond as green.

- The first is the Green Bond Principles. These are voluntary guidelines (developed by the banking industry) that define broad categories of eligible projects, such as renewable energy and biodiversity conservation, and also focus on transparency and disclosure (ICMA, 2017).
- The second is the standards developed by the Climate Bonds Initiative. These provide a certification scheme for green bonds, and eligible categories include renewable energy, public transport and low-carbon buildings (Climate Bonds Initiative, 2017b). These standards are considered to be more stringent than the Green Bond Principles because external review of bond eligibility is mandatory, not voluntary. Such bonds may also be called “certified climate bonds” (D. Hall & Lindsay, 2017).

In 2017, US\$895 billion worth of bonds (representing approximately 1% of the total global bond market) were broadly categorised as “climate-aligned” (ie, financing low-carbon and climate-resilient assets or projects). Of these, US\$221 billion worth of bonds were officially certified as “green” by the Climate Bonds Initiative (Climate Bonds Initiative, 2017a).

The global green bond market began in 2007 and is growing rapidly. In recent years, most green bonds have been issued by corporates, including by commercial banks. However, the majority of the total green bond amount outstanding comprises sovereign or sub-sovereign bonds (Climate Bonds Initiative, 2016, 2017c). Another new type of public-sector green bond gaining traction are environmental impact bonds operating on a “pay-for-success” model (Khalamayzer, 2017). These public bonds provide funding for activities such as new infrastructure, and can be understood as a “form of performance-based contracting that ensures governments limit their losses in case projects are unsuccessful, which encourages them to try novel solutions like green infrastructure” (EESI, 2017).

New Zealand’s first official green bond was issued in June 2018 by Auckland Council. The issuance raised \$200 million to fund electric trains and associated infrastructure (Auckland Council, 2018). Other green bond-related activity in New Zealand to date has included:

- a 10-year fixed-rate Green Kauri \$125 million bond sale with a yield of 3.7% issued by the IFC in 2017 (D. Hall & Lindsay, 2017);
- 6% (approximately \$72 million) of ANZ’s green bond asset pool invested in two wind farm projects in New Zealand (ANZ, 2016); and
- Contact Energy’s green borrowing programme, including wholesale and listed retail bonds to support investment in renewable energy. The programme is based on approximately \$1.8 billion of eligible geothermal assets in the Waikato and Taupō (Contact, 2017).

Internationally, most green bonds support renewable energy or energy efficiency (eg, in buildings) (ANZ, 2016). It is possible that New Zealand-issued green bonds will also follow this trend. Of additional relevance to New Zealand’s low-emissions transition would be green bonds relating to land use. While global green bond activity in this area is minimal, an environmental impact bond based on forestry is currently being investigated in New Zealand (D. Hall & Lindsay, 2017).

Several barriers to scaling up the green bond market have been identified at an international scale (Jun et al., 2016; OECD, 2015b). Table 7.1 assesses these barriers in the New Zealand context.

Table 7.1 Barriers to the scaling up of the green bond market in New Zealand

Barrier	New Zealand-focused assessment
General bond market challenges	The New Zealand bond market, and especially the domestic corporate bond market, is small by international comparison, and has a limited range of instruments (IMF, 2017). However, the New Zealand Stock Exchange (NZX) debt market has recently seen a large increase in capital value (mostly from the issuance of six Local Government Funding Agency bonds in 2015).
Limited awareness of green bond and existing international standards	New Zealand is experiencing an “increasing demand” for green financial products (NZX Ltd, sub. 101, p. 1). In late 2017 NZX released updated guidance on green bonds in an effort to “support the development of green financial products” in New Zealand (NZX, 2017a, p. 15). This guidance includes information on the Green Bond Principles and Climate Bond Initiative Standards. NZX is also “currently considering options to promote listed green bonds” (NZX Ltd, sub. 101, p. 2). Market participants sharing their experience with green bonds will play an important role in fostering confidence in the developing green bond market.
Lack of local green bond guidelines or definitions	Existing international guidelines and standards appear sufficient for New Zealand. However, the NZX is assessing whether it “should have a role in the certification process” for green bonds (NZX Ltd, sub. 101, p. 2). This work may uncover whether additional definitions or requirements are needed specific to the New Zealand context.
Cost to meet green bond requirements	The cost to obtain third-party assurance for a green bond ranges from approximately \$14 000 to \$140 000 (Jun et al., 2016). This cost may hinder smaller-scale green bond activity in New Zealand. As green bonds become more commonplace, verification costs are likely to decrease.
Lack of green bond ratings, indices, and listings	No green bond ratings, indices or listings are specific to New Zealand. However, many international indices include bonds issued in New Zealand dollars (eg, the Bloomberg Barclays MSCI Green Bond Index or the S&P Green Bond Index). The minimum issue size to be included in these indices is relatively large (from \$250 million), so may exclude some smaller activities.
Lack of supply of labelled green bonds	Lack of supply can often be traced to an inadequate pipeline of projects due to uncertainty about long-term governmental commitment to low-emissions development. More ambitious and stable climate policy in New Zealand would likely encourage more eligible projects seeking finance.
International investors unable to enter the market	Given the recent entry by the IFC into the New Zealand market, global green investors seem able to access the New Zealand market. This is likely due to the adoption in New Zealand of international standards for green bond definitions and disclosure requirements.
Lack of domestic green investors	Investors with capacity to analyse green investments are required to stimulate the green bond market. These are likely to be institutional investors with a preference for green assets. The shift towards low-emissions investments by large investors such as the NZ Super Fund (Guardians of NZ Superannuation, sub. 32) will reduce this barrier.

Source: Jun et al. (2016); OECD (2015b).

Based on the above analysis, two actions are required to scale up the green bond market in New Zealand. The first action is to promote the ongoing growth of the New Zealand bond market in general (eg, by supporting increased market liquidity). The second action is for market participants to share information about experiences with, and future availability of, green bonds. Specific government intervention in the New Zealand green bond market does not appear to be required. Even so, understanding more about the potential for green bonds in relation to land use may be useful.

F7.2

The green bond market has the potential to accelerate the transition to a low-emissions economy. The market is growing independent of government assistance. Specific government intervention in the New Zealand green bond market does not appear to be required.

Government initiatives

A potential role for Government in the transition to a low-emissions economy is to provide support that “de-risks” projects for other, private-sector, investors, such as by providing cornerstone investments or credit enhancements (Matikainen, 2017a).⁷⁰ These interventions can crowd in further investment by reducing the cost of capital. Alternatively, they may exist as standalone instruments, or be part of blended financial offerings over different stages of a project’s lifecycle. Government involvement can also reduce the perception of risk of particular projects, even where it provides no actual funds.

The New Zealand Venture Investment Fund

The New Zealand Venture Investment Fund (NZVIF) aims to help build a vibrant early-stage investment market by providing start-up capital to New Zealand technology companies. Established in 2002 as a Crown entity company, the NZVIF has two main funds – each with a distinct operating model:

- the NZVIF Venture Capital Fund of funds (\$195 million) invests in privately managed venture-capital funds, which then invest into New Zealand-originated technology companies; and
- the Seed Co-investment Fund (\$50 million) directly invests into young technology companies alongside selected angel investor groups.

The NZVIF operates at the early stage of the investment market to reduce risk and help to crowd in additional private sector finance. This makes it a suitable candidate for meeting the investment needs of low-emissions technology development. However D. Hall and Lindsay (2017) estimate that only five of the 241 companies that NZVIF has invested in since establishment might be considered low-carbon investments.

The NZVIF excludes certain investments (such as in property development, retail, mining and hospitality), but does not have any mandated priority investment sectors (MED, 2009). A recent report suggested that its investment policy could be “updated to identify low-emissions investments as a sector of interest in line with national interests” (D. Hall & Lindsay, 2017, p. 58). For example, this could entail identifying low-emissions investments as a priority category of investment within each of its funds, or specifying a target percentage of investments for each investment period into climate-focused funds or firms.

The draft report for this inquiry asked whether the NZVIF’s investment policy should be updated to identify low-emissions investments as a sector of interest. Nearly all submitters who responded to this question favoured such a mandate.

Without doubt, the New Zealand Venture Investment Fund investment criteria must reflect the drive towards a low-emissions economy. (Resilienz Ltd, sub. DR206, p. 19)

Yes. We recommend that the investment policy of the New Zealand Venture Investment Fund is updated to identify low-emissions investments as a sector of interest. Investment and innovation in this sector will be important in supporting New Zealand’s transition to a low-emissions economy. (Chartered Accountants Australia and New Zealand, sub. DR208, p. 4)

Regarding the question of whether the New Zealand Venture Investment Fund should have its policy updated to identify low emissions investments as a sector of interest, we consider that this would be consistent with support for necessary innovation and transformation towards the 2050 objective. (Te Rūnanga o Ngāi Tahu, sub. DR362, p. 10)

OraTaiao shares with the Commission the recognition of the importance of...the importance of a unified and consistent policy direction set by Government providing a clear strategy and tactical approach to ensuring NZ meets its commitments to reducing emissions. On this basis it is imperative that the NZ Venture Investment Fund be updated to identify investments that reduce emission, or are low emissions. (OraTaiao The New Zealand Climate and Health Council, sub. 378, p. 15)

However, the NZVIF considers that deal flow in New Zealand is insufficient to warrant any kind of investment focus, low-emissions or otherwise, for its investments (NZVIF, pers. comm. 8 June 2018).⁷¹ While the venture

⁷⁰ This section focuses on the role of central government. However, cities can also play an important role in financing the transition (Billington et al., 2017).

⁷¹ Deal flow refers to the rate at which investors receive investment proposals or offers.

investment market in New Zealand has grown over recent years from a small base (Deakins et al., 2015), it is still relatively shallow.

In general, the argument to prioritise investment in low-emissions activities, and to actively discourage investment in high-emitting, long-lived activities and assets is clear and persuasive. This includes at the level of venture capital (Antarciuc et al., 2018). Indeed,

the importance of NZ's venture capital markets cannot be understated, as they are a critical investment link between small-scale start-ups and larger commercial operations with the ability to 'shift the needle' on delivering low carbon. (Drive Electric, sub. DR257, p. 4)

But the core focus of the NZVIF is to accelerate the overall venture capital market in New Zealand (MED, 2009), and its operating model relies on remaining profitable to achieve this aim (NZVIF, pers. comm. 8 June 2018). Given the shallow market in New Zealand, a mandated investment focus may reduce the NZVIF's ability to direct its funds towards the opportunities it considers most likely to stimulate the domestic venture capital market (and so achieve its core policy objective and remain commercially viable).

At present, the Commission finds insufficient evidence of a suitably large stream of low-emissions investments, at the stage at which the NZVIF operates, to warrant setting a specific investment mandate. Yet it is possible that this is setting up a "chicken-and-egg" problem about whether the adequate deal flow or the mandate comes first. In other words, insufficient deal flow may continue until a mandate is enacted. However, it is unlikely that a mandate set by the NZVIF would be of sufficient influence to stimulate an adequately large flow of low-emissions investment opportunities. Rather, other elements recommended in this report, particularly higher emissions prices and greater innovation activity, are substantially more likely to contribute to greater deal flow. Particularly relevant for the innovation aspect, the New Zealand National Advisory Board for Impact Investing (sub. DR203, p. 5) notes that

[c]apability and pipeline build is vital for the success of any deal flow, with a concentrated and supported approach needed now to unlock innovation and enterprise support from early-stage, through research & development and investment readiness.

Even so, declining to set a mandate now for the NZVIF should not preclude such a mandate being implemented at a later date, particularly once other policies, such as emissions pricing, stimulate greater deal flow. The NZVIF has also requested that the Government consider a proposal for a venture capital "fund of scale" (MBIE, 2017a, p. 18), which may take the form of a more directed investment fund worth about \$300 million (Movac, 2017). This would mean the NZVIF Venture Capital Fund along with the Seed Co-investment Fund directly investing into companies instead of through the fund of funds model. If alterations are made to the NZVIF model, and particularly if more funding is allocated, this offers the opportunity to determine whether a proportion of the funding could be actively directed to low-emissions activities in a way that does not impede its commercial viability.

Finally, the Commission considers that any decisions about the NZVIF model or structure require analysis of whether an investment exclusion approach should apply to ensure that investment is actively steered away from high-emissions investments (see also the discussion on institutional investors in section 7.6). This could mean the NZVIF being actively precluded from investing in high-emitting activities such as those related to fossil fuel production. Such an approach has precedence, for example, in the decision by the World Bank to no longer finance upstream oil and gas after 2019 (World Bank, 2017).

While an investment exclusion approach may act as a largely symbolic gesture (as high-emissions investments should, given likely future emissions pricing trajectories and other policies, become less attractive propositions), it may provide a useful contributing signal to the market. Even so, such an approach would need to be carefully developed, as it would be important not to inadvertently restrict investments into technologies or processes that aim to mitigate activities or processes in high-emitting sectors.

F7.3

At present, evidence of a suitably large stream of low-emissions investments, at the stage at which the New Zealand Venture Investment Fund operates, is insufficient to warrant setting a specific investment mandate for low-emissions investments.

R7.1

Any decisions made by the Government about the model or structure of the New Zealand Venture Investment Fund should be informed by further analysis of the potential for giving priority to low-emissions investments, and whether (and if so, how) an investment exclusion should apply to high-emissions investments.

Green investment banks

Government-backed investment banks or funds are well-established forms of public support for infrastructure development. More recently, institutions (such as the European Investment Bank) have identified climate change as an investment priority (EIB, 2017), and governments have also established specialist climate-related funds. These “green” investment banks or funds (referred to here as GIBs) tend to invest in the broad areas of renewable energy, energy efficiency, or low-emissions technology. Financing approaches include equity and debt finance, as well as loans and guarantees (OECD, 2016a).

Internationally, approximately US\$93 trillion in infrastructure investment is required within the next 15 years to meet global infrastructure needs consistent with the transition to a low-emissions economy (OECD, 2015c). For developed countries such as New Zealand, this mostly comprises replacing existing ageing infrastructure with new, low-emissions infrastructure (such as for electricity generation and distribution, or related to buildings or water). The rationale for GIBs to facilitate this type of investment is that governments can efficiently use public capital to mobilise substantially greater quantities of private capital to overcome the scale of investment barriers encountered by major infrastructure projects (Energy Management Association of New Zealand, sub. 70; Auckland Council, sub. 97; Generation Zero, sub. 119).

However, governments must do this in a way that does not crowd out private investment. This specific mandate to scale up and catalyse investment that would not have happened otherwise allows GIBs to

use targeted approaches and tailored financial structuring to address the lack of suitable LCR [low-carbon and climate-resilient] investments with attributes sought by private investors (e.g. through aggregation of small-scale investments like residential rooftop solar PV investments or energy efficiency retrofits in commercial buildings). (OECD, 2015c, p. 12)

GIBs can also help to:

- provide objective information, data and skills to the market to assess investment opportunities;
- increase market confidence through reducing real and perceived investment risk; for example, by virtue of their expertise and vetting processes (and doing so more effectively and quickly than traditional government programmes);
- reduce overall financing costs (by demonstrating investment profitability to crowd in further private sector investment); and
- acting as an investment accelerator and enabler, such as by building the capacity of domestic financial institutions and to pilot or demonstrate new investment approaches (Matikainen, 2017a; OECD, 2015c; Whitney & Bodnar, 2018).

GIBs can be tailored in many ways. Their policy goals can differ, from focusing solely on helping to meet emissions reductions targets, to having additional mandates such as job creation. GIBs may be required to be profitable and can also operate according to a variety of institutional structures. For example, the Green Investment Group, established and capitalised by the UK Government in 2012 (as the Green Investment Bank), was privatised in 2017. Another example is Australia’s Clean Energy Finance Corporation, which is an independent government institution managed by a board with statutory decision-making responsibility.

GIBs may be funded in numerous ways (such as by emissions pricing revenues, appropriations, bond issuances, or utility bill surcharges). They can pursue a “wholesale” or “retail” strategy. A wholesale strategy “aims to attract relatively large amounts of private capital to combine with public capital for on-lending or investing in funds”. A retail strategy “involves delivery of funds to the project developer or individual”

(OECD, 2015c, p. 12). A wholesale strategy is useful for enabling very large-scale investments, while a retail strategy can help to stimulate activity in new markets.

GIBs are normally established in countries lacking national development banks or other institutions that actively encourage domestic green infrastructure or clean technology development (OECD, 2015c). At present, New Zealand has no equivalent bank or fund, and no international GIBs are operating that could provide finance of this type to New Zealand-based projects. GIBs are also considered to suit markets, such as New Zealand, with “relatively high institutional and financial capacity” (Whitney & Bodnar, 2018, p. 5), allowing for the mobilisation of domestic investment while also drawing on international finance.

However, establishing a GIB is a major policy decision. The OECD (2016a) provides a detailed checklist for policymakers on the rationale for a GIB (as opposed to, or working in conjunction with, other options to mobilise additional private finance to help transition to a low-emissions economy). The OECD also outlines many other factors to consider when deciding to establish a GIB, including administrative set-up and positioning, and capitalisation and financial sustainability.

Another important question is how long a GIB is expected to last. Clarity at the outset is required about whether a GIB is intended to only catalyse investment while the emissions price (Chapter 5) and levels of innovation (Chapter 6) rise to a level necessary to drive the transition more directly; or whether clear market failures are visible that suggest the need for a more enduring role. Intervention duration also has ramifications for a GIB’s structure, particularly in terms of funding source. The right structure is vital to ensure an ongoing pipeline of projects necessary to maintain profitability. This includes sectoral areas of focus, minimum investment size, or the type of co-investment provided by the Government (see also the section on government financial guarantees below).

F7.4

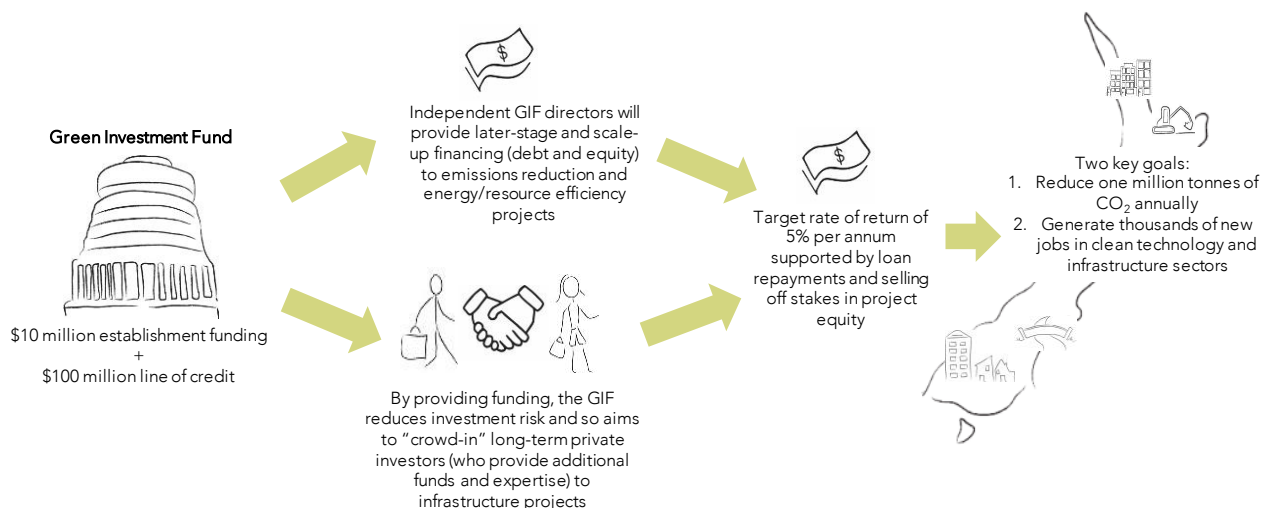
Depending on design, green investment banks can efficiently use public capital to mobilise substantially greater quantities of private capital to overcome the scale-of-investment barriers that low-emissions investments may encounter. These barriers include significant funds for major infrastructure projects, or coordinating funds for more disaggregated activities. Green investment banks can also stimulate investment by providing information, increasing market confidence, and reducing overall financing costs.

The proposed Green Investment Fund

As part of the 2017 confidence and supply agreement between the Labour and Green Parties, the Government has a goal to establish a GIB in New Zealand. The proposed features of the proposed \$100 million Green Investment Fund (GIF) are shown in Figure 7-4. The Green Party also proposed that the \$10 million establishment funding for the GIF will be provided by “ending current fossil fuel subsidies and raising oil royalty rates from the current 46 percent to the global average of 70 percent” (Green Party of Aotearoa New Zealand, 2017, p. 9).

The Treasury is currently leading the task to elaborate these proposed features, and detail how the GIF will work in practice. The GIF could focus on process heat (Chapter 14), waste (Chapter 15) and energy efficiency and space heating in buildings (Chapter 16) (ShareChat, 2018). Northland Regional Council (sub. DR226) suggested that the GIF could be directed towards assessing the viability of alternative measures to offset emissions relevant to the New Zealand context (see also Chapter 11).

Figure 7-4 Proposed Green Investment Fund



Source: Green Party of Aotearoa New Zealand (2017).

A GIF has potential to stimulate some of the technology and infrastructure needed to achieve the low-emissions transition. The relatively small size of the fund (\$100 million) may make it less suitable to large-scale infrastructure projects; yet this level of funding does not preclude it playing a role in providing smaller-scale, low-emissions infrastructure. Such a role may be more feasible if the GIF has a wide degree of flexibility in its scope or financing approach (Responsible Investment Association of Australasia, sub. DR329). Clarity of the GIF's mandate will be important, particularly for expectations about its expected rate of return. For example, Barry Coates (sub. DR374, p. 3) argues that

the Green Investment Fund needs to have a specific priority to achieve emissions reductions, rather than potentially competing priorities such as generating high returns or achieving maximum leverage for private investment. This needs to be reflected in the mandate establishing the fund and in the criteria it applies to its investment portfolio.

SRD Consulting (sub. DR173, p. 2) also notes that "[p]ublic investment into innovation will be critical in the next 5 years to build a pipeline of projects for our modest Green Investment Fund being set up with a budget of \$100m".

Finally, Mōhio (sub. DR330, p. 4) stresses the importance of distinguishing between the GIF as a "means to an end", rather than an "end-in-itself":

[T]here are two ways to think about the purpose of a green investment fund. Firstly, as an *end-in-itself*, as an instrument with a mandate to deploy its funds for climate-aligned projects that might otherwise not have mobilised finance. Secondly, as a *means to an end*, as a catalyst of transformation to a low-emissions economy which leads by example, which drives innovation, which de-risks investment into public value, and which consolidates expertise and insight. It is the prospect of this broader, deeper systems change which underlies the true value of the Green Investment Fund, but this potential could easily be neglected if it was regarded and evaluated more narrowly as an investment vehicle.

R7.2

A Green Investment Fund (GIF) has potential to stimulate some of the technology and infrastructure needed to achieve the low-emissions transition in New Zealand. In work to establish a GIF, the Government should clearly identify the market failure that it seeks to address. The Government should specify the GIF's mandate, financing approach and funding source, expected duration, institutional structure (including its degree of independence), desired minimum rate of return, relationship to existing infrastructure and clean technology funding sources, and scale of investment (wholesale or retail).

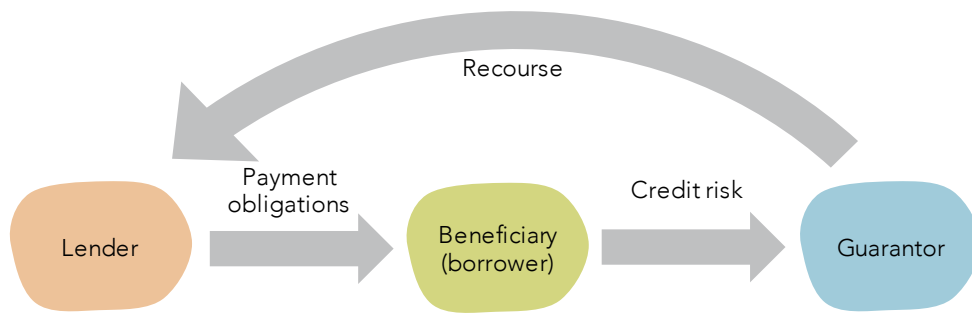
The Government should also state how the GIF will work in conjunction with any other initiatives for providing infrastructure or low-emissions technology finance.

Government financial guarantees

Another option for public sector support is to provide financial guarantees that, similar to GIBs, aim to reduce risk for private-sector investors. Financial guarantees achieve this by sharing or reducing the risk and upfront cost of low-emissions infrastructure or technology projects, as well as by freeing up balance sheets (Stiglitz & Stern, 2017; UNDP, 2018). This, in turn, makes lending by private investors more attractive. In essence, financial guarantees become a “substitute for the collateral that businesses would have otherwise needed in order to access commercial lending and thus expand available credit” (UNDP, 2018). Financial guarantees are of most interest in situations where the risk of coordination failures or credibility issues exists (Cooper, 2005).

Financial guarantees can catalyse low-emissions investments by specifying priority sectors or borrower classes (eg, energy-efficient equipment or other infrastructure development). They can mitigate against commercial default risks (ie, by providing direct guarantees that take on either the full or partial debt obligation of the borrower in the case of default) (Figure 7-5). Yet they can also be structured to mitigate political or regulatory risks (such as changes of laws or regulations), or foreign exchange risk. The nature of financial guarantees means they can pose significant risk to taxpayers so they should be used judiciously and transparently.

Figure 7-5 Sovereign financial guarantees



Source: Magnusson (1999).

Government financial guarantees are offered in many jurisdictions, such as the United Kingdom and France, and through many delivery models, such as standalone institutions or within government agencies. Given that the fiscal risk from guarantees will be a function of the success rates of guaranteed projects, governments should set project risk thresholds with this in mind.

Several options exist for New Zealand to provide a government financial guarantee to help stimulate the low-emissions transition. A financial guarantee could be one of the mechanisms through which the proposed GIF provides support. Alternatively, the Government could establish a guarantee scheme (such as the UK Guarantees Scheme that can issue up to £40 billion worth of guarantees for nationally significant infrastructure projects), but mandate an eligibility requirement. Or the Government could provide guarantees through commercial banks for loans made to low-emissions activities.

Establishing a guarantee programme, especially if it targets major infrastructure development, is a substantial undertaking. Such a programme can be more financially intensive than a GIB, potentially requiring operational subsidies as well as initial capitalisation (UNDP, 2018). The Commission does not believe that a standalone government financial guarantee scheme is required. However, an approach based on financial guarantees may be suitable as part of the proposed GIF.

F7.5

Government financial guarantees reduce risk for private investors, thereby lowering the cost of finance. A standalone government financial guarantee scheme does not appear to be required in New Zealand at present. However, an approach based on financial guarantees may be suitable as part of the proposed Green Investment Fund.

Grants and loans

Government grants and loans aim to address technology and market risks (Figure 7-2). They may be used for technical assistance (eg, R&D), capacity-building, or for start-up capital. They can reduce overall project or technology development costs that are considered to be consistent with national priorities. One example is government co-funding to fill commercially unviable gaps in the national charging infrastructure network for electric vehicles (eg, to alleviate range anxiety concerns in rural areas) (Chapter 12). Direct government investment can be particularly relevant for low-emissions pilot projects “where the associated risks are very high and the economic profit uncertain” (Amin et al., 2014, p. 19).

Grants and loans may be provided separately, or used in conjunction. They may also be conditional upon the private sector getting involved (ie, as part of a “blended” finance package), to ensure private-sector investment is crowded in, rather than crowded out.

Loans with concessional rates (ie, lower than market rates) may be particularly relevant for the transition to a low-emissions economy. This is because they lower investment costs and reduce investment risks for the first movers in a market (Buchner et al., 2015). Identifying the correct concessional rate can be complex, particularly to ensure maximum leverage from additional private-sector investment (Amin et al., 2014).

In New Zealand, a variety of publicly-provided grants and loans exist. Grants are provided by, for example, Callaghan Innovation (Chapter 6), the Afforestation Grant Scheme (Chapter 11), Low-Emission Vehicles Contestable Fund (Chapter 12) and Warm Up New Zealand (Chapter 16). The Energy Efficiency and Conservation Authority distributes \$2 million worth of interest-free loans each year to energy efficiency and renewable energy projects, and Auckland Council offers loans to energy-efficiency projects at a rate of 6.6%.

Yet it is unclear how these grants and loans are working, or could be working, in tandem with other activities as part of an overall strategy to stimulate low-emissions investment in New Zealand. In their review of New Zealand’s climate-finance landscape, D. Hall and Lindsay (2017) suggest that an opportunity exists

for the New Zealand Government to build out its role as investment manager for climate change to provide a greater level of strategic direction to other grant-making participants so that they can provide future grants in a cohesive and coherent manner. (p. 34)

Section 7.7 focuses on the need to ensure strategic alignment between government funding that aims to stimulate the transition to a low-emissions economy in New Zealand.

F7.6

Public grants and loans can reduce market risk for the development and deployment of low-emissions technology. However, it is unclear how grants and loans should operate in conjunction with other types of Government funding that also aim to support the transition to a low-emissions economy.

Climate-related financial disclosure requirements

Transparency about the risks and opportunities arising from climate change is important to scaling up and redirecting investment to enable the transition to a low-emissions economy. Disclosure is important for two main reasons.

First, it is a powerful mechanism to direct the attention of reporting entities to the impact of climate change on their own activities (and, depending on the disclosure requirement, also of their entity as a contributor to climate change). Having a clear picture of a firm or organisation’s exposure to climate risk (both physical and transition risk, section 7.2), or how its activities may respond to opportunities created by policy settings, is vital to avoiding information and inertia barriers within the entity itself (section 7.4). This reduces the risk of stranded assets, and stimulates the transition via “the adage that ‘what gets reported on gets done’” (Z Energy, sub. DR377, p. 5). Further, if the emissions cost of entity activities was more transparent, high-emitting organisations may be less likely to obtain finance. The inability to do so might encourage the market exit (or transition to another activity) of those organisations. As Vector (sub. 63, p. 5) noted:

Robust and transparent measurement and reporting of carbon is the starting point for systematic reduction. Improving the disclosure of emitted and avoided emissions at an organisational and product level will assist decision making and enable reduction targets to be set.

Second, disclosure enables investors to make decisions across investment opportunities that accurately reflect the climate risk of those choices (LSEG, 2018). Without accurate and comparable information, investors may incorrectly value assets or investment opportunities, also resulting in misdirected finance or stranded assets. Disclosure therefore helps to increase investor understanding of, and demand for, low-emissions investments. Box 7.3 highlights the demand for better future-focused disclosure in New Zealand.

Box 7.3 The demand for future-focused disclosure in New Zealand

As part of the ReportingNZ project led by the McGuinness Institute in conjunction with the External Reporting Board (XRB),⁷² preparers and users of reports published by for-profit entities were surveyed about extended external reporting (EER). EER comprises all information beyond mandatory requirements, and includes topics such as ESG strategies and impacts (including GHG emissions).

Key messages included that:

- future-orientated information is an emerging requirement because it “delivers better decision making for existing and potential investors, government and other stakeholders”;
- users in particular want to be able to “make decisions based on timely, reliable, relevant and comparable EER information”, with a focus on “reporting on goals, strategies and targets”; and
- independent assurance is critical because it “inspires trust which enables companies to build good relationships with stakeholders, including suppliers, consumers and the wider public” (McGuinness Institute & XRB, 2018, p. 3).

Demand is substantial, as is recognition of the need for, future-focused disclosure in New Zealand: 85% of preparers and 96% of users indicated future orientation was an important or very important disclosure. However, only 56% of users thought it was being reported on well. Users consider this type of information when making investment decisions, understanding company strategies and future prospects, and making judgements about the operations and wider impacts of a company.

Disclosure can take many different forms, but a key distinction is between rules-based reporting and principles-based reporting. Rules-based reporting compels reporting entities to report according to specific and prescribed requirements. In contrast, principles-based reporting focuses on providing general guidelines for reporting entities to follow. The latter requires more judgement on behalf of reporting entities, but allows for reporting to provide the best available information that is meaningful for the entity in question, rather than focusing on compliance. However, the distinction between the two types of regimes can be somewhat artificial (B. Bennett et al., 2006), and best-practice disclosure may be most effectively captured by a blend of the two approaches (Responsible Investment Association Australasia, pers. comm. 20 June 2018).

Avenues for climate-related financial disclosure

The two main avenues for climate-related financial disclosure are through voluntary reporting frameworks, or through mandatory government requirements.

Voluntary reporting frameworks

Numerous voluntary frameworks exist for the disclosure of non-financial (including climate change) risk, building on an ESG approach (section 7.2). Most are principles-based, and include the Integrated Reporting Framework, the Global Reporting Initiative, the Climate Disclosure Standards Board Framework, and the UN Global Compact. Many New Zealand organisations report against these, with Integrated Reporting noted

⁷² The XRB is an independent Crown Entity responsible for establishing a trusted accounting and assurance standards framework.

specifically by several submitters (eg, Esperance Capital Ltd, sub. DR184; Chartered Accountants Australia and New Zealand, sub. DR208; Meridian Energy, sub. 253; Z and Energy Ltd, sub. DR377).

Stock exchanges have developed their own reporting requirements. For example, since 2014, the Australian Stock Exchange (ASX) has, according to a “comply or explain” rule, required listed entities to “disclose whether it has any material exposure to economic, environmental and social sustainability risks and, if it does, how it manages or intends to manage those risks” (ASX, 2014, p. 30). A comply or explain rule means that entities must provide an explanation if they do not comply with any of the requirements. It is considered to be a type of mandatory reporting, particularly in terms of being unable to avoid material breaches of compliance (ACCA, 2018).

In New Zealand, the NZX Listing Rules together with the NZX Corporate Governance Code apply to listed firms. Recommendation 4.3 of the code states that an issuer should

provide non financial disclosure at least annually, including considering material exposure to environmental, economic and social sustainability risks and other key risks. It should explain how it plans to manage those risks and how operational or non financial targets are measured. (NZX, 2017b, p. 19)

As with the ASX rules, this recommendation operates on a comply or explain basis. The NZX has also issued an ESG guidance note that extensively references the issue of climate change (NZX, 2017a).

To enable a more comprehensive and consistent framework for climate risk, a global Task Force on Climate-related Financial Disclosures (TCFD) was established by the G20’s Financial Stability Board in 2015. The aim was to “develop voluntary, consistent climate-related financial disclosures that would be useful to investors, lenders, and insurance underwriters in understanding material risks” (TCFD, 2017, p. iii). The TCFD recommended climate-related financial disclosure requirements in four areas (Figure 7-6).

Figure 7-6 Recommendations and supporting recommended disclosures from the Task Force on Climate-related Financial Disclosures



Source: TCFD (2017).

Notes:

- Scope 1 emissions are direct emissions from sources owned or controlled by the organisation (eg, emissions from company vehicles). Scope 2 emissions are indirect emissions from sources owned or controlled by the organisation (eg, emissions resulting from generating the electricity that is then purchased by the company). Scope 3 emissions relate to all other organisational activities (eg, waste disposal, employee commuting, or upstream or downstream distribution channels) (Carbon Trust, 2018b).

The TCFD identified the following as features of these recommendations:

- adoptable by all organisations (including banks, insurance companies, asset managers and asset owners) to enable widespread understanding across the corporate sector;
- included in mainstream (ie, public) annual financial filings to foster shareholder engagement and broader use of climate-related financial disclosures;
- designed to solicit decision-useful, forward-looking information on financial impacts; and
- strong focus on risks and opportunities related to the transition to a lower-emissions economy.

While the TCFD's recommendations are voluntary, global interest in how to implement them across different jurisdictions is substantial, particularly in terms of integrating the recommendations into existing regulation and soft law (Baker McKenzie & PRI, 2017). The recommendations should enable more consistent disclosures across and within sectors, and greater clarity on the scope of best-practice disclosures.

As well as being adopted by the G20, many entities have endorsed the TCFD's recommendations, including:

- the Governments of the United Kingdom, France and Sweden;
- the European Union's High-Level Expert Group on Sustainable Finance, the Monetary Authority of Singapore and the Australian Prudential Regulation Authority; and
- approximately 250 companies, including ANZ, the London Stock Exchange Group and Qantas Airways.

No formal rules define endorsement. However, in general, endorsement by a company means that the company commits to reporting consistent with the recommendations. Endorsement by a government or a financial regulator may mean encouraging companies (or a subset of companies, such as listed companies) to comply. But, it may also result in mandatory requirements. For example, partially in response to the TCFD recommendations, the UK Government recently announced a new Streamlined Energy and Carbon Reporting (SECR) framework (see below).

Mandatory government requirements

Many jurisdictions require climate-related disclosures, particularly for large or listed firms. In Europe, Directive 2014/95/EU requires certain large "public-interest" companies⁷³ to report on environmental matters to identify sustainability risks and increase investor and consumer trust. Companies must provide

details of the current and foreseeable impacts of the undertaking's operations on the environment, and, as appropriate, on health and safety, the use of renewable and/or non-renewable energy, greenhouse gas emissions, water use and air pollution. (Directive 2014/95/EU, 2014, p. 2)

In the United Kingdom, listed companies not already subject to Directive 2014/95/EU must, under the Companies Act 2006, provide information about "environmental matters (including the impact of the company's business on the environment)" necessary to understand the "development, performance or position of the company's business" (UK Government, 2013, p. 3). This includes supply-chain risks relating to environmental issues, and an assessment of main trends and other factors likely to affect the company in the future. This requirement will save an estimated 4 megatonnes of carbon dioxide (CO₂) equivalent by 2021 (Carbon Trust, 2018a).

However, in response to the need to create domestic policy distinct from European Union requirements (as a result of Brexit), the UK Government has recently published details of its new SECR framework. This requires all quoted companies and large unquoted companies⁷⁴ to report their energy use, CO₂ emissions and energy efficiency measures in their annual reports. It will come into force in April 2019 and will increase the

⁷³ Such as banks, insurers, financial services and listed companies.

⁷⁴ The SECR framework will apply to UK-incorporated unquoted companies and limited liability partnerships with at least 250 employees or an annual turnover greater than £36 million and balance sheet total greater than £18 million.

number of companies that publicly report energy and climate change information in their annual reports from approximately 1 200 firms to 11 900 firms (BEIS, 2018b).

The French Article 173 of the Law on Energy Transition for Green Growth (2015) has received substantial global attention for requiring extensive and mandatory emissions reporting. Article 173 directs companies to disclose financial risks on a comply or explain basis relating to the effects of climate change and the measures adopted by the company to reduce them, and directs institutional investors to identify how their policies align with the national strategy for France's transition to a low-emissions economy (PRI, 2016). Despite operating on a comply or explain basis, there is "no further guidance or agreement about the expectation of what would be a satisfactory explanation for non-compliance" (PRI, 2016, p. 7) in relation to Article 173. This implies that compliance is the expected norm.

A recommended disclosure regime in New Zealand

New Zealand has three broad options to consider when determining which type of disclosure regime will best achieve the twin goals of increasing entity attention to climate risk and opportunities, and helping investors make better decisions. The options are:

- to encourage voluntary reporting via industry;
- to interpret existing requirements as requiring disclosure; or
- to establish new government-mandated reporting requirements.

Encouraging voluntary reporting via industry

As explained above, many voluntary frameworks allow for climate-related disclosure (eg, the Integrated Reporting framework, the TCFD recommendations, or the requirements of the NZX). The TCFD recommendations are a relevant mechanism for climate-related risk disclosure. Endorsement of the TCFD's recommendations by the New Zealand Government would send a strong signal to the investor community that the Government considers disclosure an important mechanism to help achieve the transition to a low-emissions economy.

Even so, it is important to recognise that the TCFD approach is only one avenue for reporting climate-related risk. Other frameworks, as noted above, also allow for climate-risk reporting (often in conjunction with the reporting of other factors, such as social issues) and should not be discouraged, particularly if they resonate more with particular organisations or sectors. Given past experience with other disclosure regimes, it is also possible that alignment will increase in the future, both internationally and in New Zealand, about what constitutes best-practice climate-related disclosure, even across voluntary frameworks (Meridian Energy, sub. DR253; XRB, pers. comm. 11 June 2018).

F7.7

The recommendations of the Task Force on Climate-related Financial Disclosures relating to governance, strategy, risk management, and metrics and targets, offer a clear and consistent foundation for investors to assess the risks and opportunities related to climate change.

R7.3

The Government should endorse the recommendations of the Task Force on Climate-related Financial Disclosures as one avenue for the disclosure of climate risk.

However, voluntary reporting is problematic for two reasons. First, a lack of coverage means that voluntary reporting is unlikely to encourage reporting across all relevant entities. For example, the limited number of firms on the NZX means that its reporting requirements will have a relatively small effect on driving investor awareness and behaviour change across the economy of the scale necessary to achieve New Zealand's mitigation goals.⁷⁵ Second, and despite the potential for convergence of frameworks, relying solely on

⁷⁵ 161 firms operate on the NZX main board. Yet this represents less than half of all New Zealand organisations with more than 500 employees, and only a quarter with more than 300 employees. As 500 employees is the minimum size for most mandatory climate reporting regimes internationally, that minimum

industry-developed reporting requirements is unlikely to allow for the type of consistent and credible reporting required for investors to make adequately informed decisions across different opportunities.

F7.8

Voluntary reporting frameworks (such as the guidelines provided by the New Zealand Stock Exchange) provide a positive foundation for firms to disclose climate-related risks. Yet their lack of coverage across the economy, and varying reporting requirements, means that they will not be sufficient to drive behaviour change across the New Zealand economy.

Interpreting existing requirements as requiring disclosure

In New Zealand, company reporting requirements are mainly set out in the Companies Act 1993. For listed firms, the Financial Markets Conduct Act 2013 also applies. These both then interact with the standards developed by the XRB (developed under the Financial Reporting Act 2013). As the XRB explains:

[T]he law states which types of entities must prepare financial statements that apply XRB standards, publish financial statements and obtain assurance on them. The XRB standards themselves then state *what* and *how* entities must report (XRB, 2018).

While the Companies Act does not explicitly oblige reporting about climate change, it may be possible to interpret some of the requirements about the content of the annual report as covering climate risk. Specifically, Section 211(1)(a) requires that the annual report must

describe, so far as the board believes is material for the shareholders to have an appreciation of the state of the company's affairs and will not be harmful to the business of the company or of any of its subsidiaries, any change during the accounting period in—

- (i) the nature of the business of the company or any of its subsidiaries; or
- (ii) the classes of business in which the company has an interest, whether as a shareholder of another company or otherwise.

Climate risk could be considered to be information material to shareholders (or potentially harmful to the business of the company) (EY, 2018b). In an analysis of climate risk disclosure practices in Australia, Foerster et al. (2017) investigated whether such an interpretation could be made of similar reporting requirements contained within Australia's Corporations Act 2001. They note that the contents of the Director's Report could be interpreted as including an analysis of climate risk, including the requirement to

contain information that members of the listed entity would reasonably require to make an informed assessment of: the operations of the entity; the financial position of the entity; and the business strategies and prospects for future financial years. (Foerster et al., 2017, p. 163)

However, the authors conclude that climate-related risks are not consistently perceived as material financial risks, even by large emissions-intensive Australian businesses. This means that climate risk is unlikely to be reported under standard guidance, and particularly unlikely to be reported in the consistent and credible manner necessary for investors to make informed decisions across different investment opportunities. New research by the McGuinness Institute (2018) also supports this view. They found that even for significant New Zealand entities, reporting of climate change (including risk, costs, targets and initiatives), was low. For example, across all significant entities identified, only 42 (11%) provided information about climate risk, and only 5.5% provided information about specific goals to reduce future emissions.

It is therefore unlikely that existing requirements will adequately incentivise necessary disclosure of climate risk. As the Insurance Council of New Zealand submission contends,

[i]t could be argued that such measures are not necessary because Boards already have a fiduciary duty to report to their shareholders about liability, impaired assets and bad debts, all of which can be adversely affected by climate change impacts. Even if this is the case, it is evident that few companies

size is used here for comparability (even though many of the NZX firms may not have 500 employees). Firm counts are derived from the New Zealand Longitudinal Business Database.

do report these risks or take a sufficiently long view, and certainly there is no consistent, clear and comparable reporting. (sub. 104, p. 4)

F7.9

Existing financial reporting requirements, including those in the Companies Act 1993, will likely be insufficient to adequately incentivise the disclosure of climate risk in a consistent and credible way.

Establish new government-mandated reporting requirements

Given the arguments against solely relying on voluntary reporting mechanisms, or existing reporting requirements as detailed above, additional mandated climate-related disclosure requirements will likely be needed in New Zealand. Some submitters supported this view, including the Guardians of NZ Superannuation (sub. 32), the Energy Management Association of New Zealand (sub. 70), the NZ Institute of Forestry (sub. 73), Meridian Energy (sub. DR253) and Z Energy Ltd (sub. DR377). Esperance Capital (sub. DR184) and Chartered Accountants Australia and New Zealand (sub. DR208) opposed mandatory disclosure.

Reporting can be made mandatory through primary or delegated legislation. Delegated legislation includes regulations and rules made by other parties (such as officials) by powers delegated to them by Parliament (McGee, 2017). As shown in the international examples above, climate-related disclosures may be enacted under primary legislation. However, in New Zealand, the possibility of issuing a financial reporting standard (a form of delegated legislation) via the XRB is also worth considering.

Under section 17(2) of the Financial Reporting Act 2013, the Governor-General can authorise the XRB to issue financial reporting standards relating to matters such as an entity's governance, strategic direction and targets and, under section 17(2)(iii), "the social, environmental, and economic context in which an entity operates". Climate-related disclosure fits neatly into this definition and would comprise an accounting standard (as opposed to an auditing and assurance standard). Accounting standards determine the reporting requirements for three main types of entities: for-profit, not-for-profit, and public-sector entities. These standards apply to entities in different ways based on a tier system (relating to the entity's size and purpose). Climate-related disclosure would need to be allocated to a particular tier or group of tiers, and consider aspects of materiality and administrative burden.

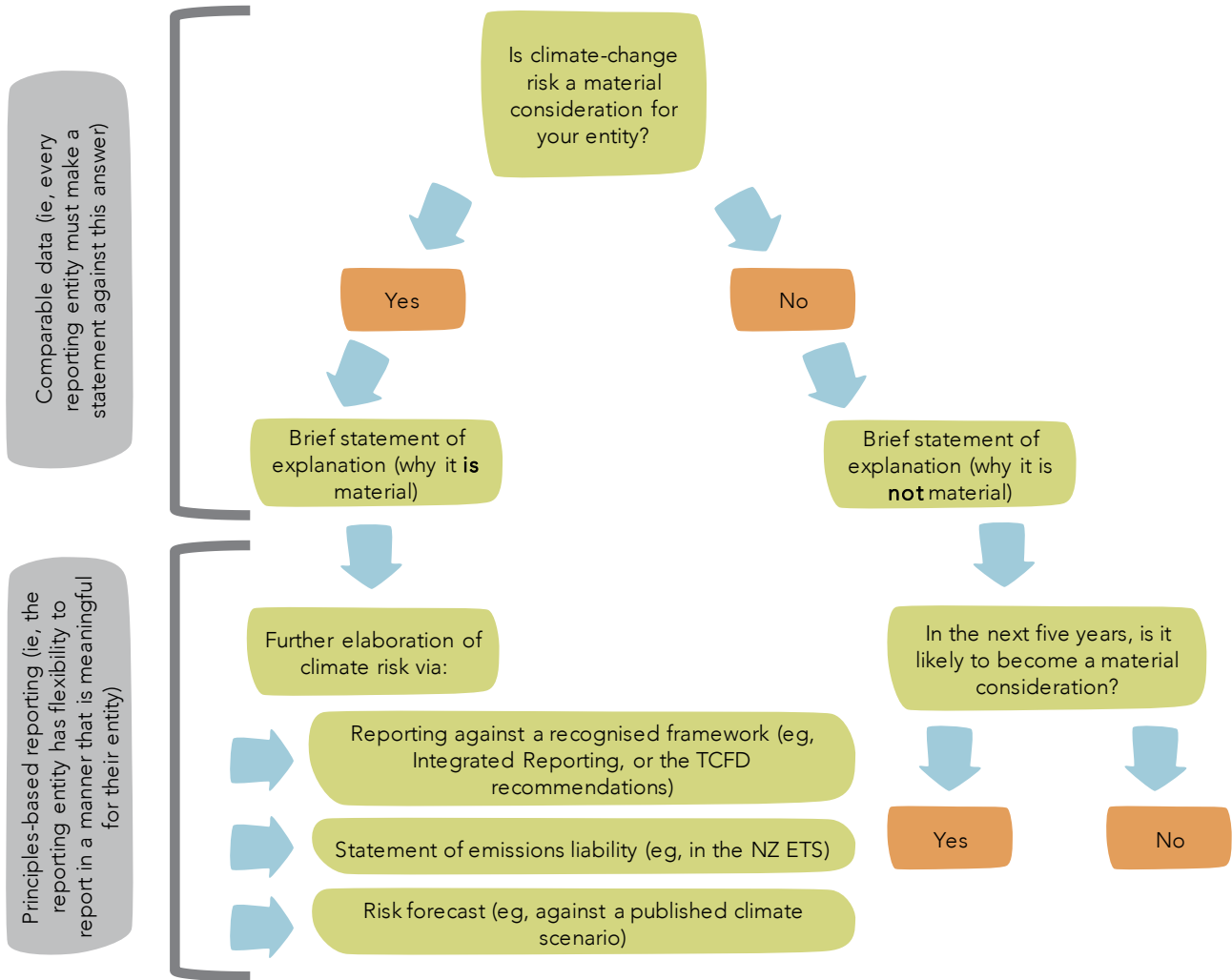
Using a delegated approach for climate-related disclosures offers many benefits, most notably the ability to provide greater detail and regulatory flexibility as opposed to the tight prescriptions of a requirement laid out in primary legislation (NZPC, 2014b). A standard could allow for a blend of rules and principles-based reporting, as shown in Figure 7-7⁷⁶ (which outlines a potential decision-tree approach for a climate-related standard on a comply or explain basis). In this blended approach, the vital comparable data for investors (ie, the more rules-based approach) is contained within the statement about materiality of climate risk. The main part of the standard (where the substantive disclosure occurs) is principles-based.

A predominantly principles-based approach, supplemented by information required of all reporting entities, is useful for numerous reasons. The base information allows for comparability and benchmarking, but the principles-based approach allows for flexibility for the entity to tell their own story about climate risk (eg, by the choice of reporting framework that is most suitable for that entity) (CDSB, 2016). The value of this blend was specifically noted by Meridian Energy (sub. DR253, p. 18):

Given the range of frameworks available internationally, we would suggest that firms retain some discretion regarding the use of a particular framework, provided that certain critical information is included as mandatory.

⁷⁶ This example focuses on the risk to the entity, but it is feasible that a complementary standard could also be developed about whether the entity was a significant contributor to climate change.

Figure 7-7 Climate-related disclosure decision tree



Notes:

1. The test for materiality can be summarised as whether it would have impacted decision making had it been known.
2. About risk forecasting, Matikainen (2017b) notes that any issued guidance should include information on common scenarios given the need for forward-looking analysis.

A principles-based approach is valuable for investors because it provides a level of confidence in the sophistication of the understanding of climate-risk by that entity (Responsible Investment Association Australasia, pers. comm. 20 June 2018). It also avoids unnecessary regulatory burden, because the inherent flexibility via the blend of a rules and principles-based approach allows for integration with other reporting frameworks and mechanisms for ESG reporting (ie, beyond climate change). This need for a holistic reporting framework across extended external reporting topics (and in a way that does not create undue reporting burden) was a notable theme of submissions (External Reporting Board, sub. DR164; Esperance Capital Ltd, sub. DR184; and Chartered Accountants Australia and New Zealand, sub. DR208).

It is important that climate-related disclosure should occur in the “mainstream annual financial filings” (TCFD, 2017, p. iv) so that it is audited and publicly available. Such disclosure is also needed to elevate the status of climate-related financial disclosure.

In New Zealand, only financial statements are required to be filed on the Companies Office register (and are audited), as compared to the wider annual report. Yet many significant entities in New Zealand do file their complete annual report (including their financial statements), and this “highlights an opportunity for government to require all companies that are currently required to file their financial statements to instead file their complete annual report” (McGuinness Institute, 2018, p. 49). Whether through such a requirement or otherwise, it will be important that climate-related disclosures occur in a manner that ensures their verifiability and accessibility will be important.

Before issuing a standard, the XRB carries out an extensive process of consultation. The Commission understands that the Ministry for the Environment (MfE), the XRB and the Ministry of Business, Innovation and Employment are currently discussing how climate-related financial disclosure requirements may be enacted in New Zealand. The numerous issues to consider (such as the relevant tier of entities required to disclose, and the specific wording of the standard) will also require substantial engagement with industry.

F7.10

A standard issued via the External Reporting Board under section 17(2)(iii) of the Financial Reporting Act 2013 is the most suitable avenue for climate-related disclosure in New Zealand.

R7.4

The Government should implement mandatory (on a comply or explain basis), principles-based, climate-related financial disclosures by way of a standard under section 17(2)(iii) of the Financial Reporting Act 2013. These disclosures should be audited and accessible to the general public.

7.6 Other supporting actors for the low-emissions transition

Central banks and financial regulators

Central banks and financial regulators play an important role in financial regulation and monetary policy. This is relevant to climate policy given the risks to market stability from an unpredictable or abrupt transition, and the potential opportunity for improved financial and macroeconomic stability if climate change is adequately factored into investors' decision-making (section 7.2 and Ryan-Collins & van Lerven, 2017). Monnin (2018) explains:

Climate change is a significant risk for our societies and transitioning to a low-carbon economy a key challenge we must meet. Central banks must not stand on the sidelines in this process. They need to safeguard financial stability by taking appropriate measures to strengthen financial market resilience vis-à-vis climate-related risks, and they need to align their policies with the shift in investments that the transition to a low-carbon economy requires (p. 13).

A role for central banks or financial regulators is to assess the exposure of their domestic financial system to climate risk (Monnin, 2018). This is complementary to, but more high-level than, the assessment of climate risk required through disclosure at the firm or investor-level. Once climate stress-testing occurs, central banks and regulators can then determine whether any changes are required, such as ensuring climate-aligned financial regulation or conducting other activities such as corporate bond purchases (Campiglio et al., 2018; Matikainen et al., 2017).

Many central banks have either recently conducted, or are in the process of conducting, such reviews. For example, the Bank of England's Prudential Regulation Authority has written to local and international banks operating in the United Kingdom to ask them how they are thinking about, and managing, climate risk. A report outlining the banks' responses is expected in 2018 (Bank of England, pers. comm. 11 October 2017).

In a review of the Dutch financial system, De Nederlandsche Bank concluded that the financial sector has considerable exposure to high-emissions sectors. In response, it intends to "embed climate-related risks more firmly in financial supervision with the aim of ensuring sustainable financial stability" (DNB, 2017, p. 4). The Swedish Financial Supervisory Authority, Finansinspektionen, also commissioned a report on "how environmental and climate change may affect financial stability in the long run, and which measures may be needed to dampen the negative effects on the financial system" (Bowen & Dietz, 2016, p. 5).

New Zealand currently has no whole-of-economy understanding of the level of financial exposure to climate risk. This lack of understanding is a substantial information deficit. As Monnin (2018, p. 5) contends, this "information is not only crucial for regulators, but also for financial market participants to adequately reflect climate-related risks in their investment decisions". One particularly suitable avenue to rectify this

information deficit is for an assessment of climate-related systemic risk in the New Zealand financial sector to explicitly form part of the Reserve Bank's regular stress-testing process (RBNZ, 2018).

F7.11

Central banks can play an important role in assessing the exposure of financial systems to climate risk, particularly in relation to risks of financial instability.

Institutional investors

Holding over US\$55 trillion in assets worldwide, institutional investors, such as pension funds and insurance companies, represent a large potential source of finance for the transition to a low-emissions economy (OECD, 2012b, 2015d). In New Zealand, the combined ACC and NZ Super Fund portfolios alone represent nearly \$67 billion⁷⁷ worth of invested funds (ACC, 2017; NZ Super Fund, 2017). New Zealand institutional investors also manage approximately \$10 billion of New Zealand equities (NZ Super Fund, 2015).

Institutional investors are increasingly moving towards diversified portfolios as a mechanism to dilute risk (OECD, 2014). As a result, infrastructure investments (as opposed to more traditional sources of institutional investment such as private equity or real estate) are becoming more prevalent (Environment Audit Committee, 2014). Low-emissions infrastructure can provide an excellent match for institutional investors, particularly due to the longer time horizons involved. However, because institutional investors have different liquidity and liability profiles (eg, life insurance funds have less scope to invest in illiquid assets because policy holders can withdraw funds at any time), there is a

need for expanded and diversified channels of financing for low-carbon infrastructure, which can cater to different investment horizons, risk appetites, liquidity needs, and capacities to invest in potentially complex and large-scale projects. (OECD, 2017c, p. 268)

There do not appear to be any major barriers to New Zealand institutional investors finding adequate low-emissions investments of a suitable type. For example, via a wholly-owned US-based subsidiary, the NZ Super Fund directly owns a 45% stake in Longroad Energy Holdings, LLC, a US company developing utility-scale renewable energy facilities throughout North America.

It is possible to require public institutional investors to prioritise low-emissions investments. For example, Christchurch City Council (sub. 13) suggested that both central and local government investments could be required to be limited to low-emissions activities. The Council also proposed that central and local government procurement of financial services could "include a weighting with regards to evaluating the providers' investments and loans in low emission activities, e.g. based on low emission indices" (p. 7). Te Rūnanga o Ngāi Tahu (sub. 83) identified preferential purchasing policies that could be applied to institutional investors as a mechanism to incentivise low-emissions businesses and business practices.

It may also be feasible that fossil fuels investments (or other particularly emissions-intensive activities) could be added to institutional investors' exclusion lists (ie, activities the fund does not invest in for ethical or other reasons). For example, the NZ Super Fund excludes investments in activities such as the manufacture of tobacco and cluster munitions, recreational cannabis, and the processing of whale meat (NZ Super Fund, 2018).

An alternative option is to guide public institutional investors using a principle-based approach. Millar et al. (2018) propose three principles that institutional investors could use when determining suitable investments (Figure 7-8). A substantial amount of further engagement with public institutional investors would be required before any changes to investment mandates occurred.

⁷⁷ ACC has \$37.3 billion of funds under management; NZ Super Fund has \$29.6 billion invested globally.

Figure 7-8 Principles to guide investment towards a stable climate

- | | |
|---------------------------------------|--|
| 1: Commitment to net-zero emissions | All industries must eventually reach net-zero emissions, even if some industries do so before others. Companies should commit to a date (or a temperature increase, such as 1.5 °C or “well below 2°C”) before which the net CO ₂ emissions associated with their activities (including both supply chains and products sold) will be zero. |
| 2: Profitable net-zero business model | Company executives should have business plans that ensure the profitability of their business, and limit supply chain risks, once emissions reach net-zero. |
| 3: Quantitative mid-term targets | Mid-term targets (for example, for 2030) that are directly relevant to achieving a net-zero business model, such as the rate and long-term trajectory of reductions in CO ₂ emissions, are vital to properly assess compatibility with the Paris Agreement. |

Source: Millar et al. (2018).

F7.12

Institutional investors, such as pension funds and insurance companies, represent a large potential source of finance for the transition to a low-emissions economy. There do not appear to be any major barriers to New Zealand institutional investors finding adequate low-emissions investments of a suitable type.

Māori investment

Iwi in the post-settlement era, and Māori land-owning trusts and incorporations, are increasingly important investors in the New Zealand economy (Te Rūnanga o Ngāi Tahu, sub. 83). The size of the Māori economy is substantial, with estimates ranging up to \$50 billion (Chapman Tripp, 2017). However, this portion of the New Zealand economy lacks centralised data gathering and projections (Te Rūnanga o Ngāi Tahu, pers. comm. 26 March 2018).

The values of kaitiakitanga guide iwi investments with a multigenerational perspective that fits with climate change mitigation strategies. The long-term and multi-objective nature of iwi investment (ie, that goes beyond maximising financial returns) is particularly relevant (TDB Advisory, 2017). Ngāi Tahu (sub. 83, p. 5) note that “kaitiakitanga is about ensuring that future generations have a relationship with Te Ao Tūroa (the natural world) that sustains them in the way that generations before have been sustained”. They also note that, like other iwi, they are heavily invested in businesses that will be at the heart of climate change mitigation and adaptation – fisheries, farming forestry, tourism and property. Te Rūnanga o Ngāi Tahu considers that these perspectives and interests make iwi natural partners with central and local government and business in achieving transformational change in the New Zealand economy.

Outside the Treaty of Waitangi settlement framework, some Māori landowners have issues with raising capital because of multiple ownership of land and the nature of Māori freehold title (Chapter 11). This makes it more difficult to invest in measures to reduce agricultural GHG emissions (Insley & Meade, 2008). Barriers to afforestation are lower, as international and domestic investors are ready to work with Māori landowners under agreements covering harvesting rights and the treatment of credits and liabilities under the New Zealand Emissions Trading Scheme.

Suggested solutions to stimulate the Māori economy include an iwi bank, and reporting on business relationships to Māori within the environmental and social spheres (Te Rūnanga o Ngāi Tahu, pers. comm. 26 March 2018). The Iwi Leaders Group also held a National Māori Leadership hui on climate change in 2018. At this hui the group supported a drive to encourage iwi members to incorporate climate change risk assessment tools to guide all investment decisions being made for collective funds.

7.7 Aligning government investment

Alignment of policies and interventions to support the transition to a low-emissions economy is fundamental (OECD, 2015a). Aligning policies ensures that government initiatives do not work at cross-purposes, do not duplicate effort and waste scarce public funds, and are also directed into those areas most likely to achieve desired emissions reductions (Matikainen, 2017a). Policy alignment is also important between regulatory settings (such as emissions pricing) and instruments that aim to de-risk and encourage further private-sector investment (Stiglitz & Stern, 2017). Further targeted support to close funding gaps must be clearly justified to avoid crowding out private-sector investment. That targeted support must also be appropriate to the stage and nature of the types of infrastructure and technology.

Many other jurisdictions have identified the need to align government investments, and to further develop the green investment landscape.

- The European Commission's *Action Plan for Sustainable Finance* (European Commission, 2018a) includes disclosure (to align requirements with the TCFD recommendations), identifying a common taxonomy for sustainable investment (Box 7.4), and incorporating sustainability in prudential requirements.
- The UK Government is currently coordinating a Green Finance Taskforce that brings together senior financial sector leaders to identify ways to accelerate the growth of green finance, and help to deliver the investments required to meet the United Kingdom's carbon reduction targets (UK Government, 2017b).
- In 2016 China developed its *Guidelines for Establishing the Green Financial System*, aiming to divert investment from high-emissions to low-emissions activities. It includes a green guarantee programme and a national green development fund (UN PAGE, 2016).
- The Norwegian *Roadmap for Green Competitiveness in the Financial Sector* identifies the need for a common taxonomy for sustainable finance and disclosure consistent with the TCFD recommendations. It recommends including climate risk in the mandate of the financial supervisory authority, and climate criteria as a requirement for all residential and commercial mortgages (Finans Norge, 2018).

Box 7.4 What should be counted as "low-emissions investment"?

Many countries' low-emissions investments strategies identify the need to understand exactly what is meant by a "green" or "low-emissions" investment. This is important so that progress (and the additionality caused by public interventions crowding-in private finance) can be measured (EU High-Level Expert Group on Sustainable Finance, 2018). Without clarity on what is or is not categorised as low-emissions investment, so-called "greenwashing" can occur. This is where business-as-usual lending is repackaged as climate-related lending. For example, the National Australia Bank has been criticised as labelling lending for business-as-usual residential property development to minimum mandated energy efficiency standards as "climate change financing" (Jewell, 2017).

While climate finance mobilised to developing countries is tracked (Ellis & Moarif, 2016; Vallejo et al., 2017), no assessment, or consistent definition, of similar types of domestic public investment yet exists in New Zealand. The OECD (2017f) recommends that countries should explore possibilities for collecting data on private finance for climate action.

New Zealand does not have a strategically aligned view of its investment system in terms of the direct funding offered by government supportive of the low-emissions transition. Nor does it have a more comprehensive view of how investment and finance policy in general could or should support the low-emissions transition. Several submitters supported taking a more strategic view (eg, Chartered Accountants Australia and New Zealand, sub. DR208; Kate McNab, sub. DR219; Pure Advantage, sub. DR239; and Carbon Neutral Waiheke, sub. DR381). Some submitters also contended for a wider scope encompassing sustainable finance, rather than just emissions mitigation.

The scope [of a low-emissions investment strategy] should be broadened...to encompass a sustainable finance strategy, recognising that investment is a part of broader financial flows and a low emissions strategy is an integral part of a broader sustainability agenda, with strong interconnections between reducing emissions and other aspects including waste reduction, resource efficiency, equity and long term sustainability. (Barry Coates, sub. DR374, p. 4)

New Zealand should not limit this opportunity to set a coherent plan for finance to greenhouse gas emissions alone and should rather be establishing a Sustainable Finance Roadmap for New Zealand, including elements of the low-emissions investment strategy, to align finance with Paris Agreement objectives, but going further to align with other national environmental and social objectives such as the Sustainable Development Goals. (Responsible Investment Association Australasia, sub. DR329, p. 7)

MfE has a specific work programme on climate finance and recently published a report on the climate finance landscape in New Zealand (D. Hall & Lindsay, 2017). This report also identifies a need to address “structural and policy misalignments that incentivise high-emissions activities and that dilute or counteract enabling factors for climate finance” (p. 3).

A strategic view across public-sector interventions is important to accelerate progress in a coordinated and non-duplicative manner, as well as to visibly monitor the impact that public-sector, climate-related investment is making (which in turn helps to reduce information and inertia barriers). There is a pressing need to consider the alignment of direct government funding. This means ensuring that grant and loan funding, the proposed Green Investment Fund, and support offered through the innovation system (Chapter 6) is carried out in a manner that both discourages high-emissions, path-dependent activities, and encourages low-emissions, path-dependent activities (Levin et al., 2012; Ballance Agri-Nutrients Ltd, sub. DR285). Learning from the efforts of other jurisdictions in this area, the Government should provide a definition what counts as “low-emissions investment” in the New Zealand context (Box 7.4).

R7.5

The Government should align its project and programme funding so that it discourages high-emissions, path-dependent activities, and encourages low-emissions, path-dependent activities. This alignment should be supplemented by work to define what constitutes low-emissions investment, with the aim of identifying a clear taxonomy.

7.8 Conclusion

The low-emissions transition requires a re-orientation of public and private investment away from emissions-intensive activities and towards those that support and catalyse low-emissions energy, land use and other activities. Stable and credible climate policy, combined with emissions pricing, will go a long way towards redirecting investment flows. But issues such as information and inertia barriers, and coordination failures, also exist and require government attention. Requiring climate-related financial disclosure is an important action government can take to encourage investment supportive of the low-emissions transition. It would encourage reporting entities to better manage their own risks during the transition, and provide investors with clear and comparable information about investment opportunities in order to mitigate against stranded assets. Other actions are needed including implementing the proposed Green Investment Fund, and ensuring that government funding (eg, via grants and loans) is aligned so that it discourages high-emissions path-dependency, and encourages low-emissions path-dependency.

8 Laws and institutions

Key points

- The long-term nature of climate change (literally spanning generations) and the deep uncertainty associated with the future, presents a credible commitment problem in formulating a long-term policy response. There are strong political incentives to avoid making long-term policy decisions that will have short-term cost and impacts, but benefits that manifest well into the future.
- Well-designed laws and institutions can play a critical role in providing a strong signal about future policy intentions and act as a commitment device to help drive the development and implementation of a long-term policy response to climate change. In this way, laws and institutions provide policy stability and credibility.
- New Zealand has an existing climate change regulatory framework, but it is not underpinned by a credible commitment to a domestic low-emissions transition. The current systems architecture lacks long-term stability and predictability about the nature and pace of New Zealand's low-emissions transition, lack of a clear plan for reducing domestic emissions, and exhibits poor policy coherence.
- New Zealand needs a reformed statutory framework that requires long-term thinking, promotes policy stability and provides signalling, yet allows flexibility about the precise path to the long-term goal: essentially ensuring an eye is kept on the long-term compass while letting the tiller be adjusted along the way.
- A new architecture for New Zealand's climate change legislation should be built on principles of transparency and accountability, with a backbone based on mandatory processes. It should include the following mutually reinforcing elements:
 - legislating for long-term greenhouse gas emissions-reduction targets;
 - a system of emissions budgeting;
 - a statutory duty to prepare and publish a long-term low-emissions economy strategy;
 - clear mandatory reporting obligations, including regular reporting to Parliament; and
 - creation of an independent climate change institution to provide objective analysis and advice.
- An independent Climate Change Commission (CCC), set up as an independent Crown entity, would help to insulate policymaking from short-term political pressures, promote stability and predictability, expand climate policy debate, and improve transparency and accountability. However, decision-rights should not be delegated to such an independent body.
- The Government should seek to achieve broad political consensus for any new climate change law, with an aim of enacting legislation that has a strong prospect of policy and legislative durability regardless of the make-up of the Government over time.
- A legislative target, mandatory processes and an independent Climate Change Commission are necessary, but not sufficient, for an effective and efficient emissions-reduction strategy. Developing the government response to meet emissions budgets and targets will be a substantive and challenging policy process. It will require leadership from the centre of government and policy alignment across government.

An important theme in this report is that a long-term perspective must be introduced into politics and policymaking, domestically and internationally. The long-term nature of climate change and deep uncertainty associated with the future requires political commitment and durability that spans many generations. For it is those future generations who will live with the consequences of policy decisions made today to reduce emissions and curb the impacts of climate change. It is therefore not surprising that in their submission to this inquiry, Generation Zero—a youth-led organisation in New Zealand—say, “We believe a Zero Carbon Act, backed by cross-party agreement, is the most urgent and important law that our next Parliament could legislate” (sub. 119, p. 3).

This chapter examines and makes findings and recommendations on:

- the role of laws and institutions in supporting a low-emissions transition;
- New Zealand’s existing emissions-reduction response, and reforms to New Zealand’s legal framework;
- the need for, and key design features of, an independent climate change institution; and
- the role of central government in leading the transition to a low-emissions economy.

8.1 The role of laws and institutions

The credible commitment problem

As outlined in Chapter 1, climate change is a long-term problem. Achieving a low-emissions economy for New Zealand requires early action and a long-term enduring response. Action is needed in the face of deep uncertainty and in the context of a global public good (with its incentives to free-ride). Yet a time inconsistency challenge exists, because optimal policy decisions for the future may be at odds with optimal policy decisions in the short-term. Further, the nature of democratic political systems (where the political executive governs based on short-term electoral cycle mandates) tends to favour short-term interests over long-term interests (Averchenkova & Bassi, 2016; Brunner et al., 2012; Hovi et al., 2009). This presents a problem for any government to credibly commit to a long-term policy response (the so-called “credible commitment problem”). The Governor of the Bank of England, Mark Carney, puts it this way, “climate change will be felt beyond the traditional horizons of most actors – imposing a cost on future generations that the current generation has no direct incentive to fix” (Carney, 2015).

Well-designed laws and institutions can play a critical role...

Well-designed laws and institutions can promote long-term stability by acting as “commitment devices” and signalling a clear, long-term policy direction.

Commitment devices help to overcome the credible commitment problem by placing political transaction costs in the path of policy change (Brunner et al., 2012). As Boston explains:

[t]he concept of a ‘commitment device’ refers to a mechanism that is designed to change the structure of intertemporal pay-offs and/or limit future discretion by binding a person, organisation or government to a particular course of action. Commitment devices can take many different forms, from marriage vows to multi-party agreements. In the policy realm they can include constitutional or quasi-constitutional mechanisms, procedural and substantive devices, and mechanisms that are designed to insulate decisions from short-term political influence (e.g. transferring decision-rights to an independent group of experts) (2016) p.23.

New Zealand’s fiscal and monetary regulatory frameworks are examples of policy domains where “strong commitment devices have been implemented to protect future-oriented interests” (Boston, 2016, p. 21); section 8.4.

Overarching framework legislation is particularly important to provide a comprehensive, unifying basis to drive climate policy (Nachmany et al., 2015). Averchenkova and Bassi (2016, p. 14) identify that “legislation can be a powerful instrument to prevent policymakers from backtracking from policy commitments.” Domestic legislation is also “the absolutely critical, essential, linchpin between action at the national level and international agreements” (Figueres, 2013); Box 8.1. Domestic law plays an important role in the context

of the Paris Agreement's "bottom-up" framework of allowing individual countries to set their own nationally determined contributions (NDCs) to reducing emissions (Chapter 2).

Box 8.1 **The relationship between international and domestic climate-change obligations**

The power to enter or withdraw from international treaties sits with the political executive. International treaty obligations are binding at international law, but the executive cannot change New Zealand's domestic law by becoming party to a treaty. So, to have effect in New Zealand, international obligations must be incorporated into New Zealand law (Costi, 2016; Legislation Advisory Committee, 2014; MFAT, 2017).

The Paris Agreement (which qualifies as an "international treaty") is unusual because it includes many provisions that are not binding. The Agreement "contains a carefully calibrated mix of hard, soft and non-obligations, the boundaries between which are blurred" (Rajamani, 2016, p. 358). Therefore it is a package of both obligations and expectations (New Zealand Government, 2016). For example, individual countries must communicate their NDC every five years, but can set their own emission reduction commitments. The Paris Agreement also establishes a "good faith expectation" that countries intend to achieve their contributions, but stops short of imposing legally binding obligations to do so (Rajamani, 2016; Rive & Harker, 2017). Detailed rules to operationalise the Paris Agreement (such as arrangements for international trading and accounting rules) are still being negotiated, with the aim of having the "Paris Rulebook" finalised by the end of 2018 (Timperley, 2017).

F8.1

The long-term nature of climate change, literally spanning generations, and the deep uncertainty about the future, presents a credible commitment problem in formulating and implementing a long-term policy response.

Well-designed laws and institutions can play a critical role as commitment devices to help drive the development and implementation of long-term response strategies.

...but must be underpinned by political consensus

Laws and institutions can reflect, and help to hold in place, political consensus about core regulatory goals and regulatory frameworks.⁷⁸ Creating new laws and institutions can potentially also help political consensus to form, as the "asymmetry" of legislation (and politics) means that a successor government may find it much harder to repeal legislation once in place than to decide not to introduce it (Rutter & Knighton, 2012). While political consensus sometimes crystallises before new laws and institutions are introduced, it can develop sequentially (as occurred for example with the Fiscal Responsibility Act 1994 and the Reserve Bank Act 1989).⁷⁹

Ultimately though, laws and institutions will not endure unless underpinned by political consensus. Legal and institutional arrangements that lack substantial cross-party support will not provide the long-term stability and predictability needed for an effective low-emissions transition. For example, if the core elements of legislation (such as a long-term, emissions-reduction target) risk being repealed by successor governments, investors will not be sufficiently confident to rely on the current law when making long-term investment decisions. This point was strongly made by a number of submitters to the Draft Report (eg, Toyota New Zealand, sub. DR177; New Zealand Super Fund, sub. DR334; Federated Farmers, sub. 310; Fletcher Building, sub. DR349; First Gas, sub. 316; Ballance Agri-Nutrients, sub. 285; PEPANZ, sub. DR328; Genesis Energy, sub. 301; Todd Corporation, sub DR 373).

⁷⁸ The UK's Climate Change Act 2008, for example, has been credited with helping to preserve the political consensus on the need for climate action and the UK's long-term ambition (Fankhauser et al., 2018).

⁷⁹ The Fiscal Responsibility Act, for example, did not have cross-party support when it was passed in 1994 by a bare National-led majority.

So support across political parties is vital; climate change is the ultimate intergenerational issue, and governments change (PCE, 2017). The United Kingdom’s (UK) Climate Change Act 2008 for example (which is viewed as world-leading climate-change legislation) was enacted with overwhelming cross-party support. Political consensus about the architecture of the legislation has been key to the Act’s success and political durability (BEIS, pers. comm., 13 November 2017; Weeks, 2017).

F8.2

Long-term political commitment is essential to the success of climate change laws and institutions. Substantial cross-party support for the core elements of the statutory and institutional arrangements will help provide policy permanence regardless of the make-up of the Government.

8.2 A regulatory framework...but no credible commitment to a domestic low-emissions transition

New Zealand already has in place a regulatory framework for mitigating climate change that includes international commitments, domestic laws, policies and institutional arrangements. Core elements of the existing regime include:

- emissions-reduction targets for 2030 and 2050 (Chapter 2);
- a central piece of climate change legislation, the Climate Change Response Act 2002 (CCRA) that “forms the backbone” of New Zealand’s climate change policy (Grantham Research Institute on Climate Change and the Environment & Law, 2018). In its current form, the CCRA has a “three-pronged” purpose: enabling New Zealand to meet its international obligations, setting up the New Zealand Emissions Trading Scheme (NZ ETS), and providing for a synthetic gas levy (section 3(1) CCRA; Rive & Harker, 2017);
- a key policy tool for reducing emissions, the NZ ETS (Chapter 5); and
- institutional arrangements within government that include a Climate Change Minister, the Ministry for the Environment (MfE) as lead department and a range of other bodies with key responsibilities in areas such as energy, transport, agriculture and forestry (Chapter 2).

Despite the existing regulatory framework, New Zealand is not on track to meet its 2030 target (Chapter 2) and has “yet to begin making a real transition to a low-emissions economy” (PCE, sub. 54, p. 3).

Barriers to “bending the curve” of emissions include various sector specific issues (identified in other parts of this report). At a broader level, key cross-cutting issues identified by submitters to this inquiry were:

- lack of stability and predictability in climate policy, reflecting the absence of political consensus about New Zealand’s transition to a low-emissions economy;
- no clear plan for reducing domestic emissions and meeting New Zealand’s existing targets;
- inadequate central government leadership to drive the low-emissions transition; and
- poor policy coherence, including inadequate coordination and lack of joined-up thinking.

These issues (discussed below) reflect the underlying challenges in establishing a credible commitment to a domestic low-emissions transition, particularly a transition that will be profound and widespread, and requires long-term thinking and decision-making under uncertainty. As observed by the Parliamentary Commissioner for the Environment (PCE), “New Zealand’s policy record on climate change reads very much as one of developing sophisticated policy tools but not being prepared to deploy them in a way that will ‘bite’” (PCE, 2018, p. 10).

Lack of stability and predictability

Climate policy in New Zealand has been subject to major changes in direction, particularly following changes of government. Between 1999 and 2008, the Labour-led Government aimed for New Zealand to be “bold”

on climate change (Clark, 2006) and put in place the world's first "all sectors, all gases" emissions trading scheme. New Zealand's stance changed to that of a "fast follower" under the National-led Government from 2008-2017, with policy "dialled back" (PCE, 2018, p. 10), including via major reform of the NZ ETS (Chapter 5). The new Labour-led Government has signalled a strengthening of action on climate change (Office of the Minister for Climate Change, 2017).

Since October 2015, cross-party collaboration on climate policy has been fostered through GLOBE-NZ (a cross-party group of New Zealand Members of Parliament that forms a national chapter of an international association of parliamentarians, GLOBE International⁸⁰), whose work included commissioning the 2017 Vivid Economics report *Net zero in New Zealand: Scenarios to achieve domestic emissions neutrality in the second half of the century*. Even so, New Zealand currently lacks political consensus about the country's long-term low-emissions goal, including how deeply its domestic emissions need to be cut, and by when. BusinessNZ highlighted the impacts of a lack of shared political commitment around targets:

[A]greed emission reduction targets or at least targets within a narrow range are as - if not more - important as the policy pathways used to achieve them. A credible shared political commitment needs to emerge around New Zealand's emission-reduction targets. While we appreciate that targets are out of scope, they are critical to the overall conversation. One need only think about the current differences in targets across the political parties (for example, 30% below 2005 levels by 2030, net zero carbon by 2050, and net zero emissions by 2050) to realise what these might mean for how targets might vacillate over time, and the concomitant implications for policy settings and investment signals for business. (sub. 89, pp. 5-6)

Political uncertainty and policy instability was a key theme raised by submitters to this inquiry (Box 8.2).

Box 8.2 **The need for stability and predictability**

Submitters highlighted a variety of stability and predictability issues, including the political uncertainty associated with short-term election cycles and its resulting (negative) impacts on investment decisions.

Clarity is required regarding the dairy and wider agricultural industry long term low emissions pathway and how this interlinks with the expectation on the other sectors of New Zealand's economy... This certainty must extend beyond the current three-year political cycle, climate change is a long term issue, which requires a long term plan. Political uncertainty simply creates an environment where inaction perpetuates." (Dairy NZ, sub. 18, p. 3)

Ultimately New Zealand's response to climate change must be depoliticised. Decisions around how New Zealand responds to climate change, and how we move to a lower carbon emissions economy, cannot be at the mercy of our three-yearly MMP election cycle. (Contact Energy, sub. 29, p. 8)

The Investor Group on Climate Change Australia-NZ survey of institutional investors found that 55% of respondents were already allocating capital to green investments and 100% were intending to increase their allocation in the future. Yet, the two main barriers to allocating capital to low carbon solutions were policy or regulatory uncertainty and lack of investable deals. (Guardians of NZ Superannuation, sub. 32, p. 5)

The major uncertainty facing Ballance in considering investments relevant to a low-emissions future is the ongoing political uncertainty regarding the pace of change required and the policy instruments to be applied." (Ballance Agri-Nutrients, sub. 34, p. 4)

During the investigation into the UK Climate Change Act, members of my staff met with a number of private sector companies. They found a general frustration with the lack of stability in climate change policy... Without a measure of predictability, companies cannot manage the risks of moving to a low-carbon economy. Nor can they invest with confidence in low carbon technologies. (PCE, sub. 54, p. 4)

⁸⁰ GLOBE International is an association of legislators that seeks to work across party political divisions to develop legislative responses to major global sustainable development challenges: see GLOBE International (2018).

Transitioning to a low-emissions economy is an intergenerational effort which will span many decades. To provide long-term stability it is important to shield actions and initiatives from political interference arising from short-term political cycles. (NZ Carbon Farming, sub. 95, p. 19)

Businesses need long-term certainty, beyond the election cycle, to make the right investments and changes to their business operations. (Sustainable Business Council, sub. 131, p. 3)

No clear plan to meet targets

Submitters were critical that New Zealand has no clear plan to reduce domestic emissions and to meet existing targets. For example:

I have read the published speeches of successive Ministers for Climate Change over the past five years and I see no evidence of a genuine intent to reduce emissions. For example, most recently Paula Bennett has said, “Large parts of our [climate change] plan are already underway, and our target will be met through a combination of domestic emissions reductions, removals of greenhouse gas emissions in the atmosphere by forests, and international carbon markets.” In fact, there is no detailed domestic emission reduction plan (e.g. including reductions per year by sector), MfE has no published reports on the matter, and domestic emissions are not, in fact reducing. (Robert McLachlan, sub. 9, p. 2)

We have a target for 2030 but no integrated plan for achieving this. (Vision Kerikeri, sub. 116, p. 4)

There is a lack of clarity and certainty on what New Zealand’s transition to a low carbon economy looks like and what each sectors role in achieving this is under the current policy framework. (Dairy NZ, sub. 18, p. 2)

The absence of an integrated approach to developing a strategy and set of actions to address how New Zealand’s should meet it’s 2030 climate change emissions reduction target or to agreeing a target date and actions to achieve a net zero position has been a concern for the Association. While a number of separate initiatives have been announced by Government there is currently no defined transition pathway to a low carbon economy. (NZ Wind Energy Association, sub. 40, p. 1)

PCE’s 2017 report highlighted the lack of direct link between New Zealand climate policy and reaching emission reduction targets:

[I]t is not shown how policies contribute to meeting targets. For instance, one of the priorities in the New Zealand Energy Efficiency and Conservation Strategy is that electric vehicles are to form 2% of the fleet by 2021. But how far will this go towards helping us achieve our Paris target?

Overall, there is no systematic quantification of reductions in greenhouse gases from climate change initiatives in New Zealand. A United Nations expert review has criticised New Zealand for this omission. The new funding for “*costed, tested and consulted policy options for reducing emissions domestically*” in the 2017 Budget should go some way to remedying this. (PCE, 2017, p. 20)

Inadequate central government leadership

Various stakeholders, including business and local government, have called for more central government leadership to help drive the low-emissions transition. Local Government New Zealand (LGNZ)’s submission for example highlighted the “growing frustration at the current lack of action on climate change by central government” (LGNZ, sub. 36, p. 11) and Auckland Council identified that “strong messaging from central government on the prioritisation of climate change action” would help to embed support for emissions reduction (sub. 97, p. 59). The Sustainable Business Council emphasised the importance of leadership, including from government (sub. 131, pp. 16-17).

Since submissions were made on the Productivity Commission’s *Low-Emissions Economy Issues Paper*, the country has seen a change of government. The current Labour-led Government has signalled that it sees climate change as a priority issue and “is committed to taking decisive action on climate change and transition to a net zero target by 2050” (Office of the Minister for Climate Change, 2017, p. 1).

Poor coherence

New Zealand's response to reducing emissions also lacks coherence. The NZ ETS is the key policy tool, but the wider regulatory framework relevant to a low-emissions economy transition does not form a coherent and consistent suite of measures. As observed by PCE:

New Zealand's laws, regulations and policies have been developed over many decades, but the conviction that, along with the rest of the world, we must reduce carbon emissions is relatively recent. It is inevitable that there will be long-standing inadvertent barriers to reducing emissions. (PCE, sub. 54, p. 9)

Palmer (2015, p. 15) argues that New Zealand's domestic law on climate change "exhibits the characteristic weaknesses of the New Zealand law-making system", with incoherence in statutory schemes arising from legislation being frequently and substantially amended without sufficient care and scrutiny. Palmer (2015, p. 15) notes that the "statute book speaks with many voices in New Zealand on climate change", citing, for example, provisions that incentivise fossil fuel exploration. Although the CCRA is New Zealand's primary climate change law, a range of other laws are also relevant to a low-emissions economy yet many do not expressly refer to climate change (such as the Energy Efficiency and Conservation Act 2000, Waste Minimisation Act 2008 and Land Transport Management Act 2003). Specific sectoral regulatory gaps and barriers are discussed in Part 4 of this report.

Submitters identified problems with coordination and a lack of joined-up thinking across government (Box 8.3).

Box 8.3 Lack of coordination and joined up thinking

Stakeholders were critical of lack of coordination and joined up thinking.

[T]here is no mutual interaction between the Minister, the MfE policy advisers, the public, and our non-governmental experts. (Robert McLachlan, sub. 9, p. 3)

In New Zealand, the development of climate policy is distributed across different government agencies, and can be crowded out by other priorities. (PCE, 2017, p. 20)

Delivering a sustainable transition to a low-emissions economy within the extraordinarily tight timeframes (20–30 years to 2050) requires a coordinated and joined-up approach to climate change and its implications, through identifying opportunities to both reduce emissions and embed resilience. (ADLS, sub. 7, p. 4)

[T]here needs to be a holistic approach to successfully transition towards a low-emissions economy. The statutory framework should not just be focused on a particular act to deal with climate change, but needs to be integrated into all sectors (such as transport, resource management, and primary production). (Rangitikei District Council, sub. 35, p. 3)

[W]e have observed a lack of 'joined-up thinking'... We believe that these decisions have suffered from a lack of coordination and alignment across the national and local government agencies around New Zealand, which each apply different policy and regulations, and give different weighting to energy, water, and environmental concerns. (Trustpower, sub. 59 (supplementary submission), p. 1)

N.Z. has a number of government departments operating in silos and their own agendas. (Vision Kerikeri, sub. 116, p. 4)

The OECD's 2015 report *Aligning policies for a low-carbon economy* highlights that policy misalignments in an economy can significantly undermine the effectiveness of climate policy efforts. Misalignments between overall policy and regulatory frameworks and climate goals can send contradictory signals and hinder the low-emissions transition (OECD, 2015a).

The CCRA is not designed to address the credible commitment problem

The existing CCRA performs valuable functions, but the CCRA is not based on political pre-commitment to a long-term low-emissions goal. Nor is its architecture geared towards promoting long-term stability in climate change policy. Rather, the purpose of the CCRA is focused on:

- machinery needed to comply with New Zealand’s international obligations (eg, powers for the Minister of Finance to manage and trade emission units, setting up a registry to record the holding and transfer of emission units, and establishing a national inventory agency to record and report information about New Zealand’s greenhouse gas (GHG) emissions by sources and removals by sinks); and
- specific policy instruments (the NZ ETS and synthetic gas levy).⁸¹

While the CCRA does provide for “targets” to be set, either via gazette notice or in regulations, the political executive has broad discretion regarding how, when and what targets are set (or changed) (section 8.5).

The CCRA has also not yet been updated to reflect the Paris Agreement. Amendments to the CCRA were not considered to be legally required for New Zealand to ratify the Paris Agreement, but “substantial amendments to implement and to comply with the [Paris] Agreement” will likely be needed (Office of the Minister for Climate Change Issues, 2016, p. 11).

F8.3

New Zealand’s current emission reduction response is not “fit-for-purpose” to transition to a low-emissions economy. A number of deficiencies exist, such as:

- a lack of stability and predictability in climate change policy, reflecting the absence of political consensus about New Zealand’s transition to a low-emissions economy;
- lack of a clear plan for reducing domestic emissions and meeting existing emission reduction targets;
- inadequate central government leadership to drive the low-emissions transition; and
- poor policy coherence for supporting a low-emissions transition.

New Zealand’s emissions are not yet declining and current policy settings are unlikely to lead to adequate emission reductions in the future.

8.3 Calls for a new “UK-style” climate change law

Support for new climate change legislation has been building. In July 2017, the (now former) PCE, Dr Jan Wright, released a report titled *Stepping stones to Paris and beyond: Climate change, progress, and predictability* (PCE, 2017). The PCE report recommended that the Minister for Climate Change Issues develop a Climate Change Transition Bill that contains the key features of the UK’s Climate Change Act 2008. In relation to mitigation, the PCE recommended emissions targets, carbon budgets, policies to ensure carbon budgets are met, and an independent Climate Change Commission. The new PCE has endorsed his predecessor’s recommendation for a UK-style law (PCE, 2018).

In addition, a broad range of stakeholders are advocating for New Zealand to adopt a climate change law modelled on the UK Act (Box 8.4). The current Labour-led Government is currently developing a Zero Carbon Bill that will set a 2050 emissions target and aims to establish an independent Climate Change Commission and processes needed to meet that target.

⁸¹ The CCRA comprises seven parts and four schedules: Part 1 – preliminary provisions, Part 2 – institutional arrangements, Part 3 – inventory agency, Part 4 – NZ greenhouse gas emissions trading scheme, Part 5 – sector specific provisions, Part 6 – targets, and Part 7 – synthetic greenhouse gas levy. Schedules 1 and 2 set out the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Schedules 3 and 4 relate to the NZ ETS (respectively, Activities with respect to which persons must be participants, and Activities with respect to which persons may be participants).

Box 8.4 Public support for a new “UK-style” climate change law

Since 2016, Generation Zero has campaigned for its own version of a Zero Carbon Act, and submitted that “a Zero Carbon Act, backed by cross-party agreement, is the most urgent and important law our next Parliament could legislate” (sub. 119, p. 3). Generation Zero’s blueprint is for legislation that commits New Zealand to zero carbon by 2050 or sooner and includes legally binding long-term targets, five-yearly carbon budgets, and an independent Climate Change Commission. Generation Zero proposes a ‘firewall’ between domestic action and international carbon trading, with the targets in the Act applying to New Zealand’s domestic emissions only. It also proposes a two-baskets approach, where long-lived gases must reach net zero by 2050 or sooner, and short-lived gases must be significantly reduced to sustainable levels, but not zero (Generation Zero, 2017).

Stakeholders show wide support for the PCE’s recommendation to implement a UK-style Act in New Zealand, including from the private sector (eg, Z Energy, Meridian, Dairy NZ, Westpac, Contact Energy), local government and non-governmental organisations (eg, the NZ Church Climate Network, Environmental Defence Society). For example:

[W]e support the PCE’s recommendation that New Zealand develops a Climate Change Transition Bill which sets emissions targets in legislation, sets carbon budgets, requires policy to be developed that meets those budgets and that we have a Climate Change Commission – an expert body to provide objective analysis and advice. This would provide predictability, reduce New Zealand’s risk of an abrupt transition and ensure co-ordination between corporates and government agencies to achieve those targets. (Contact Energy, sub. 29, p. 1)

ARPHS and the DHBs recommend a similar framework [to the UK Climate Change Act] be implemented in New Zealand, one that recognises the different dynamics of our emissions profile, and enables consistent and long-term planning across multiple terms of government in how best to meet our emission targets. (Auckland Regional Public Health Service, sub. 105, pp. 14–15)

The Parliamentary Commissioner highlights the importance of having an independent expert commission on climate change, setting emissions targets or carbon budgets in law that reduce over time to meet our Paris commitments; with the additional requirement for the Government of the day to then develop policies that enable the budgets to be met within a context of rigorous monitoring. The UK’s approach provides an example of safeguarding the independence needed to insulate the policy system from short term political pressures...The Committee supports such an approach. (ADLS, sub. 7, p. 4)

The PCE recommended a new Climate Change Act and to put emissions targets into law in recognition that a long term cross party approach is required [for] what most regard as the ultimate intergenerational issue. NZWEA shares the PCE’s view that we need to look decades ahead and supports the Report’s recommendations. (NZ Wind Energy Association, sub. 40, p. 7)

Meridian strongly supports the recent report and recommendations from the Parliamentary Commissioner for the Environment (PCE), *Stepping stones to Paris and beyond: Climate change, progress, and predictability*. The report outlines opportunities to strengthen New Zealand’s action on climate change and provides a set of ideas that would assist in embedding support for reductions in domestic greenhouse gas emissions. In particular the report advocates for the country’s Paris Agreement targets to be passed into law, and the establishment of interim carbon budgets to transparently track progress towards the targets over time and provide long-term certainty to business. (Meridian Energy Limited, sub. 55, p. 15)

The United Kingdom’s Climate Change Act 2008

The United Kingdom’s Climate Change Act 2008 (the UK Act) sought to provide a “clear, credible and long-term framework that will provide greater clarity and confidence for businesses and individuals to plan and invest in delivering the changes needed to move to a low carbon economy” and demonstrate leadership through example (Miliband, 2007). The UK Act is viewed as world-leading and has acted as a model for legislation in a number of other jurisdictions.

Despite its ambitious nature, the UK Act had overwhelming support during its passage through Parliament. A series of events had seen climate change rise rapidly up the UK policy agenda after the 2005 election, and by the end of 2006 the idea of a Climate Change Bill had cross-party support.

The UK Act sets up a framework for the United Kingdom to achieve its long-term GHG emission reduction goals, and to ensure steps are taken to adapt to climate change impacts. The core pillars of the UK Act for emissions reduction are:

- the setting of statutory long-term emission reduction targets, with accompanying five-yearly carbon budget “stepping stones” to the long-term target;
- the establishment of an independent body (the Committee on Climate Change) to advise on achieving emissions targets and budgets;
- a requirement for the Government to prepare proposals and policies to meet carbon budgets; and
- a suite of monitoring and reporting obligations, based around mandatory reporting to Parliament.

The key features of the UK Act (in the context of climate change mitigation) are summarised in Table 8.1.⁸² Further detail about the provisions in the UK Act is set out Weeks (2017).

Table 8.1 Key elements of the United Kingdom’s Climate Change Act 2008

Core element	Details
Long-term target	GHG emissions-reduction target for 2050 set in primary legislation, with a corresponding duty on the Secretary of State to ensure the target is met. The Act limits when and how the long-term target can be amended.
Carbon budgets	Secretary of State must set five-year carbon budgets (limits on the amount of net GHG emissions during the budget period) that are consistent with meeting the 2050 target (as well as a medium-term 2020 target). The Act requires that certain matters are considered when setting carbon budgets, and prescribes the process for setting budgets (which includes considering advice from the Committee on Climate Change, and explaining any deviation from that advice). The Act limits when and how carbon budgets can be amended.
Planning to meet carbon budgets	After each carbon budget is set, the Secretary of State must prepare proposals and policies to enable existing (current and future) carbon budgets to be met.
Committee on Climate Change (CCC)	The Act creates the CCC as a new independent non-departmental public body. The CCC has two key roles: <ul style="list-style-type: none"> • to advise (including in particular on carbon budgets); and • to report (on the United Kingdom’s progress towards meeting its climate change targets).
Monitoring and reporting obligations	Mandatory direct reporting to Parliament by both the Government and the CCC. For example: <ul style="list-style-type: none"> • the Government must report once a year on the United Kingdom’s GHG emissions; • the CCC must report once a year on progress towards budgets and targets; • the Government must respond to the CCC’s progress reports; and • the Government must report on its proposals and policies for meeting current and future carbon budgets.

⁸² The UK Act also contains provisions dealing with adaptation. This report does not address the adaptation provisions given this inquiry’s limited terms of reference in relation to adaptation.

The UK Act is highly regarded. It has driven action, including setting five carbon budgets that collectively cover the period 2008–2032 and preparing proposals and policies for meeting carbon budgets (including the latest Clean Growth Strategy, released in October 2017). Regular reporting to Parliament has enhanced transparency and accountability, and the independent CCC has built an excellent reputation and high credibility. During the course of this inquiry, the Productivity Commission has engaged with a range of UK stakeholders (including from the CCC, Parliament, government departments, industry organisations and NGOs) about their experience with the UK Act. The consistent overall message was very positive about the UK Act and its achievements, with a general consensus that the United Kingdom would not have made the same level of progress without the Act.

A number of other countries have modelled their laws on the UK Act. Core elements of the UK Act (long-term targets, carbon budgets, an independent body, mandatory strategies and/or reporting obligations) are found in legislation in other jurisdictions. Those jurisdictions include, for example, Denmark's Climate Change Act (2014), Finland's Climate Change Act (2015), France's Energy Transition for Green Growth law (2015), Mexico's General Law on Climate Change (2012), Philippines' Climate Change Act (2009), Sweden's Climate Act (2017), and Victoria's (Australia) Climate Change Act (2017). As each country's laws are different, the detail of the legislation in each country would need to be carefully examined to understand how far it replicates the UK Act, and the rationale for any departures from the UK model (including relevant cultural, political and constitutional contexts).

Despite the UK Act's successes, implementing the Act is likely to become increasingly challenging; indeed, some commentators have argued that the Act's ongoing political durability is at risk (Gillard, 2016; Lockwood, 2013). Although the United Kingdom met its first carbon budget (2008–2012) and is expected to outperform against its 2013–2022 budgets, a "policy gap" currently exists for meeting the subsequent budgets (the fourth and fifth budgets that cover 2023–2032). In its 2017 report to Parliament, the CCC warned:

UK emissions have fallen while the economy has grown, but progress will not continue without new policies. It would be wrong to assume that the UK has permanently shifted to a path of falling emissions. Three-quarters of the decline in emissions from 2012 to 2016 has come from the reduction in the use of coal for power generation, which is now at low levels. Eliminating the remaining coal-fired generation would deliver less than two years' worth of the required progress to 2030. In stark contrast, emissions from transport (which make up 26% of total emissions) were higher in 2016 than in any year since 2009. (Committee on Climate Change, 2017a, p. 8)

Legislation must be carefully tailored to fit the New Zealand context

There is no "one-size-fits-all" model for good climate-change legislation. International approaches (including the design of the UK Act), as well as New Zealand's own experience in other policy domains, can provide useful insights about frameworks and principles. Ultimately however, New Zealand's climate-change legislation must be carefully designed to fit the particular New Zealand context. The relevant context for New Zealand's transition to a low-emissions economy (which is materially different from the context in which the UK Act was enacted) includes:

- the relatively small size of New Zealand's economy (where, for example, a single business operation may constitute an entire industry, and there are limits to the country's research and analytic resources);
- New Zealand's unusual emissions profile (Chapter 2), which has implications for the nature of its low-emissions transition (Chapter 3);
- the NZ ETS as New Zealand's key policy tool for reducing emissions;
- the current lack of political consensus about the nature and pace of New Zealand's transition to a low-emissions economy; and

- New Zealand’s constitutional environment and political economy (including for example Te Tiriti o Waitangi, how government operates, and parliamentary procedures).⁸³

As identified by the PCE (2018), differences between the United Kingdom and New Zealand contexts mean that New Zealand’s legislation cannot simply replicate the UK Act.

The international framework for addressing climate change has also changed since the inception of the UK Act.⁸⁴ New domestic legislation in New Zealand needs to take account of the Paris Agreement and ensure that it complies with international obligations (Legislation Advisory Committee, 2014; New Zealand Government, 2016). Not all aspects of the Paris Agreement are legally binding at international law and the Agreement gives countries a high degree of sovereign discretion (Box 8.1). So decisions about precisely how the Paris Agreement is reflected in domestic law must be made.

Political durability is key

As discussed in section 8.1, laws and institutions will not endure unless underpinned by political consensus. The importance of political consensus was a strong theme in submissions (Box 8.2). BusinessNZ and others cautioned that “[n]ew Acts, institutions and mechanisms, regardless of how stable or independent they are claimed to be, are only independent (if they are that at all) and provide predictability while a political consensus exists” (BusinessNZ sub. 89, p. 5; Motor Industry Association, sub. 51, p. 3; Export NZ, sub. 91, p. 7). Submitters also expressed concern about creating an independent climate change body unless it is backed by cross-party support (Ballance Agri-Nutrients, sub. 34; Evonik Industries, sub. 46; Straterra, sub. 69; NZ Institute of Forestry, sub. 73). NZ Carbon Farming (sub. 95) emphasised the need for cross-party agreement to ensure any arrangement remains in place regardless of the make-up of government.

The importance of achieving political consensus should therefore be given high priority when developing any new statutory and institutional arrangements, with an aim of enacting legislation that has a strong prospect of being politically durable. The GLOBE-NZ initiative fostered cross-party collaboration on climate policy between 2015 and 2017, and is a valuable forum for helping to build political consensus in the current Parliament. The Minister for Climate Change Issues has indicated that he will be seeking to build cross-party support for the proposed Zero Carbon Bill (Edwards, 2018; Office of the Minister for Climate Change, 2017).

Some political compromise is likely to be needed to create durable laws and institutions. Yet it is neither necessary nor realistic for consensus to extend to all policy details about how the low-emissions transition should be achieved. The key is to have consensus about New Zealand’s long-term, low-emissions goal and the core legal and institutional architecture supporting that goal.

F8.4

Inquiry participants and others showed strong support for implementing a UK-style Climate Change Act in New Zealand.

R8.1

The broad principles and framework of the United Kingdom’s Climate Change Act should be used as a basis for designing a new architecture for New Zealand’s climate change legislation, but it should be carefully tailored to fit the New Zealand context.

R8.2

The Government should seek to achieve broad political support and consensus for new climate change legislation, so that legislation has a strong prospect of policy and legislative durability regardless of the make-up of the government.

⁸³ Legislation needs to be tailored to reflect New Zealand’s parliamentary procedures and practices. As identified by PCE, differences exist in both how governments operate, and in the parliamentary rules and practices between the two countries. For example, there is a difference in “the use of the affirmative resolution procedure for enacting secondary legislation. This procedure is commonly used in the UK Parliament, but in New Zealand is generally reserved for decisions about Offices of Parliament and parliamentary agencies...In the UK Climate Change Act, the affirmative resolution procedure is used for amending targets and baseline years, setting and altering carbon budgets, adding new targeted greenhouse gases, and setting regulations on international aviation and shipping.” (PCE, 2017, p. 25).

⁸⁴ The UK will, for example, be reviewing its long-term emissions-reduction targets in light of the Paris Agreement (Darby, 2018; Harvey, 2018).

8.4 Designing a Climate Change Act

Common threads for statutory frameworks dealing with long-term policy problems

Although the architecture of the UK Act is not mirrored in the current CCRA, some design elements are common to both the UK Act and New Zealand's statutory frameworks for regulating fiscal and monetary policy (Box 8.5). The regulatory regimes are all based on a political pre-commitment, seek to promote policy stability and require long-term thinking.

Box 8.5 New Zealand's regulatory frameworks for both fiscal policy and monetary policy

Fiscal policy

Fiscal regulation (as originally introduced by the Fiscal Responsibility Act 1994) aimed to establish a stable fiscal operating environment. The legislation "was intended to require transparent reporting of a government's fiscal intentions and to encourage governments to consider the long-term consequences of policy decisions" (The Treasury, 2005, p. 33). The statutory framework is founded on increased transparency and greater accountability, which is achieved by requiring governments:

- to be explicit about their long-term fiscal objectives and short-term fiscal intentions, and to assess them against principles of responsible fiscal management, and
- to report on a wide range of economic and fiscal information.

Monetary policy

The regulatory framework for monetary policy (under the Reserve Bank of New Zealand Act 1989) includes:

- specifying one macroeconomic objective for monetary policy (price stability);
- creating an independent central bank, the Reserve Bank of New Zealand (Reserve Bank), with autonomy to implement monetary policy directed to the price-stability objective;
- setting specific policy targets (under a Policy Targets Agreement between the Governor of the Reserve Bank and the Minister of Finance);
- accountability and reporting provisions, such as a duty on the Governor of the Reserve Bank to ensure the actions of the Reserve Bank to implement monetary policy are consistent with the policy targets, and requirements for the Reserve Bank to publish regular monetary policy statements.

Source: Lloyd (1992); State Services Commission (1996); The Treasury (2005).

While the specific design details differ, the statutory frameworks share:

- pre-commitment to clear and explicit high-level, long-term goals and a focus on progress towards those goals;
- core principles of transparency and accountability;
- mechanisms that seek to promote stability but retain a degree of flexibility; and
- mandatory procedural requirements, including transparency via reporting obligations.

These features are important elements of statutory frameworks designed to encourage long-term commitment and policy stability.

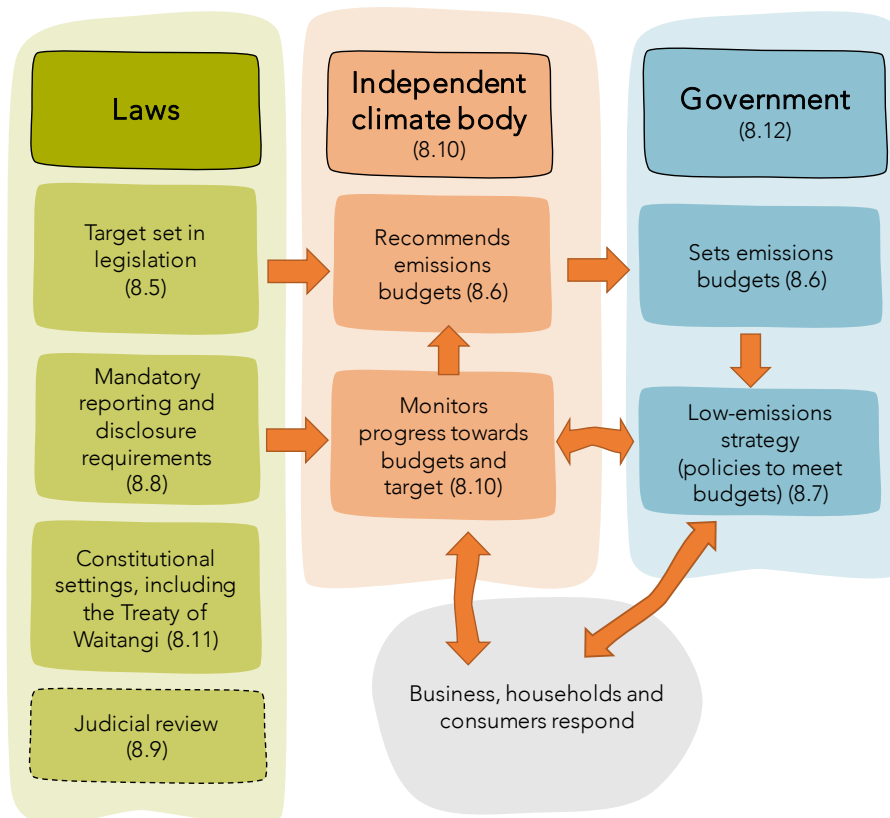
F8.5

Key elements of statutory frameworks that promote policy stability and require long-term thinking include:

- clear and explicit high-level, long-term goals and a focus on progress towards those goals;
- core principles of transparency and accountability;
- mechanisms that seek to promote stability but retain a degree of flexibility; and
- mandatory procedural requirements, including reporting obligations.

The rest of this chapter explores key elements of, and design issues for, a new Climate Change Act. Specific issues discussed are legislating emission-reduction targets (section 8.5), emissions budgets (section 8.6), a low-emissions economy strategy (section 8.7), the power of strong process (section 8.8), and achieving compliance (section 8.9). The role and design of a new Climate Change Commission is analysed (section 8.10), along with the need to recognise the Treaty of Waitangi (section 8.11) and for central government leadership (section 8.12).

Figure 8-1 Laws and institutions to support the low-emissions transition



8.5 Legislating emissions-reduction targets

A new Climate Change Act needs clear and explicit objectives, and a focus on progress towards achieving long-term goals. This section examines whether it is appropriate to legislate a (quantitative) emissions-reduction target, and discusses key design issues for such a target.

Should a (quantitative) emissions-reduction target be set in law?

Legislated targets function as a commitment device. Essentially, “the effect of legislated targets is to try to bind the hand of successor governments” (Rutter & Knighton, 2012, p. 5).

The UK Act enshrines a legislated target as a key regulatory goal. It is the duty of the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least 80% lower than the 1990 baseline.⁸⁵ By contrast, New Zealand's regulatory framework for fiscal policy does not set quantitative fiscal targets in legislation. Instead, legislating *principles* was considered preferable to legislating fiscal *targets* (Janssen, 2001; G. Scott, 1995; The Treasury, 2015a). The reasons why mandatory targets were rejected included:

- the lack of a solid theoretical justification for any particular fiscal target that can be maintained;
- other countries' experience of legislated targets suggesting that substantial risks are attached to their use, particularly that rigid adherence can seriously distort decision making and, unless carefully handled, minor variations from targets can result in significant, unnecessary damage to credibility;
- the inherent inflexibility of targets, that makes it difficult for fiscal policy to respond appropriately to the inevitable volatility of economic circumstances; and
- that fiscal targets can be effectively and often comprehensively evaded and, without the political will to achieve targets, ways are inevitably found to avoid them.

Setting targets in legislation has advantages and disadvantages, as shown in Table 8.2.

Table 8.2 Examples of potential advantages and potential disadvantages of legislating targets

Potential advantages	Potential disadvantages
Well specified legislated policy targets can help give clarity about policy objectives.	Is a low-cost way for the government to give the appearance of vigorous action without actually having to commit to take measures in the short term
Provides an internal signal to the rest of government about the priority Government attaches to an issue. More likely to influence civil service (and ministerial) behaviour than more weakly articulated priorities or statements of principles (reflecting that governments are institutionally disposed to obey the law)	Has the potential to be used as an alternative to winning the political argument and establishing a new political consensus
Provides an external signal of the seriousness of government intent	Risks a target being set without clarity on the measures required to meet it and therefore without adequate analysis of costs and benefits of trying to meet the target
Is a way to influence decision making on a continuing basis	Poorly specified targets can drive the wrong policy, produce perverse outcomes and distort spending priorities
Can make government action more resilient and less sensitive to tides of popular opinion	Introduces an element of legal uncertainty, particularly about how a target is enforced and the role of the judiciary

Source: Adapted from Rutter and Knighton (2012).

Submissions to the Commission's Draft Report were broadly supportive of legislating a long-term GHG emissions target. It was considered that this would provide a clear and concise signal for business, and the necessary certainty to encourage investment in low emissions technology and innovation (eg, Meridian, DR253; Auckland Council, sub.DR273; Chartered Accountants of Australia and New Zealand, sub. DR208; Vector, sub. DR287; Sustainability Action Group for the Environment, sub. DR286; Te Rūnanga o Ngāi Tahu, sub. DR363; Waimakariri District Council, sub. DR192). But it was noted that such a legislative target needs to be "realistic and achievable" across all sectors (Northlands Regional Council, sub. DR226), informed by science (Meridian Energy, sub. DR253; Wellington City Council, sub. DR276) and be formulated following a robust policy process (eg, First Gas Limited, sub. DR316).

⁸⁵ In addition to setting the 2050 target in primary legislation, the UK Act also provides for a system of five-yearly carbon budgets that must be set consistently with the 2050 target.

On balance, the Productivity Commission considers that setting a quantitative long-term emissions-reduction target in law is appropriate, provided the target is well designed. In particular:

- There is a global environmental imperative for setting a quantitative emissions-reduction target. The transition to a low-emissions economy is fundamentally driven by the global need to stabilise GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (Article 2, UNFCCC, 1992). This core objective is reflected in the Paris Agreement's aims of reaching net-zero global GHG emissions in the second half of this century and limiting temperature rise to well below 2°C (Chapter 2). Because the amount of GHGs released to the atmosphere directly impacts on temperature (Chapters 2 and 9), there is a science-based justification for emission reduction targets (although target setting is not a purely scientific exercise because the global nature of climate change creates political debate about each country's 'fair' share of mitigating emissions). Legislating domestic emission reduction targets aligns with the international architecture for climate change mitigation. New Zealand has committed to setting (progressively more ambitious) NDCs, and the Paris Agreement expressly provides that developed countries should "continue taking the lead by undertaking economy wide absolute emission reduction targets" (Article 4.4).
- Mitigating climate change involves long time horizons. A legislated target can function as a commitment device to require governments to take a long-term view and promote policy stability. Setting a target in law elevates its status. Given the long-term nature of climate change and the time inconsistency challenge, the internal and external signalling and ongoing influence on decision making that a legislated emissions-reduction target can provide is important. The implications of legislated targets would, for example, need to be recognised in government fiscal and economic reports and risk analyses.

Even so, legislated targets must be "constructed carefully". Characteristics of good target design include:

- a focus on the desired high-level outcome, without being overly prescriptive about how the goal is reached;
- realistic targets, which requires an assessment of the measures needed to achieve the target and an awareness of the policy tools that government has at its disposal; and
- built-in flexibility to adjust targets in the light of major changes in circumstance, but without undermining the purpose or credibility of the target (Rutter & Knighton, 2012).

Targets should not be set in law without close scrutiny of the implications of doing so, which requires (among other things) an understanding of what sort of measures might be needed to meet the target. As Rutter and Knighton (2012, pp. 12-13) highlight:

Parliament should recognise the constitutional implications of one government seeking to bind its successors and making policy more justiciable, and therefore should subject such bills to (even) more rigorous scrutiny than normal legislation. Not just the formulation of the target but also the measures that might be required to deliver it should be subject to scrutiny as well as the compliance regime.

[A] target should be seen as a means, not an end, for policy and setting a target is not a substitute for putting in place the measures needed to achieve the objective. It is too easy to applaud the government's willingness to set a heroic goal – without testing the feasibility and desirability of doing what it takes to meet that objective.

To provide long-term stability, a legislated long-term emissions-reduction target needs to be durable. The process for setting a statutory target must therefore be robust and inclusive (including rigorous analysis and debate, and broad stakeholder engagement). Achieving substantial cross-party support for a statutory target is key (section 8.1). As the Morgan Foundation (sub. 127, p. 23) observed:

In our view there needs to be a fairly high degree of rigidity around the 'what' – in particular getting strong buy-in to the emissions outcomes. This is central to the successful functioning of a UK-style law. Adaptability is mainly needed in the 'how'.

Key design issues for a long-term target

It is critical to carefully consider the details of any proposed statutory target. As identified by Rutter and Knighton (2012, p. 7), “[f]orm matters. Once a decision has been taken to put a target into law, the formulation becomes very important.” Key design issues to address include:

- the nature of a statutory target or targets (including the target year, which GHGs are covered by the target, whether the target is a point-in-time emissions target or a limit on the total quantity of allowable emissions by the target date, whether the target is for gross emissions or net emissions after carbon sink removals, and whether the target is based only on domestic emissions or allows the use of international credits);
- whether, when and how the statutory target(s) can be amended;
- the nature of the obligation to meet the target (for example, the UK Act puts an unqualified duty on the Secretary of State to ensure that the long-term target is met); and
- whether the target(s) is set in primary or delegated legislation.

A legislated target must be unambiguous and should not be easy to amend. The Productivity Commission agrees with the PCE that a transparent process for amending a target that requires the disclosure of clear reasons and seeking parliamentary assent “would instil a discipline that would discourage arbitrary changes of ambition in response to short-term considerations” (PCE, 2018, p. 20).

The current target-setting provisions in the CCRA are not a good model for legislating a target in a new Climate Change Act. While the CCRA does provide for the setting of “targets” either via gazette notice or in regulations, the political executive has broad discretion about how, when and what targets are set (or changed). In practice, use of the CCRA’s target-setting provisions has been *ad hoc*, and only non-binding targets have been set (via gazette notice) (Box 8.6).

Legislation should be designed to help deliver greater clarity about the nature and pace of New Zealand’s **domestic** low-emissions transition. There are different ways a legal framework could achieve this, for example framing a long-term target in relation to domestic emissions, or (as with the UK Act) requiring the Government to set limits on any use of international credits at specified times in the future.

Box 8.6 Target setting under the current Climate Change Response Act

Part 6 of the CCRA provides for two target-setting processes: gazetting of targets via publication in the New Zealand Gazette (section 224) and making regulations that set a target (section 225). These target-setting provisions did not form part of the CCRA as originally enacted in 2002, but were added later (section 224 in 2008, followed by section 225 in 2009).⁸⁶

The CCRA does not define the term “target”. A target must be set, but this can be done either by gazette notice or by regulation. Any number of targets may be set, and there are few constraints on when targets can be set, amended or revoked.

To date, two targets have been gazetted: various sectoral targets adopted by the Labour-led Government in 2008, and New Zealand’s 2050 target (set in 2011). Gazetted targets are not binding on the Government or other entities (Harker et al., 2017; Rive, 2011).

The extent of the executive’s target-setting discretion is evidenced by:

- the Government’s decision to simply gazette the new 2050 target, without revoking the existing 2008 sectoral targets (despite those sectoral targets no longer appearing to remain government policy when the 2050 target was set);

⁸⁶ Section 224 was introduced in 2008 following a late Supplementary Order Paper addition to the bill amending the CCRA, and section 225 followed in 2009 as part of further changes to the CCRA.

- New Zealand’s 2020 and 2030 targets having been adopted as commitments under the international UNFCCC framework, but not formally set as targets under the CCRA; and
- no targets having yet been set by regulation, despite the original intention that the 2050 target be set using the new regulation-making process (Rive, 2011; Rive & Harker, 2017).

Should targets be set in primary or delegated legislation?

The United Kingdom’s long-term target is set in primary legislation. By contrast, the CCRA provides for targets to be set via gazette notice or by regulation (Box 8.6).

Commonly accepted principles guide what material is suited to primary or delegated legislation. The accepted general rule is that matters of substantive policy should be included in primary legislation, while delegated legislation is suitable for matters of detail or implementation, of a technical nature, or likely to require frequent alteration or updating (Cabinet Office, 2017; Legislation Advisory Committee, 2014). The Productivity Commission has however previously identified that there is scope for greater use of delegated legislation in New Zealand (NZPC, 2014b).

Chapter 9 of this report lays out a framework for two distinct targets for short- and long-lived gases. These targets recognise the different atmospheric properties of short- and long-lived gases, and have different forms in law. The Productivity Commission considers that the nature and role of a long-term emission reduction target for long-lived gases means it should be set in primary legislation, and should specify the need to reach net-zero by a defined future date. Setting this target in primary legislation also elevates its status, signalling Parliament’s commitment to the priority of achieving net-zero long-lived gases. As Macrory (2014, p. 264) explains, setting a long-term target in primary legislation “gives it a moral dimension and permanence”, and while the target could be removed by a future government this would have to be done by new legislation, subject to public and parliamentary scrutiny.

In contrast, the Commission recommends that the long-term emissions reduction target for short-lived gases be established differently. The primary legislation should contain the principle for achieving a stabilised level of short-lived gases, but the explicit target level for a stable flow of emissions should be contained within delegated legislation, based on the advice of the proposed Climate Change Commission. This is because the specific quantity level for short-lived gases is less certain (eg, it depends on the relative speed at which long-lived gases are successfully mitigated). Chapter 9 explains the form of this target in more detail.

F8.6

Legislated emissions-reduction targets are important commitment devices to bind the political executive to govern in line with the long-term commitment to a low-emissions economy. Such targets would have authority and durability. Well-designed legislative targets are:

- focused on the desired high-level outcome, without being overly prescriptive about how the goal is reached;
- determined through a robust public policy process and achieve broad buy-in from those affected;
- realistic, and require an assessment of the measures needed to achieve the target and an awareness of the policy tools that the government has at its disposal;
- directly related to the underlying climate change problem;
- stable over time, yet have some built-in flexibility to be adjusted in the light of major changes in circumstance, but without undermining their purpose or credibility; and
- clear about the nature of the obligation to meet them.

R8.3

Long-term greenhouse gas (GHG) emissions-reduction targets should be set in primary legislation. Legislative emissions targets require careful design and should be formulated following a robust public policy process seeking broad agreement.

8.6 Emissions budgets

In addition to setting a long-term target, the UK Act also provides for a system of carbon budgets. Each budget covers a five-year budget period. The first three carbon budgets were set shortly after the legislation was enacted, with subsequent budgets then set approximately 12 years in advance. Carbon budgets operate to set a limit on the total amount of allowed emissions during the budget period, but allow flexibility as to how the overall budget is met.

Given the different types of GHGs (not just carbon dioxide), the Productivity Commission considers that “carbon budgets” are better termed “emissions budgets”.

Benefits of emissions budgets

Emissions budgets function as a mechanism to help achieve (and monitor progress towards) a long-term target; they are “stepping stones” that provide a clear yet flexible pathway to the long-term target (Fankhauser et al., 2018; PCE, 2017). Setting emissions budgets a number of years in advance provides valuable early signalling about the pace of a low-emissions transition, as well as protecting the budget-setting process from short-term political calculations (Fankhauser et al., 2018). A system of emissions budgets can reduce the risk of abrupt transitions, therefore helping to maximise the benefits and reduce the costs of reaching a long-term target (OECD, 2017c; PCE, 2017; RSNZ, 2016; Stern, 2007; World Bank, 2015). This is particularly so given that the lowest cost path to a long-term target “is likely to involve steady action, avoid stop-start investment and ensure sufficient lead time for making more difficult changes” (Thompson, 2016).

Importantly, emissions budgets can function as more than just “stepping stones” to help achieve an ultimate longer-term target. By setting limits on the amount of emissions allowed in each budget period (ie, the level of the carbon budget), budgets control the total volume (or “stock”) of GHG emissions released to the atmosphere in the period leading up to the long-term target date. By comparison, long-term targets are typically expressed as emission “flow” targets for a particular year. That is, they require X% reduction in GHG emissions at a particular point-in-time (for example, New Zealand’s current 2050 target is for a 50% reduction in New Zealand’s net GHG emissions from 1990 levels by 2050), but do not limit the total “stock” of GHG emissions that can be emitted leading up to the target date. A long-term, point-in-time target could therefore be met by initially allowing emissions to rise unabated, but then making late, deep cuts in emissions. In contrast, fewer emissions would be released to the atmosphere if the same target is instead met through a system of progressively tighter emissions budgets (Figure 2.1 in Chapter 2).

In the New Zealand context, the Commission proposes that separate emissions budgets are established for short- and long-lived gases (section 9.6 of Chapter 9). These emissions budgets would be used to help guide the setting of NZ ETS caps (Chapter 5) and the settings of an emissions pricing scheme for biogenic CH₄ (Chapter 9).

Designing an emissions budget system

Legislating for emissions budgets raises similar design issues to those discussed in relation to legislating for a long-term target. The detail matters. Design issues for emissions budgets include (1) the budget period; (2) what the budget covers and how it can be met; (3) the process and timing for setting budgets; and (4) whether, when and how budgets can be amended.

The basis on which emissions budgets are set, and the process for setting them, is critical. Legislation should specify key matters that must be considered when setting budgets. Those key matters should include climate science and technology, but also wider factors such as economic and social impacts and Treaty of

Waitangi considerations.⁸⁷ Emissions budgets need to be based on robust and transparent analysis that demonstrates the budget level is consistent with achieving the ultimate emissions-reduction targets while imposing least cost on the economy and society. Government should set emissions budgets, but only after considering independent expert advice (section 8.10).

An emissions budget system needs to carefully balance predictability and flexibility. To provide signalling and predictability about the low-emissions transition, budgets should be authorised by Parliament and set a number of years in advance. Once set, emissions budgets should only be able to be amended in very limited circumstances and with Parliament's approval.⁸⁸ To be credible and durable, a budget system also needs to be flexible enough to accommodate uncertainty about future pathways (Chapter 3). The nature of the flexibility mechanisms to be built into New Zealand's emissions budget system should be carefully considered. The UK Act, for example, provides flexibility through the use of multi-year budget periods (which allows smoothing of factors such as the impact of yearly weather fluctuations on emissions and short-term economic events). The Act also sets budgets on a "net carbon account" basis (so the budget does not just cover gross UK emissions, but also takes into account removals from UK carbon sinks and emission units that are traded internationally⁸⁹), and allows "banking" of any budget surpluses to the next budget period and limited "borrowing" (1% maximum) from the next budget. It also allows budgets to be amended if there have been significant changes in the factors that formed the basis on which a budget was set.

Statutory emissions budgets should drive the level of ambition in New Zealand's NDCs under the Paris Agreement (rather than the other way around). Even so, how a domestic emissions budget system fits with the Paris Agreement's NDC framework and timing cycle (eg, the requirement to submit a new or updated NDC by 2020 and every five years after that) needs to be carefully considered.

F8.7

Emissions budgets help to translate long-term targets into clear and specific short-term actions. They provide visible "stepping stones" to achieving long-term targets and help reinforce steady action on, and accountability for, achieving those targets. By setting limits on GHG emissions over a period, emissions budgets can also help to restrict the total quantity of GHGs released to the atmosphere on the path to long-term targets.

R8.4

New Zealand's climate-change legislation should provide for a system of emissions budgets for both short- and long-lived gases. The government should set the budgets periodically at levels consistent with achieving emissions reductions targets. It should report publicly on progress towards them. The system should be credible and durable, while balancing predictability and flexibility.

8.7 A low-emissions economy strategy

A legislated long-term target and system of emissions budgets would set emission reduction goals, but would leave open how those targets and budgets will be met – particularly given that budget setting and implementing policy measures to meet them, would be "decoupled in time" (PCE, 2018, p. 14). Statutory targets and budgets need to be supported by mechanisms to promote transparency about the policies that government intends to implement to meet the emissions budgets and long-term targets.

⁸⁷ The UK Act sets out the matters that must be considered when setting carbon budgets. Those matters include scientific knowledge about climate change, technology relevant to climate change, economic circumstances, fiscal circumstances, social circumstances, energy policy and international circumstances (section 10).

⁸⁸ Under the UK Act, carbon budgets are set, or amended, by order of the Secretary of State, but subject to the affirmative resolution procedure (that is, both Houses of Parliament must approve the order).

⁸⁹ International trading in the UK context includes trading by some sectors within the European Union Emissions Trading Scheme, as well as the ability for the United Kingdom to acquire other international emissions units (within set limits) to help meet carbon budgets.

A statutory requirement for the Government to prepare and publish its low-emissions strategy would provide valuable signalling to stakeholders about the Government's proposed policy settings, as well as promoting government accountability for meeting emissions budgets.

What sort of strategy?

A low-emissions strategy should set out the Government's short-term policy plans, but also look to the longer term. That is, it should set out a strategy for meeting both current and future emissions budgets, with a view to meeting the ultimate long-term targets. A long-term strategy would be consistent with the Paris Agreement, which provides that Parties "should strive to formulate and communicate long-term low greenhouse gas emission development strategies" (Article 4.19). Countries are invited to communicate these strategies to the UNFCCC by 2020 (UNFCCC, 2018a).

The 2050 Pathways Platform (a multi-stakeholder initiative launched at the 2016 UN climate conference that aims to support the development of long-term deep decarbonisation strategies) recognises that "having a good plan is never a sufficient condition for success, but not having one is always a recipe for failure" (UNFCCC, 2016). Long-term, low-emission strategies can help to place short-term actions in the context of the long-term structural changes required to transition to a low-emissions economy (Waisman et al., 2016).

A low-emissions strategy should be a broad and far-reaching economy-wide document that deals with all sectors of the economy and all relevant policy and regulatory instruments (including emissions pricing, complementary policies, investments and regulations). It should set out detailed policy proposals for the shorter term, particularly how the Government intends to ensure that the country meets the current emissions budget and, if the start of a new budget period is imminent, the intended approach for meeting the forthcoming budget. But it is not realistic to expect a strategy to be as definitive about how emission budgets for periods some way into the future will be met, particularly where budgets are set 10 years or more in advance. A statutory duty to prepare a low-emissions strategy therefore needs to consider the practical and political reality that policy will unfold over decades. Strategies for the long term will inevitably be less certain and well-defined than those for the short term (as illustrated for example in the fiscal policy context by the different character and content of the Government's long-term fiscal statement compared with three-year forecasts).

The strategy needs to take account of deep uncertainties about different potential pathways to a low-emissions economy (such as the impact of technological change) and allow an appropriate degree of responsiveness to new information (Chapter 3). A low-emissions strategy cannot be a "set-and-forget" document, as it will need to be updated to take account of new emissions budgets once set and adjusted in light of changing circumstances. It is a strategy, not a blueprint (BEIS, pers. comm., 13 November 2017).

A low-emissions strategy should not only focus on achieving the required emission reductions (eg, policies to meet emissions budgets, such as setting NZ ETS caps to limit emissions from ETS sectors). It should also reflect the need to maximise the benefits and minimise the costs of the transition, which may require additional measures such as policies to reduce abatement costs and manage the distributional effects of the transition (Chapter 10).

The UK's Clean Growth Strategy is a useful example of the sort of content that a low-emissions strategy might include, such as priority policies and proposals (including intended timeframes for implementing policies or making policy decisions and areas for future policy development), key opportunities and challenges, and modelling of potential pathways to meet future budgets (including estimated projections of emissions by sector).

R8.5

Government should have a statutory duty to prepare and publish a long-term economy-wide low-emissions strategy. The strategy should set out the Government's policies and proposals for meeting both current and future emissions budgets (and with a view to meeting the long-term targets) and should be updated after each new emissions budget is set.

F8.8

Matters to consider when formulating a requirement to prepare a low-emissions strategy include the need for:

- flexibility and responsiveness;
- recognition that strategies for the long term will inevitably be less certain and well-defined than those for the short term; and
- a strategy to not only address policies that achieve the required emission reductions, but also how to maximise benefits and minimise the costs of the transition.

8.8 The power of process

Clear, mandatory process forms the backbone of statutory frameworks that promote policy stability and require long-term thinking.⁹⁰ Statutory procedural requirements are powerful; they act as a “legal metronome that keeps ticking” (Baroness Worthington, pers. comm., 7 September 2017). Procedures can enhance transparency and help to maintain momentum for, and scrutiny of, government action on long-term policy issues. Statutory requirements (with clear deadlines) are particularly important given the time inconsistency challenge posed by climate change, as they force government to address key low-emissions transition issues rather than “kick them down the road” (BEIS, pers. comm., 13 November 2017).

Procedural requirements can also help to improve the quality of decision making by influencing the information available to decision makers at the time the relevant decision is made. For example, the UK Act’s requirement that the Government consider the CCC’s advice when setting budgets (and publicly explain any departure from the CCC’s advice) changes the “choice architecture” for government decision-making (Boston, 2017).

Statutory processes also play an important role in promoting compliance, as discussed in section 8.9.

Setting an appropriate procedural metronome

The monitoring and reporting framework in the UK Act was designed to “enhance the overall transparency and accountability of UK action on climate change” (HM Government, 2007, p. 10). It requires direct reporting to Parliament by both the Government and the CCC on a range of matters such as annual reports on GHG emissions, reporting on progress towards meeting budgets and targets, and reporting on the Government’s proposals and policies for meeting budgets.⁹¹ New Zealand’s domestic climate change statutory framework should similarly require regular reporting to Parliament on key aspects of New Zealand’s transition to a low-emissions economy.

Legislation needs to set a procedural metronome that ensures regular review and reporting, but does not over-engineer procedural obligations. An appropriate balance needs to be struck between “doing” and “reviewing”. Statutory processes also need to function as a coherent package.

In the United Kingdom, the procedural metronome is based around the five-year carbon budget cycle, with a system of annual reporting. For example, the UK Government must publish its policy proposals every five years (“as soon as is reasonably practicable” after each new carbon budget is set). The CCC reports each year on progress towards meeting budgets and targets, with the government required to respond. To better align with New Zealand’s three-year electoral cycle and provide a more frequent update of policies, the PCE has recommended that New Zealand adopt a six-year emissions budget period with government policies published after each new budget is set, followed by an interim update of policies three years later (PCE, 2018).

⁹⁰ For example, Fankhauser et al. (2018, p. 32) identify that “[a] striking feature of the [UK Act] is the clear timetable it mandates for key milestones and processes”.

⁹¹ The UK Act’s reporting details are outlined in more detail in Weeks (2017).

The statutory timeframes need to ensure that the low-emissions strategy is kept reasonably up-to-date, but also recognise that, in practice, policy will continually evolve and that formally updating a major economy-wide strategy (that addresses both short- and long-term time horizons) is likely to be a substantial undertaking. The UK's Clean Growth Strategy for example runs to 165 pages. Updates of the low-emissions strategy should be synchronised with the emissions budget period, which itself needs to be carefully considered including taking into account the practicalities of how the budget system fits with the Paris Agreement's NDC timeframes (section 8.6). It should also consider other reporting processes and timeframes, such as regular reporting on progress towards meeting budgets and targets. The Productivity Commission considers that annual progress reporting (by the Climate Change Commission: section 8.10) is appropriate, but does not see the case for requiring a formal annual response from the government. Updating the low-emissions strategy could serve as the government's formal response, coupled with less formal interim responses (such as via policy announcements and responses to Parliamentary questions).

Legislation should clearly identify *who* needs to report, on *what* and by *when*. The Productivity Commission heard suggestions from UK stakeholders about areas for potential improvement in the UK Act's procedural requirements. In particular, to set a specific deadline for the Government to publish its proposals and policies (instead of the "as soon as is reasonably practicable" requirement),⁹² and to ensure timeframes are realistic.⁹³ Reporting obligations should be clear and achievable. Legislation should set a specific timeframe to publish the Government's strategy (as recommended by, for example, the PCE (2018) and Fankhauser et al. (2018)). Even so, legislation should provide an element of flexibility to allow for exceptional situations where publication of the updated low-emissions strategy may need to be delayed (such as following a snap election for example).

R8.6

Mandatory processes should underpin a Climate Change Act. Legislation should include clear reporting obligations, including requiring regular reporting to Parliament on key aspects of New Zealand's transition to a low-emissions economy (such as GHG emissions, progress towards budgets and targets, and the Government's low-emissions strategy). Timeframes for the suite of processes should ensure regular review and reporting, but avoid over-engineering procedural obligations.

8.9 Achieving compliance with a Climate Change Act

In practice, political accountability will be a key driver for compliance with climate change law, including meeting emissions budgets and targets. This relies on notions of transparency, which has become a widespread nostrum of "good governance" in many different contexts today (Hood & Heald, 2006). Fixed and published policy goals and measures whose operation and achievement are open to public scrutiny can be a prevailing influence in promoting compliance.

Transparency mechanisms, including requiring the Government to prepare and report on its low-emissions strategy and regular reporting on progress towards meeting emissions budgets, play a critical role in enhancing political accountability and promoting compliance. The UK Act also contains specific reporting obligations that are triggered if budgets or the 2050 target are not met, including a duty to report on proposals and policies to compensate in future periods for budget excesses.⁹⁴ Central government leadership will be essential for meeting emissions budgets and targets (section 8.12).

Compliance with a Climate Change Act could also be subject to scrutiny by the courts via judicial review, but constitutional and practical limits to that role are likely – particularly in relation to enforcing emissions budgets and targets. One reason is that meeting emissions budgets and targets involves complex and

⁹² The UK's fifth carbon budget (for 2028–2032) was set in June 2016, but the Government's policy proposals (the Clean Growth Strategy) were not published until October 2017, leading to mounting criticism of the delay and threats of legal action (Johnston, 2017).

⁹³ For example, the three-month deadline (which falls over the summer period) for the Government's response to the CCC's yearly progress report is arguably too short.

⁹⁴ If the carbon budget for a budgetary period is exceeded, the Government must report to Parliament on proposals and policies to compensate in future periods for the excess emissions. If the 2050 target is not met, the Government's final statement to Parliament on 2050 emissions must explain why the target has not been met: sections 19 and 20 of the UK Act.

polycentric policy priorities and resource allocation decisions over time. In addition, legal remedies for non-compliance are arguably ineffective and/or inappropriate (Church, 2015; Macrory, 2014; McHarg, 2011; McMaster, 2008; Reid, 2012; see also Thomson v The Minister for Climate Change Issues, 2017).⁹⁵

Importantly, the value of setting emissions budgets and targets in law goes beyond the ability to legally enforce them. As observed by Lord Rooker (2007) during the passage of the UK Climate Change Bill:

Putting a duty such as this into law is important in itself. It is not just about the punishment in the event of failure; it is about trying to change institutional behaviour through a change in the law...By putting these duties into law, we are giving them a constitutional significance which will permeate down to every level of decision making. There is no other way of achieving an equivalent effect without using the law. The duty should be looked at in this broader constitutional sense, rather than just in terms of what happens in court.

F8.9

Political accountability will be a key driver for compliance with obligations in a climate change law, including meeting emissions budgets and targets. Limits to the legal enforceability of emissions budgets and targets do not negate the status and constitutional significance of putting them in law.

8.10 An independent climate change institution

Independent institutions act as a form of commitment device designed to help “insulate” policymaking from short-term political pressures. Such devices are particularly relevant in policy domains where desirable long-term policy outcomes require: 1) a capacity for long-term planning; 2) credible, consistent, stable, and predictable policy settings; and 3) periodic non-simultaneous exchanges (ie, the imposition of near-term costs to secure net long-term gains) (Boston, 2017). Climate change policy is archetypical of such requirements.

In its 2014 report *Regulatory institutions and practices*, the Productivity Commission identified a range of features that indicate a need for more, or less, regulatory independence. Those on the side of more regulatory independence and which reflect the nature of climate change as a policy problem include:

- decisions where costs are long term, and are undervalued due to a focus on electoral cycles;
- decisions weighing a politically powerful private interest against a dispersed public interest;
- decisions requiring a substantial degree of technical expertise, or expert judgement of expert analysis;
- decisions where the causal relationship between the policy instrument and the desired outcomes is complex and uncertain;
- regulatory regimes where a consistent approach over a long period of time is needed to create a stable environment;
- where decisions need to be taken urgently; and
- where public confidence that the regulator is impartial is important.

Internationally, various countries have set up independent climate change institutions as part of their national climate change mitigation frameworks, with both similar and different roles and functions, governance, organisational form and capabilities. The UK’s statutory framework for example includes the CCC, which is an independent non-departmental public body made up of experts in fields such as climate science, economics, behavioural science and business. The two core functions of the CCC are to advise (including in particular on carbon budgets), and to report (on the United Kingdom’s progress towards meeting its climate change targets). Examples of other independent climate change institutions include the

⁹⁵ See Weeks (2017) for further discussion of potential obstacles to judicial enforcement of emissions budgets and targets.

Danish Council on Climate Change, the Finnish Climate Panel, the Swedish Climate Policy Council and Australia's Climate Change Authority.

In New Zealand, support has been growing for the creation of an independent body to assist New Zealand's transition to a low-emissions economy, especially as a mechanism to promote stability, clarity and accountability. The creation of an independent body was expressly supported by numerous submitters to this inquiry, including for example: industry bodies (eg, Dairy NZ, Fertiliser Association of NZ, New Zealand Institute of Forestry, Beef and Lamb NZ), the energy sector (eg, Vector, Contact Energy, Meridian, First Gas Ltd), local government (eg, Auckland Council, Bay of Plenty Regional Council, Christchurch City Council, LGNZ, Waimakariri District Council, sub. DR192), NGOs (eg, Generation Zero, Wise Society, Scion, Ora Taiao), agriculture sector (eg, Fonterra) and individuals (eg, Graham Townsend) (Box 8.7).

The current Labour-led Government has announced its intention to establish an independent Climate Change Commission, along with an Interim Climate Change Committee, as a precursor to establishing the Commission (Office of the Minister for Climate Change, 2017).

Box 8.7 **Benefits of an independent body identified by inquiry participants**

Inquiry participants showed strong support for establishing an independent body that would advise on climate change matters.

An independent body to oversee climate change commitments would carry the obvious advantage of being able to plan with a longer time horizon and be free of shorter term, political influence. (Energy Management Association of New Zealand, sub. 70, p. 32)

Establishing an independent commission who oversees New Zealand's domestic and international climate change commitments and develops carbon budgets outlining how the country will meet these will provide businesses the certainty they need in factoring in climate change mitigation into their strategies and therefore support the transition to a low-emissions economy. (Dairy NZ, sub. 18, p. 15)

Strong stable policy settings and quality public education are drivers for public and private action on climate change, but require cross-party support. To this end, an independent body may be useful. (Guardians of NZ Superannuation, sub. 32, p. 3)

Currently there is significant risk for the sector due to the potential for changes in policy with changing governments. An independent Climate Change Committee / Commission, with a similar role to that described for the UK legislative process, which provides independent advice and reporting, could smooth the fluctuations in direction introduced by successive governments and help provide consistency in approach. (Fertiliser Association, sub. 61, p. 8)

New Zealand needs an independent body to provide accountability and advice on New Zealand's climate change commitments...Given the gravity of climate change in human and economic terms, the communities and businesses of Aotearoa New Zealand should be able to find out from an independent and impartial source whether we are likely to meet the targets that are set, and whether existing emission reduction policies require change. (Generation Zero, sub. 119, p. 8)

Some submitters questioned the need for an independent body, instead emphasising that what is required is "a properly funded body with a serious mandate to develop and implement a plan for how the Paris targets are to be achieved" (Bioenergy Association, sub. 37, p. 14; Hitachi Zosen Inova, sub. 68, p. 14; Oji Fibre Solutions, sub. 71, p. 11), and that it could also advise on the appropriate targets that could be achieved. Concern was also raised about creating an independent body in the absence of political consensus, to the extent that any independent institution can be dismantled or have its mandate politicised (Box 8.8).

Box 8.8 Political consensus important to the success of an independent institution

A number of submitters highlighted that political consensus is important to the success of an independent institution.

[Policy] consensus and ‘independent’ institutions can be undone...The presumption that independence will provide policy durability is a chimera. New Acts, institutions and mechanisms, regardless of how stable or independent they are claimed to be, are only independent (if they are that at all) and provide predictability while a political consensus exists. (BusinessNZ, sub. 89, pp. 5–6; similar submissions made by Motor Industry Association, sub. 51, p. 3; Export NZ, sub. 91, p. 7)

The ongoing absence of political consensus means that putting in place an independent body now would be too soon as its appointments and terms of reference will in turn be viewed to be politicised. There is also the risk that an independent body such as a Climate Commission may enable politicians to disassociate themselves from the difficult decisions to be made, potentially negating the role of parliament’s checks and balances. (Ballance Agri Nutrients, sub. 34, p. 10)

At present the absence of political consensus on stringency of NZ’s domestic policy and targets means that putting in place an independent body now would be too soon. (Evonik Industries, sub. 46, p. 9)

There has been discussion about an independent Climate Change Commission established by an Act of Parliament, as if this entrenches climate policy. In reality, we would suggest this only has merit if there is bilateral political support for such an Act and the goals it would espouse – otherwise a future Government could simply repeal the legislation. (Straterra, sub. 69, p. 3)

[A]n independent agency may struggle for traction in the absence of a bipartisan approach to this area of policy. (NZ Institute of Forestry, sub. 73, p. 9)

F8.10

Given the long-term nature and time-inconsistency problem associated with climate change policy, an independent institution, at “arm’s length” from government, can play an important role as a commitment device. It would help insulate policymaking from short-term political pressures, expand climate policy debate, promote stability and predictability, and improve transparency and accountability. Such an institution will be more enduring if established through broad political consensus.

R8.7

The regulatory framework to support New Zealand’s transition to a low-emissions economy should include an independent climate change institution (a Climate Change Commission) that operates at “arm’s length” from government.

Independence is multi-faceted and more than just designating an agency as at “arm’s length” from government

It is important to recognise that independence is not a binary condition: institutions can be more or less independent in a range of ways. In its 2014 report *Regulatory institutions and practices*, the Productivity Commission identified that “independence” is multi-faceted and is more than a matter of legally designating an agency as “independent” or at “arms-length” (NZPC, 2014b). The dimensions of independence include:

- the ability to adjust the regulatory settings and rules (regulatory independence);
- the ability to undertake functions without interference (operational independence);
- funding arrangements that protect the regulator from external pressure (budgetary independence); and

- formal distance from the Executive and security of tenure for governors and senior management (institutional independence).

New Zealand's state sector includes a wide variety of independent institutions that undertake a range of roles in different policy domains and take different types of institutional form (Table 8.3). The design of each institution differs in terms of the various dimensions of independence.

Table 8.3 Examples of independent institutions in New Zealand

Institution	Type	Role
Parliamentary Commissioner for the Environment	Officer of Parliament	Investigates environmental concerns independently of the Government of the day. The Commissioner reports to Parliament through the Speaker of the House and the Officers of Parliament Committee.
Environmental Protection Authority	Crown agent	Regulates activities that affect New Zealand's environment: administers applications for major infrastructure projects, regulates new organisms (plants, animals, genetically modified organisms) and hazardous substances and chemicals, helps industries work safely with hazardous substances, administers the NZ ETS and New Zealand Emission Unit Register, manages the environmental impact of activities in New Zealand's Exclusive Economic Zone.
Electricity Authority	Independent Crown entity	Electricity market regulator responsible for the efficient operation of the New Zealand electricity market.
Law Commission	Independent Crown entity	Reviews, reforms and develops New Zealand law, and makes recommendations to Government to improve the law.
New Zealand Productivity Commission	Independent Crown entity	Provides advice to the Government on improving productivity, primarily by undertaking in-depth inquiries on topics referred to the Commission by the Government. The Commission also carries out productivity-related research that assists improvement in productivity over time; and promotes understanding of productivity issues.
Reserve Bank of New Zealand	State services (unique organisation form)	New Zealand's central bank. The Reserve Bank's role includes: operating monetary policy to achieve and maintain price stability, helping to keep the banking, finance company and insurance sectors running smoothly and supplying New Zealand's currency. In most areas, the Governor of the Reserve Bank has statutory independence about how outcomes are achieved, but performance is monitored by the board (under review).

The institutional design of a Climate Change Commission (such as its function and form) needs to consider a range of matters, including the different dimensions of independence and the need for role clarity. Yet a well-designed statutory framework is not sufficient. Ultimately, the success of a Climate Change Commission will also depend on how it operates in practice (for example, its culture and leadership).

F8.11

"Independence" is multifaceted, and includes regulatory independence, operational independence, budgetary independence and institutional independence. No single "blueprint" for an independent body exists: successful design and operation relies on a whole suite of elements.

The rest of this section examines (1) the role of a Climate Change Commission; (2) its institutional form; (3) its membership; and (4) how it would operate in practice.

Role of a Climate Change Commission

It is critical that regulatory bodies have a clear mandate – that is, clarity about what they are authorised or tasked to do. A clear mandate can help promote accountability, compliance, focus, legitimacy and predictability (NZPC, 2014b). Legislation establishing a Climate Change Commission therefore must clearly specify the role of the Commission.

Two key (interrelated) questions arise about the role of a Climate Change Commission:

- Should a Climate Change Commission be a decision maker or an advisor?
- What issues should fall within the Climate Change Commission’s remit?

Should a Climate Change Commission be a decision maker or an advisor?

In designing the proposed Climate Change Commission, a fundamental issue is whether decision-making powers should be delegated to the Commission, or whether it should provide non-binding advice.

Boston identifies that, in democracies,

virtually all the decision-rights in the critical area of fiscal policy – whether in relation to taxation, expenditure, the fiscal balance, or levels of public debt – are held by elected officials or representative institutions; they have not been transferred to politically independent bodies. Much the same applies to major decision-rights in most other policy domains, not least those where long-term policy investments are often required and hence intertemporal trade-offs arise. (Boston, 2017)

A key exception is in relation to monetary policy, where (in New Zealand and various other jurisdictions) independent central banks have been vested with decision-making powers over the implementation of monetary policy. In New Zealand, while the Reserve Bank has short-term, tactical decision-making powers, it still operates within the context of a target set by Government. The rationale for delegating certain decision-making powers in the context of monetary policy but not delegating fiscal decisions is explained by Scott:

New Zealand’s record of complete political control of day-to-day monetary policy was associated with high and unstable rates of inflation and very large costs to the taxpayers from underwriting exchange rates. Against this background it was thought wise to create a central bank that was insulated substantially from short-term political pressure and free to exercise its discretion about short-term interest rates while targeting a medium-term inflation rate that is set by government. Fiscal decision-making, in contrast, goes to the very heart of a government’s development strategy and political priorities, and cannot be delegated in the same way. Only the implementation of detailed fiscal decisions can be delegated. (G. Scott, 1995, p. 15)

In the United Kingdom, the question of whether the CCC should be more involved in policymaking was expressly considered during the pre-legislative scrutiny process. The Government’s clear view (supported by Parliamentary committees) was that the CCC’s role should be advisory only:

We continue to believe that the Committee’s role should be to provide advice on budgets but that the Government should be responsible for setting them: as the Joint Committee argued, giving the responsibility for setting budgets to the Committee would probably be unworkable and would mean devolving significant policy decisions to an unelected body. (HM Government, 2007, p. 25)

The Productivity Commission agrees that it is not appropriate for a Climate Change Commission to have decision-making powers. New Zealand’s transition to a low-emissions economy will have profound and widespread impacts, and require the weighing of a range of economic, environmental, social and foreign policy considerations. Decisions about emissions reduction targets and economy-wide budgets (and policies to meet them) are highly political. Like fiscal policy, they go “to the very heart of a government’s development strategy and political priorities” (G. Scott, 1995, p. 15). Boston (2017) identifies that no government has so far been willing to transfer decision-rights on climate change mitigation matters to an independent body.

Even without decision-making powers, advisory institutions can still be highly influential and play a valuable role as an “insulating device” to protect against short-term political pressures impeding a long-term climate change response strategy. The United Kingdom’s CCC, for example, is an advisory body that is highly

influential – to the extent that the government is very unlikely to depart from the CCC’s advice (BEIS, pers. comm., 13 November 2017).

How a Climate Change Commission fits within the wider regulatory framework is critical. As identified by Generation Zero, there is no point in the Commission providing advice in a vacuum; rather, the Commission’s functions should be woven into the policy architecture, so that legislation provides a clear mandate for the Commission’s work to feed into the policymaking process (sub. 119, pp. 8–9). The PCE’s submission noted that the UK’s CCC is one element of the comprehensive system set up in the UK Act, and stressed that “[a]n independent advisory body set up on its own without the other elements would be far less effective” (sub. 54, p. 4). The Productivity Commission agrees that an independent climate change institution should be a statutory body (with its role clearly specified in legislation) that forms an integrated part of the wider legal framework. Influence is also determined by other factors that affect the credibility of institutions, including culture and leadership (as discussed below).

The statutory framework should include:

- requirements for the Government to consider⁹⁶ and respond to the Climate Change Commission’s recommendations, and to give reasons for any material departure from the Commission’s advice;
- mechanisms to promote transparency and accountability in the Climate Change Commission’s work, including, for example, by requiring the Commission’s advice to be published.

F8.12

Decisions about New Zealand’s transition to a low-emissions economy (including the setting of emissions budgets) are highly political and go to the heart of a Government’s development strategy and political priorities.

Independent institutions can be highly influential and play a valuable role without having decision-making powers.

R8.8

The independent Climate Change Commission should take an advisory role. Decision rights should not be delegated to such a Commission.

What issues should fall within the Climate Change Commission’s remit?

To help insulate policy decisions about the low-emissions transition from short-term political pressures and provide a robust information base for decision making, the Climate Change Commission should:

- advise the government (with a corresponding statutory duty for the government to have regard to the advice) on:
 - setting and reviewing statutory targets;
 - emissions budgets, and the setting of NZ ETS caps consistent with the overarching budgets;
 - other matters materially relevant to New Zealand’s low-emissions transition (for example, being consulted on any proposed NZ ETS reforms).
- undertake and publish research about the opportunities, costs and risks of New Zealand’s transition to a low-emissions economy (to help deepen New Zealand’s knowledge base and stimulate debate about specific opportunities, costs and risks of the transition);⁹⁷

⁹⁶ There are various options for the precise wording of the statutory obligation to consider the Climate Commission’s advice, such as “take into account” or “have particular regard to”. The appropriate language should be carefully considered during the legislative process.

⁹⁷ This proposed function is similar to the Productivity Commission’s statutory functions, which comprises “core” inquiry work as directed by the government but also includes “on its own initiative, to— (i) undertake and publish research about productivity-related matters; and (ii) promote public understanding of productivity-related matters” (s 9(1)(b) New Zealand Productivity Commission Act 2010).

- assess and report to Parliament each year on New Zealand’s progress towards meeting emissions budgets and the long-term target, including assessing the performance of policy instruments (including, but not limited to, the NZ ETS) and identifying emerging risks; and
- in carrying out its role, to engage in outreach and public communications (including having the power to invite and publish submissions, and consult with stakeholders as it sees fit).

Legislation should provide clear parameters for the Climate Change Commission’s advice, including guiding principles and any hierarchy of objectives (NZPC, 2014b). In particular, the Commission must have a clear mandate for its advice on emissions budgets. For example, the UK Act sets out what advice the CCC must give in relation to carbon budgets (including the level of carbon budget, the extent to which the carbon budget should be met by domestic reductions versus use of international credits, and sectoral contributions and opportunities). The CCC’s recommendations are “derived from detailed economic, engineering and science modelling, long-term scenario planning and a deep understanding of the long-term technological, economic and behavioural transformations that are required” (Fankhauser et al., 2018, p. 13). The factors the Commission must consider when recommending emissions budgets is critical, and should include climate science and technology, as well as broader factors such as economic and social impacts (section 8.6). The Climate Change Commission should recommend emissions budgets that, based on robust and transparent analysis, it considers to be achievable (even if ambitious) and consistent with the long-term emissions reduction target while imposing least cost on the economy and society.

The Government (rather than the Climate Change Commission) should formally develop the low-emissions strategy for meeting emissions budgets and long-term targets (section 8.7). The Government is best placed to make detailed economy-wide policy design and prioritisation choices that require cross-government coordination and allocation of funds, and the particular choice of policy measures “sit[s] squarely with elected representatives” (PCE, 2018, p. 29). Even so, without needing to be formally tasked with recommending a low-emissions strategy, the Climate Change Commission will over time input into (and review) the Government’s strategy and policy choices. In proposing emissions budgets that it considers are achievable, the Climate Change Commission would need to have an idea of how the budgets might be met, and that analysis would feed into the policymaking process. The Government’s policy choices would also be subject to scrutiny via the Climate Change Commission’s regular progress reports. UK Government officials noted that the CCC carries out “deep dives” into areas it sees as particularly problematic and makes specific policy recommendations but, while that advice influences the policy process, the Government does not feel beholden in the same way as it does with the CCC’s advice on setting budgets (BEIS, pers. comm., 13 November 2017).

R8.9

The Climate Change Commission should be responsible for:

- providing advice on emissions budgets, targets and New Zealand Emissions Trading Scheme (NZ ETS) caps (based on clear statutory parameters for that advice), and other matters materially relevant to New Zealand’s low-emissions transition;
- reporting on progress towards emissions budgets and targets, including assessing the performance of policy instruments and identifying emerging risks;
- undertaking and publishing relevant research into transitioning to a low-emissions future; and
- engaging in outreach and public communications (as required to carry out its role).

Legislation should also oblige the government to have regard to the Climate Change Commission’s advice when making decisions on emissions budgets, targets and NZ ETS caps, and give clear reasons for any material departure from that advice.

Choosing an appropriate institutional form

State sector organisations have many forms – from government departments and departmental agencies (both legally part of the Crown), to various forms of Crown entity (standalone agencies governed by a board and not legally part of the Crown), and Officers of Parliament.

So what institutional form should a new independent climate change body take? The choice of institutional form is important both for what it signals around expected levels of agency independence, and for the legal protections associated with particular agency forms (NZPC, 2014b). To properly perform its role, retain credibility over the longer term, and be viewed as independent to maintain public confidence, an independent climate change body should have a high degree of operational and institutional independence. Therefore, it should have:

- broad discretion to exercise functions at “arm’s length” from the executive and legislative branches of government or industry; and
- formal distance, and security of tenure for governors and senior management.

Some have suggested that New Zealand’s independent climate change body should be an Officer of Parliament (Taylor, 2017; Christchurch City Council, sub. 13), but others favour creating the body as an independent Crown entity (PCE, 2017). Both are institutional forms that signal greater levels of operational and institutional independence.

Officers of Parliament are associated with the oversight of executive authority and perform functions that the House of Representatives might perform. They should be subject to the conditions applying to an arm of the legislative branch of government (such as being outside the public service and not being subject to control of its actions by the executive). As such, they must be seen to act impartially to retain the integrity and confidence of the whole House of Representatives (McGee, 2017).

Box 8.9 Officers of Parliament

New Zealand currently has three Officers of Parliament: the Controller and Auditor-General, the Ombudsman, and the Parliamentary Commissioner for the Environment. The position of Officer of Parliament is not defined under statute. Criteria for the position are also not defined. Rather, the status of Officer of Parliament is attached on an individual basis to particular positions, with the main powers, duties and functions of the officers determined by the individual statutory provisions applying to each. The accepted criteria for considering whether it is appropriate to make a particular position an Officer of Parliament are that:

- an Officer of Parliament must only be created to provide a check on the arbitrary use of power by the executive;
- an Officer of Parliament must only discharge functions that the House of Representatives itself, if it so wished, might carry out;
- an Officer of Parliament should be created only rarely;
- the House of Representatives should, from time to time, review the appropriateness of each Officer of Parliament’s status as an Officer of Parliament; and
- each Officer of Parliament should be created in separate legislation.

Source: Legislation Advisory Committee (2014); McGee (2017).

By contrast, Crown entities are standalone corporate bodies that are not legally part of the Crown, but are still ultimately managed (though from a distance) by Ministers (NZPC, 2014b; State Services Commission, 2014). Crown entities can take three different institutional forms: Crown agent, autonomous Crown entity,

and independent Crown entity. Each form displays different levels of operational and institutional independence.

- Crown agents, where there is a high degree of Ministerial oversight (eg, Maritime New Zealand, Environmental Protection Agency, New Zealand Transport Agency). They are governed by a board, which can be appointed and removed at the responsible minister's discretion. They are operationally independent, but must give effect to government policy when directed.
- Autonomous Crown entities, which have an intermediate degree of Ministerial oversight and independence in decision making (eg, New Zealand Teachers Council, Commission for Financial Literacy and Retirement Income). They are governed by a board, which can be appointed and removed for just cause by the responsible minister. They are operationally independent, but must have regard to government policy when directed.
- Independent Crown entities, where there is a high degree of independence from Ministerial influence (eg, Commerce Commission). They are governed by a board, which can be appointed and removed for just cause by the Governor-General on advice of the responsible minister given after consulting the Attorney-General. There are no ministerial powers of direction. Typically, legislation expressly requires independent Crown entities to act independently when performing their functions and duties, and exercising their powers.⁹⁸

Overall, the Productivity Commission considers that a Crown entity model is a more appropriate institutional form for an independent climate change body than an Officer of Parliament model. A key differentiating factor is that, as part of the executive branch of government, Crown entities are more readily able to develop working relationships within government. A positive strategic working relationship with government is capable of being managed in a way that does not undermine the Climate Change Commission's independence, and would enable valuable sharing of information – for example, the ability to draw on the resources of other government agencies (PCE, sub. 54, p. 4), as well as develop a good mutual understanding of both parties' work programmes and viewpoints. The ability to share resources between public sector agencies is particularly important given that, due to its small size, New Zealand has limited research and analytic resources compared with other jurisdictions.

The UK's CCC (a non-departmental public body), for example, operates under a Memorandum of Understanding with government and interacts regularly with key government departments. Importantly, the CCC remains a "highly independent voice" with "immense authority" and "high credibility" (Department of Energy and Climate Change (UK), 2014; Macrory, 2014; BEIS, pers. comm., 13 November 2017).

More specifically, of the three different Crown entity models identified above, an independent Crown entity model is the most appropriate institutional form for an independent body focused on climate change. An independent Crown entity has a high degree of operational and institutional independence to properly perform its role and retain the necessary credibility.

R8.10

To properly perform its role, retain credibility over the longer term, and be viewed as independent, the Climate Change Commission should have a high degree of operational and institutional independence.

The Climate Change Commission should have:

- broad discretion to exercise functions at "arm's length" from the executive and legislative branches of government or industry; and
- formal distance, and security of tenure for governors and senior management.

The Climate Change Commission should be set up as an independent Crown entity.

⁹⁸ For example, the Productivity Commission is an independent Crown entity, and section 9 of the New Zealand Productivity Commission Act 2010 provides that "[e]xcept as expressly provided in this or any other Act, the Commission must act independently in performing its functions and duties and exercising its powers".

Membership

Design of the Climate Change Commission needs to address the Commission's membership, including its composition and how members should be appointed (and dismissed).

Submitters expressed strong (though not universal) support for the creation of an independent **expert** body, rather than a committee of stakeholders. Proposed relevant areas of expertise for an independent body include climate science, business and economics, energy and agricultural technology, finance and investment, the Treaty of Waitangi and tikanga Māori, Māori interests, and social transformation (eg, Generation Zero, sub. 119; LGNZ, sub. 36; Ora Taiao, sub. 72; PCE, 2017; 2018).

To tackle the complex and economy-wide issues involved with the transition to a low-emissions economy, the Climate Change Commission needs to be a multidisciplinary expert body (not a committee of special interest or advocacy representatives). More specifically, the Climate Change Commission should comprise Commissioners and staff (a high-quality secretariat) with a governing board that is responsible for output. If capacity gaps occur within New Zealand, the Climate Change Commission should be able to appoint overseas experts to its ranks. Relevant economic expertise will not be limited to economic forecasting, as the profound nature of the low-emissions transition will require broad and deep economic understanding and policy wisdom.

The appointment process is an important dimension of institutional independence (NZPC, 2014b). To help maintain institutional independence, Climate Change Commission members should not be appointed directly by the responsible minister. Rather, members should be appointed by the Governor-General on the recommendation of Cabinet, following (as proposed by the PCE) consultation with other political parties.

The success of a Climate Change Commission will also depend on how it operates in practice

The success of an independent body will depend not only on its statutory design, but on a range of other factors that affect how the institution operates in practice (such as culture and leadership, and funding).

Culture and leadership

The leadership and culture of organisations is critically important to organisational success and how success is achieved (NZPC, 2014b). Culture relates to the norms, values and beliefs of an organisation which are, in turn, profoundly shaped by the actions of organisational leaders. Organisational leaders set the tone, behaviour and aspirations of a new organisation, drawing on their own experiences, values and assumptions about how to interact with stakeholders, identifying organisational priorities, and how best to achieve their statutory purpose (Schein, 2010).

The Productivity Commission heard from a range of UK stakeholders that the chairs of the CCC (Lord Turner followed by Lord Deben) have played an invaluable role in building its credibility and strong reputation. Different leadership strengths (such as bipartisanship and consensus building skills versus deep technical knowledge) may best suit different stages in the lifecycle of the Climate Change Commission. How the Climate Change Commission builds its public profile and reputation (so it cannot be easily shut down if government dislikes its advice) is also important (CCC, pers. comm., 11 October 2017; BEIS, pers. comm., 13 November 2017).

The quality of the relationship between the Climate Change Commission and the Government will be vital. There will be tensions and vigorous debates, and a Climate Change Commission needs to have institutional robustness to confront conflict. It also needs to manage its role and relationships in a manner that helps to build a credible commitment, recognising that the Commission and the government are both engaged in a process of discovering over time how to meet long-term emissions targets.

The nature and extent of the climate change challenge also calls for thought leadership. As Gruen (2018) argues, while independence is prized in our public culture, most independent public sector agencies are tethered to the career public service and "think like bureaucrats". However, independent bodies should be bold and show intellectual leadership. Gruen points to the Bank of England as an institution that is prepared to lead the process of intellectual search – as evidenced by, for example, its blog that explores a range of

interesting and important questions. Thought leadership can be supported by giving an organisation a clear mission and focus, valuing professionalism and technical capacity, and judging personnel performance on that basis.

Funding

A Climate Change Commission should be funded via its own budget line(s) (non-departmental appropriations) as part of the Government's annual budget process. This is the usual funding basis for independent Crown entities. The level of funding affects the capacity of agencies to perform their role (NZPC, 2014b). So that the Climate Change Commission can provide robust advice, its funding needs to be adequate to properly resource an appropriately sized secretariat and enable the Commission to attract (and retain) high calibre personnel. Under-funding would hinder the Commission's ability to perform its role, and therefore undermine its value.

F8.13

Independence is earned as much as granted. The success of an independent body will therefore depend not only on its statutory design, but also on how the institution operates in practice (including the quality of appointments, its culture and leadership, and adequacy of ongoing funding).

8.11 Recognising the Treaty of Waitangi

The Treaty of Waitangi/Te Tiriti o Waitangi is the foundation of the Māori–Crown partnership. The fundamental elements of the relationship are understood now, but questions remain about how iwi and hapū would work with the Crown in developing the country's future (Constitutional Advisory Panel, 2013).

Te Rūnanga o Ngāi Tahu submitted that “there is greater potential to get things right when viewing economic benefits, and associated co-benefits, from an indigenous perspective, through the lens of Treaty partnership”. (sub. 83, p. 7)

This section is about the Treaty of Waitangi and the legislative framework for a low-emissions economy. It discusses how the Treaty is typically referenced in legislation, current developments and the opportunities for a partnership approach in achieving the goal of a low-emissions economy.

References to the Treaty or to the principles of the Treaty are found in statutes that govern physical resources and the environment where Māori have strong iwi and hapū relationships, often involving kaitiaki relationships – including land, water, important sites, wāhi tapu and other taonga. Most statutes that contain “Treaty clauses” contain regulatory provisions or confer regulatory powers and responsibilities, and they often create obligations on a range of parties (NZPC, 2014b).

A Treaty clause in the legislative framework for a low-emissions economy would be consistent with current practice. It would acknowledge both the importance of the kaitiakitanga role of mana whenua and the stability and longevity of the fundamental constitutional arrangements on which a low-emissions future would be achieved.

Treaty clauses in previous legislation have focused on how the Crown or its agents should “have regard to”, “give recognition to”, “take into account” or “give effect to” the principles of the Treaty of Waitangi. Māori have advocated Treaty clauses as a means to protect their rights. Many statutes have focused on consultation requirements in satisfying Treaty principles, but often with little specificity or conviction.

A particular example is the current CCRA, which requires under various sections that “the Minister must consult, or be satisfied that the chief executive has consulted, representatives of iwi and Māori that appear to the Minister or chief executive likely to have an interest in” the pre-1990 forest land allocation plan, the fishing allocation plan, regulation-making powers in relation to eligible agricultural activities, regulations relating to unique emissions factors, the gazetting of targets, and regulations relating to targets.

However, in recent years the trend is towards both more specificity around consultation and greater Māori participation. For example:

- The Resource Management Act is specific about when local authorities are deemed to have consulted iwi. Consultation includes fostering iwi capacity to respond to an invitation to consult, establishing processes for the opportunity to consult, and indicating how to address issues identified by iwi as a concern to them (Schedule 1, 3B).
- To recognise and respect the Crown's responsibility to take account of the Treaty of Waitangi, the Environmental Protection Authority Act 2011 established a Māori Advisory Committee to advise the Authority on policy, process, and decisions.
- Recent changes to the Resource Management Act are intended to facilitate and enhance Māori participation in resource management processes through Mana Whakahono a Rohe (iwi participation arrangements) (MfE, 2017l; NZPC, 2017a) (Box 8.10).

Box 8.10 Principles in initiating, developing, and implementing a Mana Whakahono a Rohe

The participating authorities must use their best endeavours—

- (a) to achieve the purpose of the Mana Whakahono a Rohe in an enduring manner:
- (b) to enhance the opportunities for collaboration amongst the participating authorities, including by promoting—
 - (i) the use of integrated processes:
 - (ii) co-ordination of the resources required to undertake the obligations and responsibilities of the parties to the Mana Whakahono a Rohe:
- (c) in determining whether to proceed to negotiate a joint or multi-party Mana Whakahono a Rohe, to achieve the most effective and efficient means of meeting the statutory obligations of the participating authorities:
- (d) to work together in good faith and in a spirit of co-operation:
- (e) to communicate with each other in an open, transparent, and honest manner:
- (f) to recognise and acknowledge the benefit of working together by sharing their respective vision and expertise:
- (g) to commit to meeting statutory time frames and minimise delays and costs associated with the statutory processes:
- (h) to recognise that a Mana Whakahono a Rohe under this subpart does not limit the requirements of any relevant iwi participation legislation or the agreements associated with that legislation.

Source: Section 58N: inserted, on 19 April 2017, by section 51 of the Resource Legislation Amendment Act 2017 (2017 No 15)

More meaningful consultation and enhanced participation (and developing Māori capacity and capability to do so), should be considered when reflecting the Treaty partnership in the legislative framework for a low-emissions economy. It is appropriate for the legislative framework for a low-emissions economy to provide mechanisms for Māori to advise the Government on policy, process, and decisions relating to emissions budgets and the Government's strategy to achieve them.

The Commission has previously noted however, that good practice in upholding Treaty principles of partnership, mutual respect and good faith cannot be legislated for. It crucially depends on the quality of leadership (NZPC, 2014b).

In a submission to the *Regulatory institutions and practices* inquiry from Environment Canterbury, Dame Margaret Bazley offers insight on effective approaches to working in partnership with Māori, and also points to the weaknesses of simply relying on legislative requirements:

Environment Canterbury has experience and insight to offer on effective approaches to working in partnership with Māori... in terms of its *Tuia* partnership with Ngai Tāhu. This partnership has been built

from the ground up, and has been progressed from identifying and respecting past issues and grievances to working shoulder to shoulder to set in place new ways of working focussed on solutions and practical outcomes. *Tuia* is premised on mutual good faith and commitment to do what is right and in the best interest of the iwi and the region, not on narrow legislative requirements. (NZPC, 2014b, p. 172)

The submission's focus on "working shoulder to shoulder to set in place new ways of working focused on solutions and practical outcomes" seems entirely consistent with the goal of working towards a low-emissions economy.

F8.14

Inclusion of a Treaty of Waitangi clause in the legislation would acknowledge both the importance of the kaitiakitanga role of mana whenua and the stability and longevity of the fundamental constitutional arrangements on which a low-emissions future would be achieved.

R8.11

The legislative framework for a low-emissions economy should provide mechanisms for Māori to advise the Government on policy, process, and decisions relating to emissions budgets and the Government's strategy to achieve them.

F8.15

The legislative framework could strongly signal a partnership approach between Māori and the Crown to achieve the goal of a low-emissions economy. However, legislative provisions alone will not be sufficient to uphold Treaty principles of partnership, mutual respect and good faith. Much will depend on the quality of leadership.

8.12 Leadership from the centre

The change to legislation and institutional settings proposed above would significantly ease some of the problems outlined in section 8.2 – namely, the lack of policy stability and clarity about the nature and pace of the transition to a low-emissions economy. Further changes are needed within the executive to resolve the outstanding issue of poor policy coherence across government and to deliver actual progress towards lower national emissions. This section discusses options for improving that coherence.

Institutional change outside the executive is necessary but not sufficient

A legislative target and independent advisory body are necessary, but not sufficient, conditions for an effective and efficient emissions-reduction strategy. The legislative targets and independent advice from a Climate Change Commission will need to be responded to by the Government. UK experience suggests that this process can be fraught. While the first three carbon budgets recommended by the CCC were accepted by the UK Government, the fourth and fifth budgets required much larger reductions in emissions and were more controversial.

- The Cabinet split over whether to accept the CCC's advice on the fourth budget, and only accepted it following the intervention of the Prime Minister. However, the finalised government budget differed from CCC advice, in particular rejecting the recommendation that all emissions reduction should be achieved by domestic action. A number of scholars have argued that the initial cross-party consensus that led to the passing of the Act has weakened, especially as the likely costs of the transition become clearer and closer (Benson & Lorenzoni, 2014; Carter, 2014; Gillard, 2016; Lockwood, 2013; Rollinson, 2010).
- A government response to the fifth carbon budget was scheduled for release in 2016, rescheduled to early 2017, and then delayed further.
- Although the UK Government did ultimately publish its response to the fifth carbon budget in the form of a "Clean Growth Strategy" in October 2017, the CCC has argued that the Strategy "does not go far

enough” (Committee on Climate Change, 2018). The CCC concluded that even “if delivered in full, existing and new policies, including those set out in the Clean Growth Strategy, miss the fourth and fifth carbon budgets by about 10-65 MtCO₂e – a significant margin” and called on the UK Government to “urgently firm up policies and proposals in the Clean Growth Strategy”, “develop and implement new policies to close the remaining ‘emissions gap’” and “address the risks of under-delivery” (Committee on Climate Change, 2018).

Leading the government response to the Climate Change Commission’s advice

Developing the government response to the Climate Change Commission’s advice will be a substantive policy process, with agencies assessing the Commission’s proposals, selecting alternative priorities or pathways, identifying the impacts on affected sectors and communities, and designing suitable policy, regulatory and fiscal responses. Processes must also be in place to monitor compliance with Cabinet’s final decisions.

Submissions to the Commission’s Draft Report agreed that coordinated and coherent government response to the Climate Change Commission’s advice is important, that this is a substantive policy process extending across the economy and agencies, and that the institutional capability required for this is currently lacking in New Zealand in regard to reducing GHG emissions (eg, Vector, sub. DR287; Trust Power, sub, DR249; Catherine Leining, sub. DR279).

Crafting a response will require close Cabinet involvement and oversight, and the agency or agencies leading the policy development process will require specific skills and capabilities. In particular, the organisation(s) responsible for providing advice on the Commission’s recommendations and monitoring compliance with emissions budgets will need to:

- have the capability and knowledge to understand and robustly assess the Commission’s recommended actions in each sector;
- have the ability to take an economy-wide, strategic view and to consider the full range of benefits and costs;
- be linked to the fiscal budget process, to ensure that Cabinet decisions are suitably resourced; and
- have the mana to bring together the range of portfolio agencies, work through any differences of view to develop a coherent and robust set of policy proposals, and monitor the government’s progress against Cabinet decisions.

The Productivity Commission was not able to identify any one agency within the current public sector with the full range of capabilities and attributes. In assigning responsibility for leading the response to the Climate Change Commission’s advice, the Government should get an assurance from the relevant chief executive(s) that the agency or agencies have, or will quickly obtain, the necessary skills and knowledge.

F8.16

Developing the government response to the Climate Change Commission’s advice will be a substantive and challenging policy process and will present major coordination issues. The organisation(s) responsible for providing advice on the Climate Change Commission’s recommendations will need:

- the capability and knowledge to understand and robustly assess the Climate Change Commission’s recommended actions in each sector;
- the ability to take an economy-wide, strategic view and to consider the full range of benefits and costs;
- links to the fiscal budget process, to ensure that Cabinet decisions are suitably resourced; and

- the mana to bring together the range of portfolio agencies, work through any differences of view to develop a coherent and robust set of policy proposals, and monitor the Government's progress against Cabinet decisions.

No single agency within the current public sector has this full range of necessary capabilities and attributes. New arrangements will be required to deliver these capabilities.

Ministerial influence will be important

Regardless of which agency is responsible for leading the response to meet emissions budgets and targets, achieving alignment across government will require ongoing efforts to ensure that new regulatory, policy or fiscal proposals do not undermine progress towards the goal of moving to a low-emissions economy. The transparency and disclosure requirements recommended below will help reveal the climate impacts of new regulatory proposals, but not other policy and fiscal initiatives. Keeping sight of these other proposals will depend on constant vigilance at the Cabinet level.

Under current government arrangements, the Minister for Climate Change sits outside Cabinet. This could limit the Minister's ability to have sight of the full range of new initiatives and to assess their compatibility with national emissions reductions objectives.

The Productivity Commission has commented on similar arrangements in its inquiry into *Regulatory institutions and practices*, noting that the regulatory reform portfolio originally sat outside Cabinet and that assigning this responsibility to a senior Cabinet minister has significant advantages, as seniority provides:

- the ability to take a whole-of-government perspective;
- the capacity to maintain the Government's focus in improving the system;
- the authority to ensure that initiatives are implemented; and
- access to the information required to develop and implement policy (NZPC, 2014b).

Similar considerations would apply to climate change policy.

F8.17

Developing a robust and enduring cross-government emissions reduction strategy will require coordination across both departments and Ministers.

Would wider legislative obligations on Ministers or the public service be beneficial?

As discussed earlier, the legislative target and reporting obligations, and the independent Climate Change Commission, are examples of "commitment devices" that provide some assurance that decision makers will act in a certain way or pursue specified goals. Other types of commitment devices are possible, such as legislative obligations on decision makers to take into account certain climate change related factors.

Obligations on decision makers

Ministers could be required by law to take into account specific climate change-related factors when making decisions. For example, the Victorian Climate Change Act 2017 requires that "a person making a decision or taking an action" in specific statutory circumstances "must have regard to:

- (a) the potential impacts of climate change relevant to the decision or action; and
- (b) the potential contribution to the State's greenhouse gas emissions of the decision or action; and
- (c) any guidelines issued by the Minister...[section 17(2)]

In having regard to these climate change impacts, decision makers must in particular consider:

- (a) potential biophysical impacts; and
- (b) potential long and short term economic, environmental, health and other social impacts; and
- (c) potential beneficial and detrimental impacts; and
- (d) potential direct and indirect impacts; and
- (e) potential cumulative impacts. [section 17(3)]

Further, the Act lays down “guiding principles” that the Minister may “have regard to” when issuing guidelines under the law, namely “informed decision making”, “integrated decision making”, “risk management”, “equity”, “community engagement” and “compatibility.”

Assessment obligations

Alternatively, more general obligations could be placed on Ministers and agencies to conduct climate-change assessments of decisions, in a similar manner to the Cabinet Office’s current requirements to conduct impact analysis on proposals for regulatory change (DPMC, 2017). A Private Member’s Bill was introduced to Parliament in 2015 proposing that all government Bills “have a Climate Impact Disclosure Statement – a report, prepared by the Ministry for the Environment, that outlines the likely impact of the legislation on the climate” (Green Party of Aotearoa New Zealand, 2015). The Labour–Greens Confidence and Supply Agreement includes the goal that all “new legislation will have a climate impact assessment analysis” (New Zealand Labour Party & Green Party of Aotearoa New Zealand, 2017, p. 3).

Transparency is preferable

Given the need to ensure that any new climate change legislation and institutions are durable and provide sufficient flexibility for future Governments, the Productivity Commission does not favour adding process-based decision-making principles in legislation along the lines of those used in Victoria. Such principles are inevitably cast at a high level and open to wide variations in interpretation. In addition, the proposed combination of a legislated long-term target and regular emissions budgets already provides significant constraints within which government decisions will have to be made. Adding more constraints in the form of principles risks creating uncertainty around how those principles will or should be applied, judicial challenge, and potentially reduced flexibility for future Ministers. The Commission is not persuaded that the possible benefits of such principles outweigh these costs.

Even so, some form of assessment and disclosure regime around climate change impacts would be valuable for Ministers, Parliamentarians and the wider public, and could help ensure that individual policy decisions make a cumulatively positive contribution to national emissions-reduction goals. To avoid creating unnecessary process burdens or duplications, climate change assessment requirements should be built into the existing Regulatory Impact Analysis (RIA) system. A corresponding obligation should be placed on agencies to consult with the organisation responsible for developing advice on the Climate Change Commission’s recommendations when considering any climate change impacts, and to ensure the agency’s comments are fairly and accurately reflected in any final assessment. Embedding these assessments into the RIA process would also ensure that a wider array of legislative instruments (ie, not just new primary legislation) would be subject to climate impact analysis.

R8.12

Treasury should update the Regulatory Impact Analysis requirements to explicitly include consideration of climate change impacts, where relevant.

The Cabinet Office should update its circular to require agencies making proposals for regulatory changes with climate change implications to consult with the organisation responsible for developing advice on the Climate Change Commission’s recommendations, and to ensure that the agency’s comments are fairly and accurately reflected in any final assessment.

Local government will play an important role in the national response, and should be appropriately included and consulted

Changes to land use and land transport will be critical contributors to any national emissions-reduction strategy, given that agriculture and transport are New Zealand's two largest sources of GHG emissions. Local government plays a key role in shaping land use and transport activities. This is through its regulatory roles (eg, land use regulation through the Resource Management Act 1991), funding and investment activities (eg, management of public transport services and local roading under the Land Transport Management Act) and waste management obligations. Local government will therefore need to be appropriately included in any national climate change strategies.

The Productivity Commission has previously explored the regulatory roles of local government, and commented on the need for an improved relationship between local and central government. Among other things, the Commission found limited analysis by central government of local government's capability or capacity to implement regulations before new regulatory roles were allocated, little understanding by central government of the local government sector, and an "uneasy relationship" and "generally poor engagement" between the two levels of government (NZPC, 2013). Therefore, the Commission recommended that local and central government should find new arrangements for working together, with clearly defined roles, appropriate representation, and processes to work through issues of common interest. Developing the government response to the Climate Change Commission's recommendations would be a good opportunity to set up these new arrangements.

F8.18

Local government will play an important role in any national emissions-reduction strategy, given the responsibilities it has for regulating land use and managing land transport. The development of a government response to the Climate Change Commission recommendations would be a good opportunity to establish new, more effective arrangements for local and central government to work together on issues of common interest.

8.13 Conclusion

There are strong political incentives to avoid making long-term policy decisions that have benefits that will not manifest until well into the future, but will have short term costs and impacts. Well-designed laws and institutions can play a critical role in binding the political executive (across policy cycles and parliaments) to govern, within flexible limits, in line with long-term commitments. Crucially, they can entrench disciplined processes for promoting transparency and accountability, and signal policy intentions.

The design of laws and institutions needs to recognise that the underlying policy objective is not simply to transition to a low-emissions economy; reducing emissions is key, but the nature of the transition matters too. Laws and institutions should support a low-emissions transition that maximises benefits to New Zealand, and seeks to maintain and build natural, human, economic and social capital.

Getting a new Climate Change Act on the statute books and establishing an independent Climate Change Commission are important steps towards supporting New Zealand's low-emissions transition. But the success of laws and institutions depends on much more than statutory design. To endure, they need cross-party support and ongoing leadership.

A key strength of a "UK-style" Act is that it operates at an overarching framework level; it provides core legal and institutional architecture to guide the transition, but does not prescribe particular policies to reduce emissions. This allows flexibility about precisely how the transition is achieved. It means consensus on overarching laws and institutions can co-exist with ongoing political debate about specific policy measures. Indeed, in reflecting on 10 years of the UK Act, Fankhauser et al. (2018) credit it with transforming the political debate on climate change (by keeping climate change on the political agenda via regular reporting procedures, and by helping build a credible independent evidence base to enlarge and support the political debate). But the authors also rightly caution that a "good framework law does not guarantee automatic policy delivery. Climate action requires strong leadership" (Fankhauser et al., 2018, p. 5).

9 Short-lived and long-lived gases

Key points

- Greenhouse gases (GHGs) have different atmospheric lifetimes. Some, such as carbon dioxide (CO₂), are long-lived. They accumulate in the atmosphere and so any current emissions irreversibly warm the planet. Others, such as methane (CH₄), are short-lived so the bulk of the warming effect of current emissions occurs within 20 years.
- The atmospheric stocks of short- and long-lived GHGs are both important to the Paris Agreement goal of limiting warming to well below 2°C. However, the irreversibility of long-lived gases means their emissions must fall to net-zero to prevent ongoing warming. The sooner net-zero (or lower) is achieved, the more likely it is the planet will remain within this limit. Conversely, while emission reductions of short-lived gases will also be needed to achieve the 2°C goal, they do not need to reach net-zero to stabilise temperature.
- The relative proportion of a country's short- to long-lived gas emissions has implications for its choice of mitigation targets, emission-reduction trajectories, and policy frameworks. In thinking about these choices, various factors such as the abatement costs of different GHGs, and the flexibility to adjust policy over time, must be considered.
- The emissions profiles of most other developed countries are dominated by CO₂. As such, the focus is on mitigating long-lived gases. In comparison, New Zealand has a high proportion of short-lived gases (mainly biogenic CH₄ from livestock production). This distinctive emissions profile means that the relative priority of mitigating short- and long-lived gases is of special interest.
- While New Zealand needs to give priority to reducing emissions of long-lived gases to net-zero because of their irreversibility, benefits will also accrue from lowering its emissions of short-lived gases over the coming decades. These benefits include to create "room" for a (slightly) greater budget for long-lived gas emissions, to reduce short- and medium-term warming, and to signal of the need to transition to a low-emissions economy.
- Emissions metrics are used to help make mitigation comparisons across different GHGs by calculating their carbon dioxide equivalence (CO₂e). Standard metrics show the cumulative effect on warming of emitting one tonne of different GHGs over a given period (most commonly 100 years) compared to emitting one tonne of CO₂. A newly-proposed metric, GWP*, is different in approach and better captures the warming effects that arise from the different dynamics of short- and long-lived gases. It can thereby help people make better decisions about mitigation.
- New Zealand has considered treating short- and long-lived gases differently before, and it is one of the options under review as part of the Zero Carbon Bill. The country now has the opportunity to enact an innovative policy solution that recognises the different scientific properties of short- and long-lived gases.
- The Commission recommends New Zealand establish separate long-term emissions reduction targets for short- and long-lived gases, as well as separate emissions budgets for short- and long-lived gases. It also recommends the inclusion of all long-lived gases in the New Zealand Emissions Trading Scheme, and the inclusion of biogenic CH₄ from agriculture and waste in some form of an emissions pricing scheme to incentivise reducing emissions.

This chapter explores the physical differences between short- and long-lived greenhouse gases (GHGs), and the associated policy implications of these differences. It proposes a dual approach to dealing with

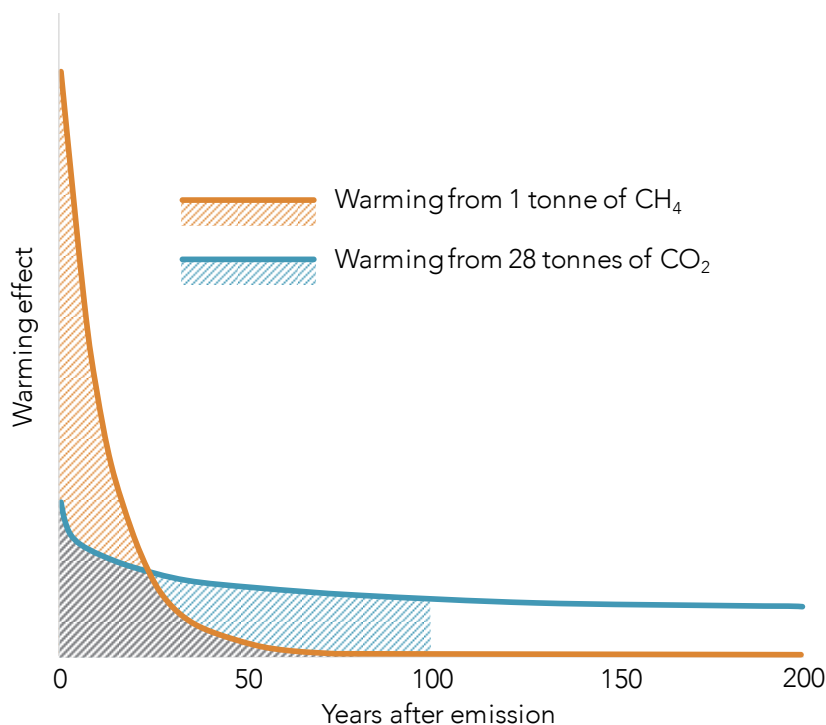
New Zealand's distinctive emissions profile, including separate targets, emissions budgets and policy approaches for short- and long-lived gases.

9.1 Short- and long-lived gases

GHGs have different atmospheric lifetimes.⁹⁹ Some are long-lived, such as carbon dioxide (CO₂) which can stay in the atmosphere for centuries, or nitrous oxide (N₂O) which has a lifetime of around 120 years. Others are short-lived, which means their emissions largely disappear from the atmosphere within 20 years. These include methane (CH₄) which has a lifetime of 12 years, and some hydrofluorocarbons (HFCs) with a lifetime of only a few days.

GHGs also have different relative strengths. These interact with their different atmospheric lifetimes to influence warming at any point in time. For example, over 100 years an emission of a tonne of CH₄ is 28 times more potent in terms of its warming effect compared to an emission of a tonne of CO₂ (Figure 9-1), and sulphur hexafluoride (SF₆) is 23 500 times more potent. However, as shown, the distribution of their warming effects is very different.

Figure 9-1 Comparing the warming effect of CO₂ and CH₄



Source: Adapted from Reisinger and Stroombergen (2011).

Notes:

1. The figure compares the warming effect of the emission of 1 tonne (t) CH₄ with 28 t CO₂. Because CH₄ is more potent it takes 28 times as much CO₂ to cause the same warming effect over 100 years (the blue and orange shaded parts of the graph are equal in area). However, the warming is distributed very differently over the 100 years. The figure also shows that over a longer period CO₂ continues to have a warming effect while CH₄ does not.

A stock of atmospheric greenhouse gases consistent with 2°C

Emissions of both short- and long-lived GHGs contribute to the overall stock of atmospheric GHGs. This stock (or concentration) of GHGs is important because it directly relates to temperature, and specifically, the peak warming limit of 2°C specified in the Paris Agreement (Box 9.1).

⁹⁹ An atmospheric lifetime is the average time that a molecule resides in the atmosphere before it is removed by chemical reaction or deposition. Specifically, it refers to the length of time it takes for a single pulse emission of a GHG to be reduced to 37% of its initial amount (Hollis et al., 2016).

Box 9.1 The Paris Agreement and the goal of limiting peak warming to well below 2°C

Peak warming refers to the maximum temperature arising from human-induced climate change. The central aim of the Paris Agreement is to ensure peak warming is limited to well below 2°C above pre-industrial levels (UNFCCC, 2015b), and ideally does not exceed 1.5°C. However, this 1.5°C target is now considered by some to be very unlikely (less than a 5% chance) (Raftery et al., 2017).

The Paris Agreement also aims to achieve net-zero GHG emissions by the second half of this century. Net-zero emissions is when the amount of greenhouse gases emitted into the atmosphere because of human activity is matched by the amount sequestered or offset (eg, by forestry) as a result of human activity. The overriding goal is to achieve the lowest possible level of peak warming.

Long-lived GHGs accumulate in the atmosphere and, barring their sequestration, have an essentially irreversible effect on temperature change (IPCC, 2014a). In other words, the stock of long-lived GHGs in the atmosphere at any one time is the cumulative total of all previous emissions.¹⁰⁰ This means that the only way for long-lived gases to achieve a steady-state (ie, to stabilise the stock) is for emissions to cease (ie, get to absolute or net-zero). CO₂ is particularly important because of its persistence in the atmosphere “well beyond the timescale of human experience” (Matthews & Caldeira, 2008, p. 4).

But, because of the relatively short lifetime of a short-lived gases, its atmospheric stock changes by the difference between its inflow rate (ie, its emissions) and its outflow rate (ie, its decay). A steady-state stock of a short-lived gas is achieved when its inflow equals its outflow.¹⁰¹ Stabilising the stocks of short-lived gases at current levels will stop them contributing to further warming. However, as explained below, this is unlikely to be enough to achieve the Paris Agreement goal – and short-lived gases will need to reduce before stabilising at lower levels.

Figure 9-2 uses CH₄ and CO₂ as examples to show the different warming behaviour of short- and long-lived gases in three scenarios: rising emissions, constant emissions and falling emissions. The graphs show that when CO₂ emissions are not rising, or even when they are falling, they are still contributing to increased warming because of the way they accumulate in the atmosphere.

The overall policy goal for both short- and long-lived gases is a steady or declining stock of GHGs consistent with keeping global temperatures well below 2°C. To achieve this goal, three factors must be considered: the current stock of long-lived gases (ie, those already emitted, and which have accumulated in the atmosphere); future inflows (ie, emissions) of long-lived gases; and, future inflows and outflows of short-lived gases.

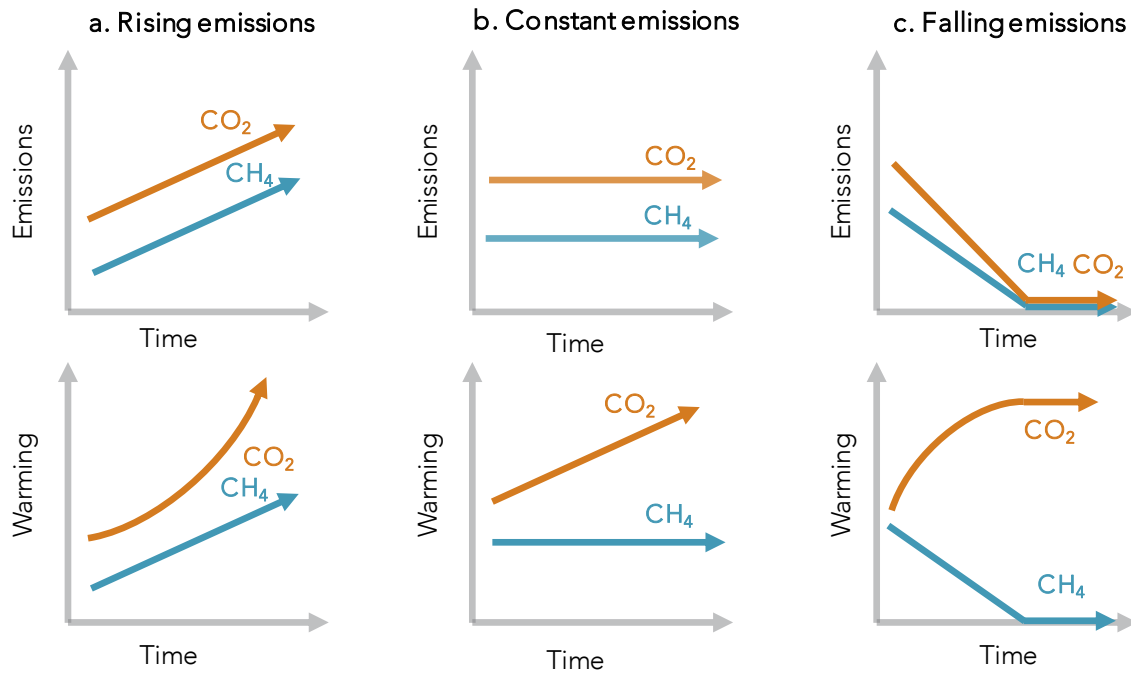
Figure 9-3 illustrates what this stock could look like by using the analogy of a bathtub, where the level of the top of the tub is the maximum total amount of GHGs consistent with 2°C warming. It shows that the committed stock of long-lived gases is the most important, because that stock is irreversible. In other words, the emissions of short-lived gases can only influence peak warming in relation to this committed stock of long-lived gases (Bowerman et al., 2013; Pierrehumbert, 2014). New research by Tanaka and O’Neill (2018) shows that remaining below the Paris Agreement peak warming limit does not require all GHGs to reach net-zero, but that a “zero-emissions target for CO₂, rather than GHGs, is more likely to be consistent with the Paris temperature targets” (p. 323).¹⁰²

¹⁰⁰ Negative emissions technologies like bioenergy carbon capture and storage could theoretically remove CO₂ from the atmosphere, but they do not yet exist on a scale to make any measurable difference to warming. However, they may be needed in the future to limit warming to well below 2°C.

¹⁰¹ See Andy Reisinger (sub. DR233) for a discussion about a minor ongoing warming effect after atmospheric concentrations of CH₄ have stabilised.

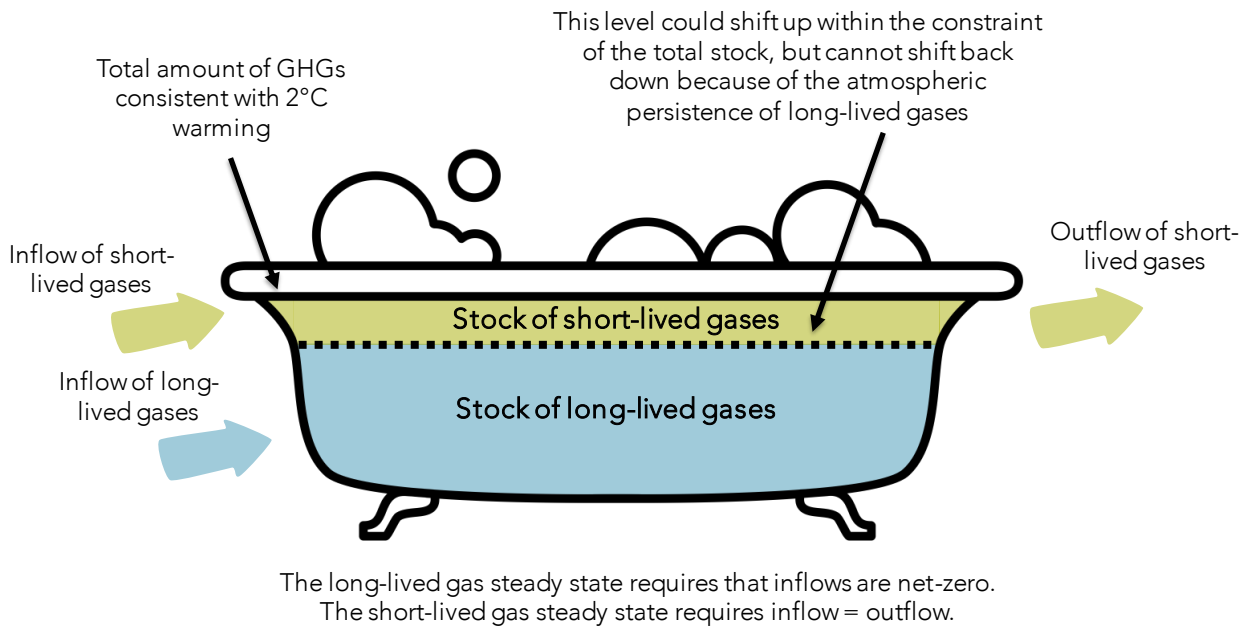
¹⁰² Whether it is considered acceptable to overshoot the temperature target (eg, warm to 2.5°C and then decrease to 2°C or less using negative CO₂ emissions technologies) influences this conclusion. Tanaka and O’Neill (2018, p. 323) state that they “find no cases in which net zero GHG emissions are required unless the temperature overshoots and then declines”.

Figure 9-2 Relationship between emissions and warming for short- and long-lived gases



Source: Allen et al. (2017).

Figure 9-3 Atmospheric stocks of short- and long-lived gases



While the warming related to short-lived gases can alter relatively quickly (by changing the rate of inflow versus outflow), the warming related to long-lived gases is essentially permanent. However, as noted above, it is also very likely that achieving the 2°C goal will require global net-negative CO₂ emissions (Gasser et al., 2015). Therefore “net zero long-lived gases is only a milestone, not an end-goal” (Andy Reisinger, sub. DR233, p. 1).

For long-lived gases, the trajectory towards net-zero matters

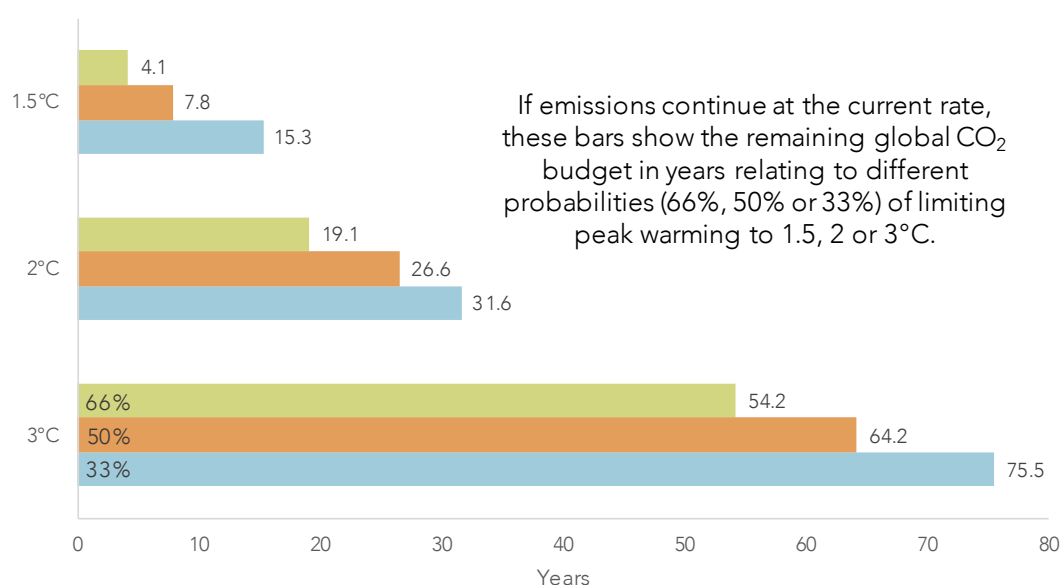
Emissions of long-lived gases (especially of CO₂ due to its abundance and atmospheric persistence) must be reduced to net-zero, at a minimum, to stabilise the climate well below 2°C (Figueres et al., 2017; Hollis et al., 2016; Millar et al., 2017). Because emissions add permanently to the stock, the speed at which long-lived gas emissions are reduced to net-zero will substantially determine the likelihood of staying within the 2°C limit

(G. P. Peters, 2018a; van Vuuren et al., 2018). But different estimates exist of the date at which long-lived gases must reach net-zero. For example, at a global scale, to

meet the 2°C target of the Agreement with 50–66 per cent probability at least cost, and taking into account the current commitments made by countries in the period to 2030, modelling suggests that carbon dioxide emissions will need to reach net zero by 2060–80, and that total GHG emissions would have to reach net zero between 2080 and 2100. (Vivid Economics, 2017a, p. 7)

As Chapter 2 explains, a common approach is to express the amount of CO₂ the world can emit while still having a chance to limit temperature rise within a targeted ceiling as a carbon budget. While much uncertainty surrounds carbon budgets (Hausfather, 2018), at the current rate of emissions, one estimate of the remaining carbon budget for a 2°C limit is approximately 1 000 billion tonnes. This is expected to be used up in 19 years (Figure 9-4). How this budget is translated into a target is a function of factors such as expected technological change, and the capacity for economies to make emissions reductions that reflect their national circumstances (UNEP, 2017).

Figure 9-4 Estimated remaining global carbon budget



Source: Carbon Brief (2017).

All long-lived gases must get to net-zero, not just CO₂

Much of the international attention focuses on CO₂ because it represents two-thirds of global emissions (IPCC, 2014a). But, even though CO₂ “must always be the “central” focus of mitigation efforts in the short, medium and long term” (Hollis et al., 2016, p. 1) because of its magnitude and atmospheric persistence, other long-lived gases must also get to net-zero. This is because they also accumulate in the atmosphere.

Emissions reductions of long-lived N₂O are particularly important for New Zealand (Andy Reisinger, sub. 28; Generation Zero, sub. 119). This is because of the relative abundance of N₂O as a proportion of New Zealand’s total emissions (Chapter 2), and the desirable co-benefits from emissions reductions such as improved water quality (Dairy NZ, sub. 18). Kerr (2016) summarises, “in order to stabilise the climate, ever and at any temperature, net CO₂ plus N₂O emissions must be reduced to net zero levels because both CO₂ and N₂O accumulate in the atmosphere” (p. 8).

Short-lived gas emissions must also reduce before stabilising at a lower level

Reductions in short-lived gas emissions will be needed to stabilise peak warming at 2°C or less (Allen et al., 2016; Shindell et al., 2017; Xu & Ramanathan, 2017).

However, the reductions in short-lived gas emissions needed, and the dates by which they should occur, is less certain (Rogelj et al., 2014). In part, this is due to uncertainty about the level at which the stock of long-lived gases, and especially CO₂, will peak (R. B. Jackson et al., 2017). Even so, warming to which the planet is

already committed, because of previous and current actions, means the remaining budget for short-lived gas emissions is unlikely to be large (Mauritsen & Pincus, 2017).

The following example explains a stabilisation level for short-lived gases at a global level hypothetically. If, by the time long-lived gases reach net-zero, the stock of long-lived gases commits the planet to 1.5°C of warming, that allows for a stock of short-lived gases consistent with an additional 0.5°C warming to stay within the maximum 2°C limit. However, if the stock of long-lived gases commits the planet to 1.95°C warming, then the allowable stocks of short-lived gases (and their emissions consistent with that stock) are substantially reduced to only 0.05°C warming.¹⁰³ As S. M. Smith et al. (2012) explain, “there is a trade-off to be made between the two: higher emission rates of shorter-lived GHGs will require lower cumulative emissions of long-lived GHGs, and vice versa” (p. 537).

F9.1

The contribution of greenhouse gases (GHGs) to warming is a function of their stocks in the atmosphere. The stocks of short- and long-lived GHGs both matter if peak warming is to be limited to 2°C or less as required by the Paris Agreement. Because of their atmospheric persistence, emissions of long-lived gases must reach net-zero or negative levels. Stocks of short-lived gases must stabilise by inflows equalling outflows, but at a lower level than current emissions rates.

F9.2

Because emissions of long-lived gases have an irreversible effect on warming the planet, the sooner their emissions are cut to net-zero (or lower), the more likely warming will not exceed 2°C. This means giving relative priority to reducing emissions of long-lived gases. Reductions in short-lived gas emissions can also contribute to limiting peak warming to well below 2°C. Because the final total stock of long-lived gases is uncertain, the allowable stock of short-lived gases and therefore the needed reduction in short-lived gas emissions is also uncertain.

9.2 Reasons to also mitigate short-lived gases in the short and medium term

The above section emphasised that the priority must be to reduce emissions of long-lived gases to net-zero, and the quicker that this occurs, the more likely peak warming will be limited to 2°C. But, short-lived gas mitigation will also be needed. The above section also explained that it could be possible to wait until long-lived gas emissions had reached net-zero before worrying about reducing emissions of short-lived gases (Figure 9-3). But, there are many reasons why mitigating short-lived gases over the coming decades is also important.

Allowing a (slightly) greater budget for long-lived gas emissions

Substantial and sustained reductions in short-lived gas emissions over the short and medium term could enable a slightly larger amount of long-lived gases to be emitted, while still reaching the same level of peak warming (Reisinger & Stroombergen, 2011).

Even though emissions of CH₄ do not need to go to zero to be consistent with long-term climate goals, there is a clear and quantifiable benefit from reducing CH₄ emissions as much as possible. This is because a lower (sustained) flow of CH₄ emissions allows a (slightly) greater carbon budget to reach the same peak warming level. As a result, lower CH₄ emissions would allow slightly later peaking of long-lived GHG emissions and a slightly later point at which long-lived emissions have to reach net zero. This would allow deferral of some of the considerable costs associated with a rapid reduction of CO₂ emissions (or to make the actual achievement of temperature goals more likely). (Andy Reisinger, sub. 28, pp. 4–5)

¹⁰³ If warming exceeds 2°C due to long-lived gases, then negative emissions will be necessary to create room within the overall GHG budget for short-lived gases.

If substantial and sustained CH₄ mitigation occurs (while also continuing to mitigate long-lived gases), Reisinger et al. (2013) estimate that long-lived GHG emissions may have an additional 10 to 15 years in which to peak. Reisinger (2017a) also estimates that without effective mitigation of non-CO₂ gases (including N₂O), active atmospheric removal of CO₂ will be required before 2050 to remain well below 2°C.

However, while sustained short-lived gas mitigation can create *room* for additional long-lived gas emissions (ie, provide for a slightly more gradual transition away from fossil fuels which may be less socially disruptive), it does *not* mean that long-lived gas mitigation should be deferred. Hollis et al. (2016) clearly state, “methane mitigation is not a reason to delay CO₂ mitigation” (p. 20).

Bowerman et al. (2013) further explain that short-lived gas emissions “in any given decade can only have a significant impact on peak warming under circumstances in which CO₂ emissions are falling” (p. 1021). In other words, no amount of short-lived gas abatement can avoid the warming due to failing to reduce emissions of long-lived gases to net-zero or less (Pierrehumbert, 2014; Rogelj et al., 2014). If mitigation consistent with net-zero long-lived gas emissions does not occur, there is little point abating short-lived gases to limit peak warming (Reisinger, 2017b).

Reducing short- and medium-term temperature change

Emissions reductions of short-lived gases could avoid up to 0.6°C of warming by 2050 (UNEP, 2017). This means they could help to avoid potential tipping points in the climate system (Molina et al., 2009; Tauranga Carbon Reduction Group, sub. 77; New Zealand Church Climate Network, sub. 121). Tipping points are critical thresholds where a major or irreversible change in the state of the climate occurs, such as melting of Arctic permafrost, or the collapse of the Gulf Stream (Lenton et al., 2008). Even so, substantial emissions reductions of short-lived gases on their own can merely delay tipping points being met – only reductions of long-lived gases can avoid them (Hollis et al., 2016; Shoemaker et al., 2013).

Reductions in short- and medium-term temperature change could help to “ensure that ecosystems, food production and the economy can adapt” (Clare St Pierre, sub. 115 p. 11). Essentially, mitigating short-lived gas emissions is valuable because it helps to slow warming and this gives time for societies and ecosystems to adjust (Bowerman et al., 2013).

Signalling the need to transition

Reducing emissions of short-lived gases over the short to medium-term to help slow temperature change is also likely to help ease the transition to a low-emissions economy and avoid stranded assets.

To make large changes in CH₄ in the long term, New Zealand would need to act now (not only through research and development but also development of policies and early adoption of new land uses, practices and technologies), in order to be ready to act fast later. Early action on CH₄ and clear signals of a future transition to low-CH₄ would avoid New Zealand being locked into a high-CH₄ pathway – and facing high levels of stranded assets if required to reduce CH₄ rapidly in future. (Kerr, 2016, p. 10)

The parts of the New Zealand economy that emit short-lived gases will need to transition to a lower-emissions future. If this transition begins now, the change will be more gradual and less abrupt (and potentially less disruptive) than if change is delayed.

F9.3

Benefits arise from reducing emissions of short-lived gases over the coming decades. Benefits include allowing a slightly greater carbon budget, helping to avoid or delay dangerous tipping points in the earth’s climate system, providing further time to adapt to temperature change, and providing a more gradual low-emissions transition. Yet this does not mean that short-lived gas mitigation can replace reducing emissions of long-lived gases to limit peak warming to 2°C.

9.3 Using emissions metrics to direct mitigation efforts

Emissions metrics compare the potency of emissions of different GHGs in terms of their impacts on warming over a given time period (NIWA, 2017). The relative weighting that emissions metrics give to different GHGs has significant consequences for how different gases are prioritised in terms of mitigation action, and how they are recognised in national emissions inventories (Forster et al., 2007). Box 9.2 examines how actual emissions (focusing on CO₂) are addressed in terms of emissions accounting.

Box 9.2 The carbon cycle and emissions accounting

The measurement of CO₂ as part of the carbon cycle (“carbon counting”), and the way CO₂ is measured in emissions inventories (“carbon or emissions accounting”) differs.

The carbon cycle is

the process through which carbon is cycled through the air, ground, plants, animals, and fossil fuels. People and animals inhale oxygen from the air and exhale carbon dioxide (CO₂), while plants absorb CO₂ for photosynthesis and emit oxygen back into the atmosphere. Carbon dioxide is also exchanged between the atmosphere and the oceans. This natural system of processes keeps CO₂ levels in the atmosphere stable over time. (NETL, 2018)

When the carbon in places such as trees or soils decomposes, or during the combustion of fossil fuels, it is emitted into the atmosphere as CO₂. This atmospheric CO₂ is then re-absorbed into places like the ocean or by trees as they grow.

In contrast, emissions accounting address the problem of

how to take those measurements and the factors impacting them and create a global set of rules for translating the changes in carbon stocks and the factors impacting them into ledger entries on which people can make decisions. (Zwick, 2013)

A rough explanation of emissions accounting is that it is interested in the change to levels of CO₂ over and above the normal cyclical process of the carbon cycle. For example, when a fossil fuel is used it emits CO₂. This adds to the stock of CO₂ in the atmosphere. CO₂ can be “removed” from the atmosphere when more CO₂ is absorbed than is released. For example, when an additional area of trees is grown to offset the CO₂ emitted from other sources (such as via the combustion of fossil fuels). Emissions accounting is also focused on the changes caused by human activity rather than natural events (eg, chopping down trees as opposed to a forest fire caused by lightning).

New Zealand uses afforestation as a way to offset about 30% of its GHG emissions (including of CO₂) from other sources (MfE, 2018d). It can use forestry (that sequesters CO₂) to offset non-CO₂ gases by the use of a standardised emission metric.

Emission metrics convert emissions of one GHG into equivalent emissions of another GHG, based on their relative climate impacts (MIT, 2014). This concept of equivalence is represented in a measure called “carbon dioxide equivalent” (CO₂e). As Brander (2012) explains, for “any quantity and type of greenhouse gas, CO₂e signifies the amount of CO₂ which would have the equivalent global warming impact” (p. 2).

The primary emissions metric used for calculating CO₂e is global warming potential (GWP) over 100 years (GWP₁₀₀). GWP₁₀₀ figures are determined by the Intergovernmental Panel on Climate Change (IPCC). GWP₁₀₀ is a relative measure of radiative forcing¹⁰⁴ over 100 years and is expressed as a multiple of CO₂ (where the GWP₁₀₀ of CO₂ is one). For example, the GWP₁₀₀ of CH₄ is 28. This figure of 28 represents the net effect of CH₄’s greater potency in terms of higher energy absorption but shorter lifetime (US EPA, 2018b) (see also Figure 9-1). In other words, compared to CO₂, the warming effect of CH₄ is powerful but short.

¹⁰⁴ Radiative forcing is the key driver of climate change and is the difference between incoming solar radiation and outgoing infrared radiation. GWP is a way of expressing the different rates at which GHGs absorb infrared radiation and therefore contribute to warming.

Alternative emissions metrics

Emissions metrics provide information on the likely relative damage of emitting different GHGs and the associated benefit of avoiding that damage. This information is useful when making decisions and trade-offs about mitigation opportunities. However, because of their different atmospheric properties, the concept of treating emissions of short- and long-lived gases “as completely interchangeable via CO₂ equivalence is rather problematic” (Reisinger, 2017a).

Some researchers have criticised GWP₁₀₀ for under-valuing emissions of long-lived gases, and over-valuing emissions of short-lived gases, if the aim is to limit peak warming (Forster et al., 2007; Shine et al., 2007; S. M. Smith et al., 2012). Ocko et al. (2017) also criticised it for under-valuing emissions of short-lived gases, and over-valuing emissions of long-lived gases, in the context of short- and medium-term temperature change.

GWP was not originally intended to be used in policy. Tanaka et al. (2010) note that it was used in the first IPCC report only to illustrate the difficulties inherent in the concept. One history of GWP also suggests that it was supported as a policy tool because the economies of most countries (especially most developed countries) are based on activities that cause CO₂ emissions. So, a metric showing that emissions reductions of other GHGs are worth “more” than CO₂ reductions was welcomed because these were likely to be cheaper and easier to abate (Skodvin, 1999).

Due to problems with GWP, other emissions metrics have been developed, such as global temperature potential (GTP) (Forster et al., 2007; Shine et al., 2005). In contrast to GWP, which measures cumulative radiative forcing, GTP is an end-point metric that estimates the impact of the emission of one tonne of gas on global average surface temperatures at a specified point in the future. Further alternatives include GTP on a time-dynamic basis (ie, values would be updated over time due to how quickly the world was approaching peak warming) (Persson et al., 2015), or hybrids of GWP and GTP.

It is also possible to measure GWP or GTP over different time scales, such as 20 or even 500 years (Allen et al., 2016; Shine et al., 2007). Because New Zealand’s emissions profile comprises a relatively high proportion of short-lived gases, these time scale changes can make a large difference. For example:

- changing from GWP₂₀ to GWP₅₀₀ reduces New Zealand’s total emissions (in 1990 terms) by 70% (Skodvin & Fuglestedt, 1997); and
- the contribution to total New Zealand emissions (in 2008) from the agriculture sector changes from 62% (GWP₂₀), to 46% (GWP₁₀₀) to 26% (GWP₅₀₀) (Reisinger & Stroombergen, 2011).

These different percentages show that the choice of time scale, particularly in relation to GWP, is a value judgement about how important warming is over different time periods (IPCC, 2013; Tanaka et al., 2010). These percentages also show how the choice of metric can strongly influence priorities and trade-offs about mitigation action (Manning et al., 2009; Ocko et al., 2017).

More recently however, an entirely new type of emissions metric has been proposed by Allen et al. (2018). GWP and GTP work by specifying radiative forcing or temperature change over a fixed period. In contrast, while it still refers to the warming effects of different gases, GWP* focuses on the different atmospheric lifetimes of short- and long-lived gases.

GWP* gives an equivalence between a one-off, but *permanent* increase in the emissions rate of a short-lived gas (ie, the flow rate for CH₄ as shown in Figure 9-2b), and a one-off pulse in emissions of a long-lived gas (eg, CO₂). Each of these (a permanent increase in the flow of a short-lived gas and a one-off pulse of a long-lived gas) contribute to an increase in the stock of gas in the atmosphere. And, has been shown, it is this stock that matters for warming. But GWP* also reflects the relative power of the warming effects coming from the increased concentration of each gas.

GWP* has greater scientific integrity because it is a more accurate way to measure the impact of short- and long-lived gases on global temperature. It better reflects the different atmospheric lifetimes of different GHGs, while continuing to capture their different warming effects. It is however important to note that unlike GWP₁₀₀, GWP* does not provide a simple way to calculate the sum of emissions in any given year.

GWP*'s greater accuracy would justify its use to guide policy decisions about relative mitigation efforts between short- and long-lived gases, and in designing an emissions pricing mechanism. For example, because CH₄ is a more powerful warming agent, a permanent increase in the flow of CH₄ would be penalised significantly more than a one-off pulse of CO₂ – even though they each lead to increased concentrations of CH₄ and CO₂ respectively. On the other hand, constant CH₄ emissions represent no additional warming effect and therefore no penalty or reward would be applied.

Making choices about emissions metrics

New Zealand uses GWP₁₀₀ to calculate CO₂e in its emissions inventory because this is the metric used under the Kyoto Protocol to which New Zealand remains a party (New Zealand Parliament, 2014; UNFCCC, 2008). New Zealand applies the Kyoto Protocol framework of rules to its emissions from the 2013 to 2020 period (MfE, 2018d) and is likely to continue to use GWP₁₀₀ after the Kyoto commitment period ends (MFAT, pers. comm. 19 December 2017). New Zealand also converts all GHGs into CO₂e (using GWP₁₀₀) for the purposes of its targets (including its NDC to the Paris Agreement)¹⁰⁵ and policy mechanisms (New Zealand Government, 2011a).

Discussion of emissions metrics in New Zealand is not new. For example, Manning et al. (2009) argued that relying on a single metric, or doing away with emissions metrics completely, is unlikely to be useful for policymaking purposes. Hollis et al. (2016) suggested the possibility of giving lower weights to short-lived gases like CH₄. In their submissions to this inquiry, Dave Frame (sub. DR270) and Scion (sub. DR366) highlighted the potential for GWP* to radically alter how emissions are calculated and mitigation is prioritised in New Zealand.

When thinking about the future emissions budget that will limit peak warming to no more than 2°C, an emissions metric is needed. This is because it is necessary to compare the climate effects of short- and long-lived gases within the temperature constraint, and to determine New Zealand's mitigation targets (section 9.6). GWP* has significant promise as a more scientifically robust metric (eg, as compared to GWP₁₀₀) to enable CO₂e to be calculated in the future.

F9.4

The choice of emissions metric can make a large difference to the estimated effects of the different GHGs on warming, and so can strongly influence mitigation priorities. The newly developed GWP* emissions metric has potential as a more scientifically-robust metric for calculating carbon-dioxide equivalence because it considers the different atmospheric lifetimes of short- and long-lived gases as well as their relative potency.

9.4 New Zealand's short-lived and long-lived gases

New Zealand's GHGs, their atmospheric lifetimes and GWP₁₀₀ are shown in Table 9.1.¹⁰⁶ Just over half of New Zealand's GHG emissions are long-lived (measured using GWP₁₀₀).

Table 9.1 New Zealand's short-lived and long-lived gases

Gas	Short- or long-lived	Atmospheric lifetime	GWP ₁₀₀	Percentage of gross emissions (2016)	Main source in New Zealand
Carbon dioxide (CO ₂)	Long-lived	Up to millennia	1	43.8%	Transport
Methane (CH ₄)	Short-lived	12 years	28	42.8%	Agriculture

¹⁰⁵ The Paris Agreement allows countries to choose how to express their contributions to the global emissions reduction effort, including in terms of emissions metric. For example, Brazil used GTP₁₀₀ in addition to GWP₁₀₀ in its first NDC (Government of Brazil, 2015).

¹⁰⁶ All figures in this section refer to gross emissions (ie, excluding land use, land-use change and forestry (LULUCF); Chapter 2).

Gas	Short- or long-lived	Atmospheric lifetime	GWP ₁₀₀	Percentage of gross emissions (2016)	Main source in New Zealand
Nitrous oxide (N ₂ O)	Long-lived	121 years	265	11.6%	Agriculture
Hydrofluorocarbons (HFCs)	Short- and long-lived	Between 5.2 and 47.1 years	677 - 4 800	1.8%	Substitutes for ozone depleting substances (eg, refrigeration)
Perfluorocarbons (PFCs)	Long-lived	Between 2 600 and 50 000 years	6 630 - 11 100	0.06%	Aluminium production
Sulphur hexafluoride (SF ₆)	Long-lived	3 200 years	23 500	0.02%	Electrical equipment and other product use

Source: MfE (2018d); Myhre et al. (2013).

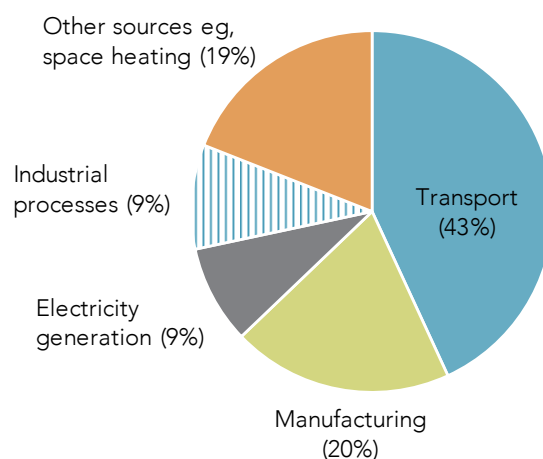
Notes:

1. GWP₁₀₀ figures are standard values from the IPCC's Fifth Assessment Report (Myhre et al., 2013) (ie, they do not take into account uncertain climate-carbon feedbacks). GWP₁₀₀ figures for CH₄ refer to biogenic CH₄ (see Box 9.3).
2. Seven different HFCs are emitted in New Zealand. The table shows the lifetimes and GWP₁₀₀ of these specific gases: HFC-125 (lifetime: 28.2 years, GWP₁₀₀: 3 170), HFC-134a (lifetime: 13.4 years, GWP₁₀₀: 1 300), HFC-143a (lifetime: 47.1 years, GWP₁₀₀: 4 800), HFC-227ea (lifetime: 38.9 years, GWP₁₀₀: 3 350), HFC-245fa (lifetime: 7.7 years, GWP₁₀₀: 858), HFC-32 (lifetime: 5.2 years, GWP₁₀₀: 677), and HFC-365mfc (lifetime: 8.7 years, GWP₁₀₀: 804).
3. Three PFCs are emitted in New Zealand. The table shows the lifetimes and GWP₁₀₀ of these specific gases: PFC-14 (lifetime: 50 000 years, GWP₁₀₀: 6 630), PFC-116 (lifetime: 10 000 years, GWP₁₀₀: 11 100) and PFC-218 (lifetime: 2 600 years, GWP₁₀₀: 8 900).

Carbon dioxide (CO₂)

Most of New Zealand's CO₂ emissions are from fossil-fuel combustion, with CO₂ emissions rising by 35% between 1990 and 2016. The proportion of CO₂ emissions as a share of New Zealand's gross emissions has also risen, mostly due to a substantial increase in transport emissions relative to agricultural emissions (MfE, 2018d). Transport is the largest source of CO₂ emissions (Figure 9-5), although a substantial amount also comes from manufacturing and electricity generation.

Figure 9-5 New Zealand's CO₂ emissions by source



Source: MfE (2018e).

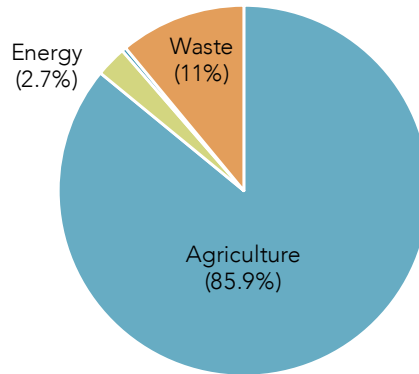
CO₂ is regulated by the NZ ETS. Free allocations are given for emissions-intensive, trade-exposed industries (Chapter 5). Other policies also target CO₂ emissions due to their sectoral focus, such as the Road User Charge exemptions for electric vehicles (Chapter 12).

Methane (CH₄)

CH₄ is New Zealand's dominant short-lived gas. Total CH₄ emissions rose slightly (4.4%) between 1990 and 2016. In most other developed countries, such as in the United States, the largest individual source of CH₄ is

from fossil fuel production (US EPA, 2017a). In New Zealand CH₄ occurs primarily in the agricultural sector as a result of animals digesting their food (through a process known as enteric fermentation) (Figure 9-6 and Chapter 11). As a result, reducing New Zealand's CH₄ emissions means reducing stock numbers, or lowering the amount of gas released per unit of agricultural product (Chapter 10). The difference between fossil and biogenic CH₄ is discussed in Box 9.3.

Figure 9-6 New Zealand's CH₄ emissions by source



Source: MfE (2018e).

Note: 1. CH₄ emissions from industrial processes and product use (0.3% of the total) are not labelled due to scale.

Box 9.3 The difference between fossil and biogenic CH₄

When CH₄ is released into the atmosphere it has a more powerful warming effect than other GHGs like CO₂, but its duration in the atmosphere is shorter (section 9.1). It breaks down in the atmosphere by turning into other greenhouse gases (GHGs), including CO₂, carbon monoxide and water vapour. These other GHGs cause additional warming (Hollis et al., 2016).

In measuring atmospheric GHGs, it is possible to distinguish between CH₄ emitted naturally (such as from wetlands or the oceans), and that from human activity (such as raising livestock, extracting fossil fuels, or landfills). Approximately two-thirds of global CH₄ is the result of human activity (Saunio et al., 2016). Emissions accounting (eg, in the national inventory) only counts CH₄ that is the result of human activity (known as anthropogenic CH₄).

Because CO₂ is created during the decomposition in the atmosphere of anthropogenic CH₄, a question arises whether this CO₂ should also be counted in emissions accounting (Box 9.2)? The answer is that it depends on the original source of that CH₄.

- *Biogenic* CH₄ comes from sources like cows and sheep (when they belch after eating organic compounds such as grass), or from the decomposition of organic matter in landfills. Because this CH₄ comes from organic matter, the CO₂ that is created during the decomposition of biogenic CH₄ (either naturally, or via the flaring of CH₄ at landfills) is part of the natural carbon cycle, and so is **neutral** from an emissions accounting point of view.
- *Fossil* CH₄ occurs when fossil fuels (such as coal, oil or gas) are extracted from the ground, or during the transportation of gas in pipelines. The CO₂ that is created during the decomposition of fossil methane is not considered to be part of the natural carbon cycle, and so is counted as **additional** CO₂ from an emissions accounting point of view.

The difference between biogenic and fossil CH₄ is well-known and is reflected in current emissions accounting by way of different GWP figures (section 9.3). The GWP₁₀₀ for biogenic methane is 28 and for fossil methane is 30, reflecting the additional warming effect as a result of the CO₂ that arises during its decomposition (Myhre et al., 2013).

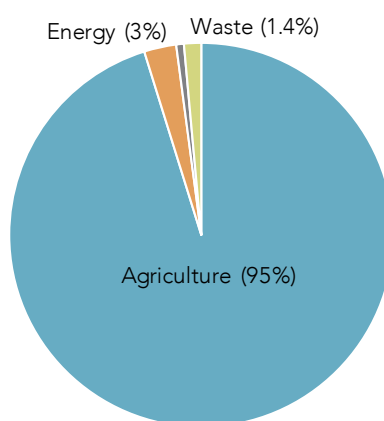
Emissions of CH₄ must be reported but are otherwise mostly unregulated in New Zealand because agricultural emissions do not require units to be surrendered under the NZ ETS. Even so, agricultural CH₄ mitigation is the subject of a substantial amount of research activity (Chapter 11).

Biogenic CH₄ emissions from waste are addressed under the CO₂e framework of the NZ ETS (MfE, 2011a), and by other waste minimisation approaches under the Waste Minimisation Act 2008 and resource management regulation such as the National Environmental Standards for Air Quality (Chapter 15). Fossil CH₄ emissions from the energy sector in New Zealand arise mainly through fugitive emissions from fuels, and, within this, mostly from the production and distribution of natural gas. These emissions are captured via the NZ ETS. Reducing fossil fuel production would therefore have the side effect of also reducing CH₄ emissions from energy.

Nitrous oxide (N₂O)

N₂O is a relatively powerful long-lived gas that, in New Zealand, overwhelmingly arises due to agricultural production (Figure 9-7).¹⁰⁷ Within agriculture, N₂O emissions are caused by urine and dung deposited by grazing animals (about two-thirds of emissions) and the application of synthetic fertilisers to pastures (about one-third of emissions). Emissions of N₂O rose 28% between 1990 and 2016 (MfE, 2018d).

Figure 9-7 New Zealand's N₂O emissions by source



Source: MfE (2018e).

Notes:

1. Not labelled (due to scale) are N₂O emissions from industrial processes and product use (0.6% of the total).

Reducing N₂O emissions in New Zealand is mostly a question of reducing stock numbers and controlling nitrogen inputs on farms (eg, by more efficient fertiliser use, Chapter 11). Other options include the use of stand-off pads and grazing management. Substantial co-benefits (eg, relating to water quality) would result from emissions reductions of N₂O in New Zealand. As with CH₄, N₂O emissions are mostly unregulated due to the exclusion of agriculture from the NZ ETS. However, nitrate levels in waterways are regulated through other mechanisms, including at regional council level. Methods implemented to reduce nitrate levels (eg, by reduced fertiliser use) may therefore also have an associated effect of reducing N₂O emissions (Chapter 11).

Other N₂O emissions categorised under the waste sector, notably indirect emissions of N₂O from industrial wastewater from the dairy and meat industries, are also not directly regulated (even given the effect of waterway regulations noted above) (Chapter 15). However, as with CH₄, some minor N₂O emissions from other sources (such as fuel combustion) are regulated through the CO₂e framework of the NZ ETS.

Fluorinated gases

Fluorinated gases (F-gases, also known as synthetic gases) comprise hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃).¹⁰⁸ F-gases comprise about

¹⁰⁷ In other developed countries (eg, the United Kingdom or the United States), agriculture accounts for approximately 75% of N₂O emissions (Skiba et al., 2012; US EPA, 2017b).

¹⁰⁸ While nitrogen trifluoride (NF₃) falls under the UNFCCC, New Zealand does not produce or consume NF₃ so it is not discussed further.

2% of New Zealand's GHG emissions and arise entirely from the category of industrial processes and product use (MfE, 2018e).

New Zealand does not produce any HFCs or SF₆ (all are imported). HFCs are mainly used in industrial processes for refrigeration and air conditioning where HFCs are used as a coolant, and emissions occur as they leak out slowly over time. SF₆ is used in the electricity-distribution sector (eg, in electrical switchgear, where emissions also arise from leakage and during maintenance processes) and for small-scale medical and scientific applications (eg, in eye surgery). Practically all PFC emissions in New Zealand are caused as a by-product of domestic aluminium production at Tiwai Point (MfE, 2018d).

Bulk importers of HFCs and PFCs, and users of SF₆ above a minimum threshold, are required to register with, and surrender emissions units to, the NZ ETS. Manufacturers of PFCs have the same obligations. Currently, the NZ ETS provides no cap (ie, no effective quantity limit) on imports of F-gas into New Zealand and also allows exporters of F-gases to earn emission units. There are no free allocations of New Zealand Units (NZUs) for F-gases because importers and users "are able to pass the costs of their NZ ETS obligations on to their customers" (MfE, 2016g). Importers of HFCs and PFCs in goods and motor vehicles face an emissions price through the Synthetic Greenhouse Gas (SGG) Levy, where the rate is linked to the unit price under the NZ ETS.

Under current settings, New Zealand's HFC emissions are projected to double by 2030 (MfE, 2017i), due in part to greater use of air conditioning as average temperatures increase. However, the period 1990 to 2016 saw a 95% reduction in PFC emissions (due to improved management of anode effects in aluminium production) and a smaller downward trend of a 13% reduction in SF₆ emissions (MfE, 2018d). New Zealand plans to regulate HFCs in response to commitments made under the Montreal Protocol on Substances that Deplete the Ozone Layer (Box 9.4).

Box 9.4 **Regulating HFC emissions in response to the Kigali Amendment**

Agreed in 2016, the Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer focuses on phasing down HFCs by cutting their production and consumption.¹⁰⁹ The aim is to achieve an 80% reduction in HFC consumption by 2047. This reduction is expected to avoid up to a 0.5°C increase in global temperature by the end of the century.

As a party to the Montreal Protocol, New Zealand is proposing an import licensing system, including import caps, to phase down HFCs. This system would work in conjunction with the existing arrangements under the NZ ETS, and would enable New Zealand to ratify the Kigali Amendment (MfE, 2017i). It comprises a series of progressively more restrictive stepped import controls that would limit imports by 2036 to 19% of baseline consumption (average imports from 2010 to 2015). If enacted, this system would be the primary mechanism to reduce HFC emissions in New Zealand.

Given the structure of the import licensing system (reducing imports to 19% of baseline consumption, rather than 0%) and the intent to globally phase down, rather than phase out HFCs, New Zealand could still see some HFC emissions by 2036 and later particularly within products or vehicles. However, technological change inspired by requirements to meet Kigali Amendment obligations in other countries makes it likely that alternatives will appear as substitutes to HFCs (much as HFCs themselves were substitutes to ozone-depleting substances).

9.5 International and domestic targeting of different gases

It is rare to explicitly prioritise emissions reductions of specific GHGs

The emissions profiles of most other developed countries are dominated by CO₂. Therefore, there is a natural fit between reducing long-lived gases and targeting their largest source of emissions. For example, Germany's *Energiewende* (energy transition programme) focuses on moving away from fossil-fuel energy

¹⁰⁹ The Kigali Amendment only controls bulk HFCs (ie, it does not control HFCs contained within goods or vehicles).

sources such as coal so as to achieve a target of 60% renewable energy by 2050 (BMW, 2011). In other words, for many countries other than New Zealand, a CO₂e focus is not substantially different from a CO₂ focus. China is a little different as it also has an explicit CO₂ reduction target (as opposed to a target expressed in CO₂e) (Carbon Brief, 2015).

Short-lived gas emissions are a much smaller proportion of total emissions for most other developed countries. For example, Australia's national inventory shows CO₂ dominates emissions at 72% of the total, while CH₄ is only 21% (Government of Australia, 2018).¹¹⁰ Therefore, it is unsurprising that efforts to reduce short-lived gases do not receive much attention.

At a sub-national level, cities and regions target mitigation in a wide variety of ways. These range from reducing emissions by specified percentages, to carbon neutrality, to being fully net-zero in relation to all GHG emissions. Most efforts, like those at the national level, focus on CO₂e. A notable exception is California. Under a legislated commitment to reduce overall GHG emissions to 40% below 1990 levels by 2030, Senate Bill No. 1383 requires a 40% reduction in emissions of CH₄ and HFCs by 2030 compared to 2013 levels. The key rationales for the law are to reduce short-term temperature change and provide health co-benefits (E. G. Brown, Jr, 2016). The law includes a specific focus on emissions reductions of CH₄ from livestock and dairy manure management operations.

New Zealand's experience with prioritising reductions of different gases

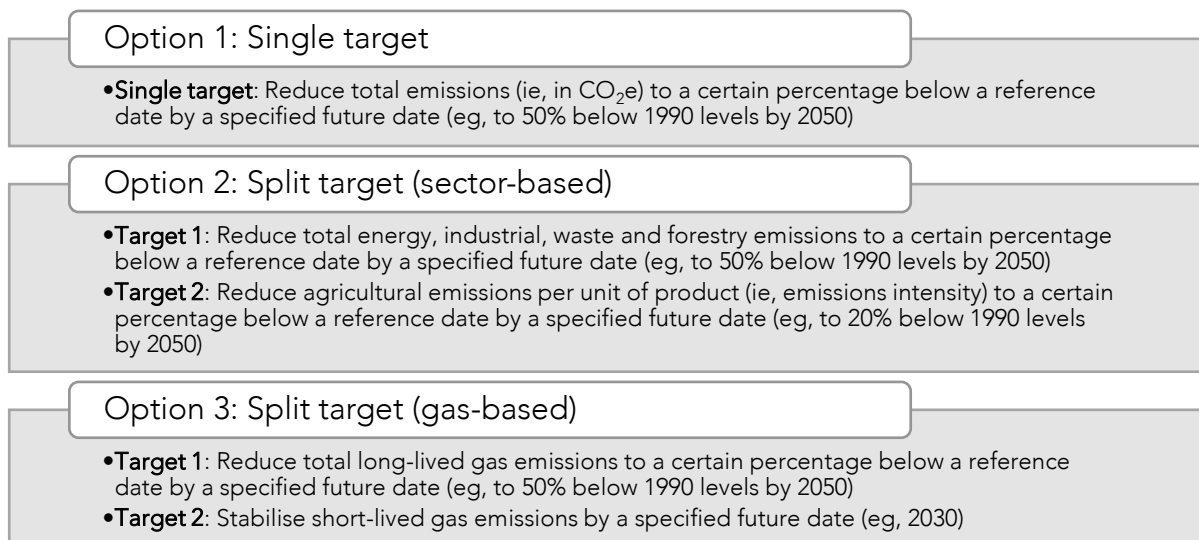
In New Zealand, GHGs are not targeted individually. This is because the standard GWP₁₀₀ CO₂e metric is used in the NZ ETS. Even so, some gases are exposed to greater mitigation attention than others due to the current design of emissions and other environmental policies. For example, CO₂ from fuel combustion and (some) CH₄ from waste are subject to the NZ ETS, but agricultural CH₄ and N₂O are not. As well as the NZ ETS, other policies that aim to reduce emissions include:

- road user charge exemptions for electric vehicles (resulting in avoided CO₂ emissions, Chapter 12);
- research activity directed towards agricultural mitigation technologies (which directly aims to reduce both CH₄ and N₂O, Chapter 11);
- regulation of nitrate levels in waterways (with the co-benefit of reduced N₂O emissions, Chapter 11); or
- the SGG Levy that targets small importers of HFCs and PFCs.

Because of New Zealand's distinctive emissions profile (especially the large proportion of biogenic CH₄ compared to other developed countries), the idea of more explicitly separating short- and long-lived gases with different policy mechanisms or targets is not new. For example, Kerr (2016) outlined how agricultural GHGs (CH₄ and N₂O) could be dealt with using separate policy mechanisms and targets. Distinguishing between GHGs is a core element of Generation Zero's proposal for a Zero Carbon Act (Generation Zero, sub. 119), and Simon Upton, then-Director of Environment at the Organisation for Economic Co-operation and Development, also highlighted the possibility (Upton, 2016).

The New Zealand Government examined the possibility for separate targets for different gases in the lead-up to the United Nations Framework Convention on Climate Change (UNFCCC) 21st Conference of the Parties (where the Paris Agreement was ultimately agreed). Figure 9-8 explains, using hypothetical target ranges and dates, the difference between three of the main options considered. In documentation prepared for the Government, The Treasury (2015b) recommended a split target based on sectors (option 2). This recommendation was based on several factors. These included that option 2 better reflected the scientific need to focus on long-lived gases as compared to option 1, and, that among the options considered internationally credible, option 2 was the least-cost option.

¹¹⁰ A substantial amount of this is fossil methane, categorised as fugitive emissions from the extraction, production, flaring, processing and distribution of fossil fuels.

Figure 9-8 Options for New Zealand’s 2030 target

Source: Based on The Treasury (2015b, p. 13).

Notes:

1. Target 2 under option 3 did not specify a level at which short-lived gases should stabilise (the implication of the target was only that they do not continue to rise).

The Government ultimately chose a single target based on CO₂e (option 1). This was, in part, because the Ministry of Foreign Affairs and Trade advised that a split target at the level that New Zealand was contemplating would be potentially damaging to New Zealand’s reputation. It was concerned about New Zealand’s access to international emissions trading markets, and to securing agreement to optimal forestry accounting rules (Office of the Minister for Climate Change Issues, 2015).

F9.5

The idea of prioritising emissions reductions of short- or long-lived gases is not new in New Zealand. Researchers and policy officials have previously highlighted the possibility, or recommended, that New Zealand distinguish between short- and long-lived gases in terms of policy mechanisms and targets.

Prioritising different gases or sectors can be described as a “two-baskets” approach (Daniel et al., 2012; S. C. Jackson, 2009). Many submitters to this inquiry supported pursuing such an approach, particularly separate mitigation targets to drive emissions reductions. However, submitters offered a variety of suggestions about how to structure a two-baskets approach.¹¹¹

[Establishing] separate targets for long-lived and short-lived gases is fully supported...A sensible and balanced policy response is to account for methane and nitrous oxide separately to carbon dioxide. This will be a major contributor to the agricultural sector’s acceptance of an ETS with realistic price signals. (Waimakariri District Council, sub. DR192, p. 3)

Support for concept of separate targets for short-lived and long-lived gases, but only if they are in addition to an ‘all gases’ target, which should remain the primary measure. (Sustainable Business Network, sub. DR254, p. 3)

[t]he Government should establish separate domestic targets for short-lived (e.g., ruminant methane) and long-lived gases (e.g., carbon dioxide and nitrous oxide). There are many potential strategies and pathways to a low-emissions economy. New Zealand has to choose the approach that best suits its unique circumstances. (Federated Farmers, sub. 310, p. 4)

We suggest a ‘two baskets’ approach based on “biological” and “fossil” emissions, for both budget and target setting, and accounting...In this context the biological basket would include sources and sinks of

¹¹¹ See also the detailed discussion in the submission from Dave Frame (sub. DR270) and Scion (sub. DR 366).

greenhouse gases that are part of the carbon cycle, or have a biological origin, but is not releasing ancient stores of greenhouse gases into the atmosphere...The fossil basket would include sources of greenhouse gases that are releasing ancient stores of greenhouse gases into the atmosphere. (Samuel Lang and Pubudu Senanayake, sub. DR382, p. 2)

Some of those in support of a two-baskets approach expressed concern about New Zealand's alignment with the international framework for GHGs (eg, New Zealand Super Fund, sub. DR334). However, given that this is an evolving area of both science and policymaking, it seems unlikely that the "GWP₁₀₀ status quo" will persist indefinitely.

Other submitters did not favour treating short- and long-lived gases differently. Reasons included that doing so would overly complicate the NZ ETS, create regulatory distortion or encourage political expediency by treating sectors differently (eg, Bioenergy Association, sub. 37; Hitashi Zosen Innova Australia Pty Ltd, sub. 68; Oji Fibre Solutions, sub. 71; NZ Institute of Forestry, sub. 73; Todd Corporation, sub. 122 and sub. DR373; and Genesis Energy, sub. DR301).

9.6 A New Zealand approach to short- and long-lived gases

New Zealand has committed to ensuring that its GHG emissions are appropriately mitigated in accordance with the Paris Agreement. Yet, New Zealand faces a distinctive challenge compared to most other developed countries whose emissions profiles are dominated by CO₂ (meaning that it is, by default, the focus of mitigation attention). Because New Zealand's emissions profile has a relatively high proportion of short-lived (and biogenic) CH₄, bundling short- and long-lived gases together is problematic.

This is because bundling does not allow adequate transparency (and therefore targeting) about which emissions reductions are needed, and that different end goals are important for short- and long-lived gases. Critically, it also fails to signal that achieving net-zero long-lived gases should be the priority because of their irreversibility, and that the quicker this happens, the more likely the 2°C goal will be achieved. In other words, bundling does not provide sufficient direction to prioritise "steps that stop stock accumulation while managing the warming that the flow of short lived gases provides" (Upton, 2016, pp. 4-5).

Neither does bundling gases together encourage the development of policy mechanisms that recognise the different atmospheric properties of GHGs. The following sections outline a series of changes that the Commission considers will help drive mitigation of short- and long-lived gases at the pace and scale required to achieve New Zealand's ambitions under the Paris Agreement.

Mitigating long-lived gases

Target

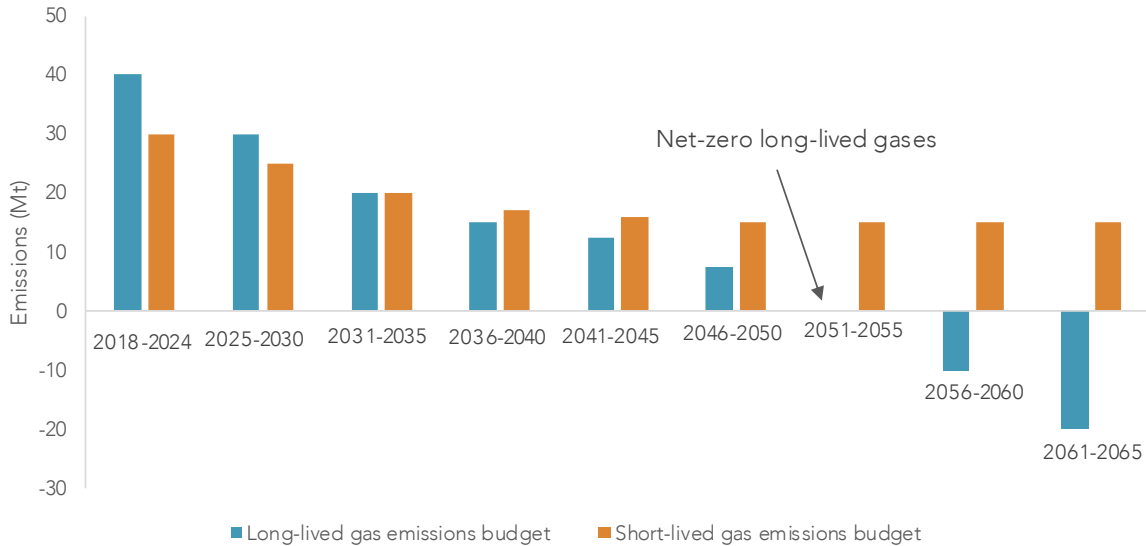
Long-lived gases must reach net-zero, at a minimum, to stabilise temperature well below 2°C. Therefore, the recommended long-lived gas target has an end goal of net-zero GHG emissions by a specified point in time (eg, 2050). It is important to specify a date for long-lived gases to reach net-zero so as to achieve an orderly transition towards a low-emissions economy (Rogelj et al., 2015b). This target should be set in primary legislation (Chapter 8).

R9.1

The Government should seek to enact a long-lived gas target of net-zero by a specified point in time (eg, 2050) in primary legislation.

Emissions budgets

Long-lived gases should have separate emissions budgets that step towards the long-lived gas target (ie, they focus on achieving a gradual transition to net-zero or lower) (Figure 9-9). These budgets, set by government based on the advice of the proposed Climate Change Commission, would guide the setting of quantity caps for NZUs within the NZ ETS (Chapter 5) and define a clear mitigation pathway (see Chapter 8 for more on emissions budgets). They therefore help to create a stable and predictable environment for investment (Chapter 7).

Figure 9-9 Stylised depiction of separate emissions budgets for short- and long-lived gases**Notes:**

1. Relative emission volumes across the two types of gases are not to scale (to show the different budgets on the same graph).

R9.2

The Government should establish separate emissions budgets for short-lived and long-lived gases and set their sizes based on the advice of the Climate Change Commission.

Policy

All long-lived gases, regardless of origin, should be in the NZ ETS. The steadily decreasing quantity caps on emissions and rising emissions prices (linked to the long-lived gas emissions budgets and target) will incentivise mitigation. The Commission also recommends treating two less-common types of short-lived gases as special cases and including them in the NZ ETS. They are fossil CH₄ and short-lived F-gases.

The Commission considers that fossil CH₄ should be included in the NZ ETS because the CO₂ it decomposes into is of fossil origin (Box 9.3). Fossil CH₄ represents 3% of total CH₄ in New Zealand or 0.01% of all emissions (taking a CO₂e approach) (MfE, 2018e). Submitters to this inquiry pointed out the importance of distinguishing between fossil and biogenic CH₄ and prioritising mitigation of the former (Fossil Fuels Aotearoa Research Network, sub. DR178; Dave Frame, sub. DR270; Scion, sub. DR366; and Samuel Lang and Pubudu Senanayake, sub. DR382).

At present, bulk imports of all F-gases are included in the NZ ETS. Despite some HFCs being short-lived, given the small volume of HFC emissions in New Zealand, and the fact that New Zealand is intending to regulate HFCs using an import licensing system (Box 9.4), the administrative and compliance costs of changing this approach do not appear warranted. Therefore, the Commission recommends treating HFC-125, HFC-134a, HFC-245fa, HFC-32, HFC-365mfc as exceptions, and regulating them as long-lived as per current arrangements. These gases together represent 0.6% of total New Zealand emissions (MfE, 2018e).

R9.3

The New Zealand Emissions Trading Scheme (NZ ETS) should include all long-lived greenhouse gases, as well as fossil methane (CH₄) and all fluorinated gases.

Mitigating short-lived gases

Target

In addition to the long-lived gas target, the Commission recommends a separate target for short-lived gases (specifically, biogenic CH₄). The target would focus on New Zealand making a fair contribution to stabilising the stock of biogenic CH₄ in the atmosphere *within a temperature limit*. In other words, the goal is to achieve a steady-state stock of biogenic CH₄ where inflow equals outflow, within the 2°C temperature constraint. This stabilisation principle should be put in primary legislation (Chapter 8). The principle then needs to be supplemented with an explicit target for a stable flow of New Zealand’s emissions of biogenic CH₄ by a certain date (ie, a maximum emissions rate). This will provide clear direction to emitters. It will also communicate the different nature of the short-lived gas target compared to the long-lived gas target (Box 9.5).

Box 9.5 Communicating target complexity

While the long-lived gas target is simple to explain, the biogenic CH₄ gas target is more complex. This may make it more challenging to communicate to the public, all of whom will need to participate in the transition to a low-emissions economy (Chapter 10). However, communicating the different targets and the reasons for them to the public is likely to prove valuable, since it will create a more informed community that better understands the decisions about mitigation policy.

Dual targets may also be difficult to communicate internationally – particularly the need to explain how New Zealand’s short- and long-lived gas targets work together to comprise “economy-wide absolute emission reduction targets” (UNFCCC, 2015b, p. 3) that are ambitious and demonstrate progression over time in its nationally determined contributions (NDC) to the Paris Agreement. But this is not insurmountable.

New Zealand’s dual targets and proposed policies cover all GHGs across the New Zealand economy so are economy-wide and absolute. They also demonstrate progress over time by way of declining emissions budgets. However, their level of ambition will be directly related to the specified date for each target and the explicit target level for the stable flow of biogenic CH₄.

New Zealand’s target framework will also be of interest to other countries either currently in similar situations, or whose emissions profiles will look more like New Zealand’s as they successfully decarbonise their economies. As Millar et al. (2017) state, “separate reporting of long-lived and short-lived greenhouse gases in national pledges would help clarify their long-term implications” (p. 5).

Primary legislation will need to direct the government to set a precise quantity level at which biogenic CH₄ emissions are to be stabilised within delegated legislation¹¹² based on advice from the proposed Climate Change Commission.¹¹³ This quantity level could be specified as a percentage reduction by a specified point in time (eg, an annual flow of biogenic CH₄ emissions that is X% below 1990 levels by 2050), or a quantity of allowable emissions by a future time period (eg, in tonnes over an annual period). The quantity level would be used to set the biogenic CH₄ emissions budgets (see below) and would be determined in advance to allow for a more gradual transition.

It will be important to specify the factors that the Climate Change Commission can use to inform its advice on the appropriate quantity level for the biogenic CH₄ gas target. These factors could be in primary legislation (as in Section 10 of the United Kingdom’s Climate Change Act) and be similar to the specific key matters that will need to be included in legislation for the setting of emissions budgets (section 8.6 of Chapter 8). The determination of this quantity level could therefore have regard to:

¹¹² Delegated legislation describes all types of legislation made under powers delegated by Parliament. It is also known as regulation, subordinate legislation or secondary legislation.

¹¹³ In the relevant primary legislation, information could be included (eg, in the preface) about the use of GWP* to calculate the equivalence between a single pulse of CO₂ compared to a constant flow of biogenic CH₄, to provide further guidance about the recommended quantity level.

- the relative cost for abating biogenic CH₄ versus CO₂ (eg, using GWP* to calculate the cost per unit of reduced warming) (Allen et al., 2018)¹¹⁴;
- the global stock of both short- and long-lived gases in the atmosphere (Rogelj et al., 2015a) and the relationship between the remaining carbon budget and the warming contribution of biogenic CH₄;
- New Zealand's historical and ongoing contribution to the global stocks of GHGs;
- the abatement potential for biogenic CH₄ that is considered acceptable in terms of social and economic consequences; and
- an assessment of what New Zealand's "fair share" of global biogenic CH₄ emissions comprises (MfE, 2015a; The Treasury, 2015b).¹¹⁵

The above issues are relevant because they build into the policy decision a recognition of competing values and priorities, anticipated economic and social costs over time, including transaction and compliance costs, and the costs of not transitioning to a low-emissions economy. It will be a challenging task for the Climate Change Commission to provide advice on all these factors and how they interact. The Climate Change Commission will need to be adequately resourced if it is to provide rigorous and evidence-based advice on the target quantity level (Chapter 8).

A further value of putting the decision to set the quantity level in delegated legislation is that it more easily allows for the level to change over time if necessary. The primary legislation containing the stabilisation principle should allow for the target quantity level to be periodically reviewed by the Climate Change Commission which would then advise the government on whether the level remained appropriate or should be changed. The review process could have regard to the same factors as noted above. For example, mitigation costs could be influenced by technological advancements such as a CH₄ vaccine that could make significant emissions reductions possible at relatively low cost (Chapter 11) or changes in consumer preferences (eg, if animal protein (meat and dairy) become less desirable, Chapter 10). The reduction in emissions of long-lived gases will also need to be considered (eg, if long-lived gas emission reductions occur at a faster or slower rate than predicted, Andy Reisinger, sub. DR233). The authorities would need to give ample prior notice of any changes in the target quantity level.

The short- and long-lived targets should not be bundled together into an all-gases target set in primary legislation. In the draft report for this inquiry, the Commission recommended that separate domestic targets for short- and long-lived gases should be supported by a single all-gases target in primary legislation for the purposes of New Zealand's international commitments. But this all-gases target would be based on GWP₁₀₀ and, after further investigation and analysis into emissions metrics and related issues, the Commission concludes that the scientific credibility of such a target is insufficient to merit inclusion in law. Even so, an all-gases calculation could be used in New Zealand's NDC if considered necessary. New Zealand would also need to continue to compile its national emissions inventories using agreed international conventions. But it should craft its mitigation strategy to be in line with its separate emissions targets and budgets for short- and long-lived GHGs.

A different type of single target could be possible, such as one that aims for New Zealand to stop contributing to further global warming by a set date. But this would not adequately capture the need to *reduce* emissions of biogenic CH₄. Just because the level of biogenic CH₄ emissions stabilises (meaning no net increase in warming occurs due to biogenic CH₄), this does not mean that efforts to reduce the level of peak warming cannot or should not occur partly by way of further biogenic CH₄ mitigation. This is similar to the likely need for emissions of long-lived gases to become negative at some point. All activities that produce GHGs have a role to play in limiting peak warming to well below 2°C.

¹¹⁴ It is also valuable to compare reduction in total tonnes of long-lived gases as compared to the flow rate of biogenic CH₄ to demonstrate that emitters of both types of GHGs are contributing to the overall mitigation effort.

¹¹⁵ Another potential consideration is the availability of negative emissions technologies. If levels of long-lived gases can be further reduced in such a manner, greater room is available within the overall stock of GHGs for a larger stock of short-lived gases to reach the same temperature level.

R9.4

The Government should enact in primary legislation the principle that New Zealand's emissions of biogenic CH₄ should be lowered to a specified level by a specified date, consistent with the Paris temperature limit. The legislation should also specify a framework for guiding how the target level of CH₄ should be set.

The legislation should establish an obligation on the Government to set the specific target level of emissions for biogenic CH₄ based on the advice of the proposed Climate Change Commission. The legislation would include the power to change the target from time to time in the light of new information.

Emissions budgets

As with long-lived gases, separate emissions budgets for biogenic CH₄ would provide steps towards the short-lived gas target. These budgets comprise the total emissions of biogenic CH₄ within each budget period (eg, five years).

Separate emissions budgets for short- and long-lived gases will also help to indicate that emissions reductions need to occur in the short term across all sectors of the New Zealand economy, including in agriculture (Kerr, 2016). Figure 9-9 shows an example of emissions budgets over time (including a potential negative emissions budget for long-lived gases beyond 2050). Box 9.6 discusses the trade-offs between flexibility and scientific integrity regarding separate emissions budgets.

Box 9.6 Trading off some flexibility for scientific integrity?

Separate targets, emissions budgets and policy measures for short- and long-lived gases have greater scientific integrity because they recognise the different time dynamics of each type of GHG. However, they may have a potential downside in reducing the flexibility across the economy to make mitigation trade-offs between GHGs (the essence of the CO₂e approach) and may over-prescribe the trajectory of New Zealand's low-emissions transition.

One of the key messages of this report is the need to keep options open, particularly in the face of uncertainty. Separating short- and long-lived gases does not necessarily mean that this flexibility is lost. Trade-offs are possible across all GHGs in the long-lived "basket", as well as between different sources of biogenic CH₄. Importantly, trade-offs can also be made over different time periods. This occurs when the separate emissions budgets are set, as their respective rates of reduction over the same period provides substantial flexibility across the system. For example, if technological developments mean that it is comparatively easier and less-costly to abate biogenic CH₄ than CO₂, a steeper mitigation trajectory could be recommended for biogenic CH₄ so that a slower trajectory could be recommended for CO₂. Finally, as discussed above, while the end-point for long-lived gases is fixed (at net-zero), there is flexibility to change the target quantity level for biogenic CH₄. This is a key reason why the quantity level is set in delegated rather than primary legislation.

R9.5

The Government should establish separate emissions budgets for biogenic CH₄ based on the advice of the Climate Change Commission.

A mechanism to regulate short-lived GHGs

While the NZ ETS is the key mechanism for regulating long-lived GHGs, biogenic CH₄ from agriculture and waste should also be exposed to a pricing mechanism to incentivise behaviour change (Chapter 5). However, there are several options to consider.

1. Including biogenic CH₄ in the NZ ETS under a single cap. This means continuing with the NZ ETS as currently structured (including the reforms laid out in Chapter 5), but with all biogenic CH₄ emitters (ie,

from agriculture and waste) included. Emissions reductions would be driven throughout the economy relative to their marginal cost of abatement across the different mitigation opportunities for all types of GHGs measured using GWP₁₀₀.

2. Including biogenic CH₄ in the NZ ETS but with a separate cap and associated separate emissions units. In a dual-cap NZ ETS, each cap would be set in direct relation to the emissions budget for each category of GHG and would result in the creation of two separate types of NZUs: a long-lived NZU and a short-lived NZU. Given that the caps would be set at different emission quantities, the price of each type of NZU would be independently determined in its own market. Each cap would have similar rules to the existing NZ ETS, in that a permit would be surrendered for each emitted tonne of biogenic CH₄ and each tonne-equivalent of long-lived gas emissions. Trading, and therefore abatement flexibility across participants, would be restricted to solely within each cap.
3. Establishing a separate trading and pricing system for biogenic CH₄. Box 9.7 and Figure 9-10 explain the broad parameters of a potential mechanism – a methane quota system (MQS).

Some submitters suggested policy mechanisms similar to options 2 and 3. Dave Frame (sub. DR270) and Scion (sub. DR366) proposed a “rampdown” option for biogenic CH₄ using GWP*. This would work by using a pricing mechanism to incentivise farmers to reduce emissions faster than a specified rate. Steven Cranston also suggested a “net-methane” approach through which farmers who increase emissions are taxed, farmers who reduce emissions are rewarded, and farmers who continue to emit at a steady rate are neither taxed nor rewarded. Cranston suggests that this approach would act as a “far stronger signal to farmers to encourage behaviour change...[and provide] a far greater dis-incentive on intensification” (sub. DR170, p. 8).

Box 9.7 **A methane quota system**

A methane quota system (MQS) is a type of emissions pricing mechanism that aims to induce efficient behaviour by emitters of biogenic CH₄ consistent with the budgets and targets set at a national level. As a pricing mechanism, its rationale is similar to that of emissions pricing more generally (Chapter 5) (Stiglitz & Stern, 2017).

An MQS has strong parallels with the quota management system (QMS) currently operating to manage New Zealand’s fishery stocks (Box 5.2 in Chapter 5):

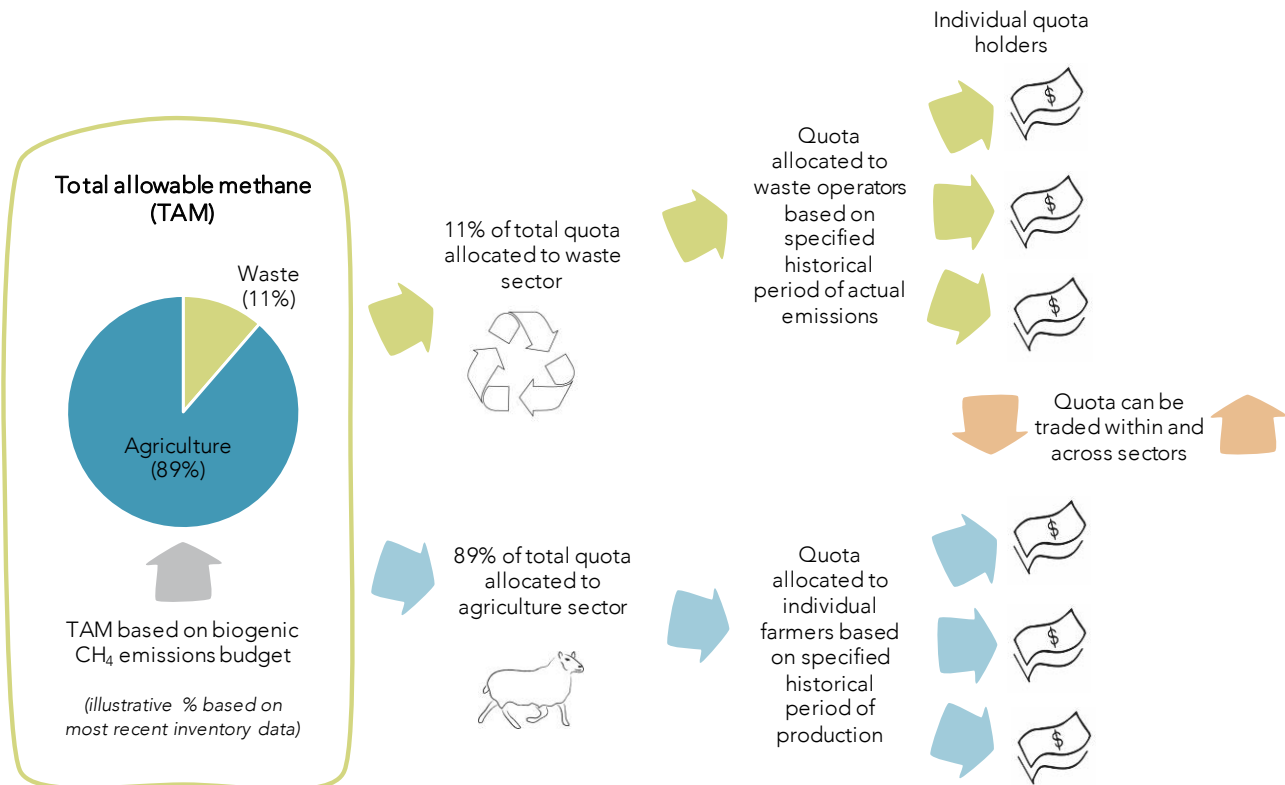
- In the QMS, a fisher must own individual transferable quota to catch fish of a certain species up to a specified limit per period. Quota ownership is a flow entitlement – to catch a certain quantity of fish each year. This quantity is defined not as an absolute tonnage but as a proportion of the total allowable catch (TAC) for the year. The TAC is set ideally to realise the maximum sustainable yield of the fishery. In practice, the TAC is based on an expert assessment of how many fish can be caught for consumption each year while also ensuring the ongoing health of the fish stock.
- In an MQS, an emitter must own individual transferable quota to emit biogenic CH₄ up to a specified limit per period. Quota ownership is a flow entitlement – to emit a certain amount of biogenic CH₄ each year. Again, this quantity is not defined as an absolute tonnage, but as a proportion of the total allowable methane (TAM) for the year. The TAM is set to achieve the relevant emissions budget for short-lived gases. In turn, the budgets will have been set to achieve the long-term target level for a constant flow of CH₄ emissions. The target is an expert assessment of the level to which New Zealand’s biogenic CH₄ emissions should be limited to contribute to the global task of keeping global warming to well below 2°C. The TAM will reduce over time (in line with emissions budgets), but changes would be signalled well in advance and made in line with guidelines that are well understood.

In the fisheries QMS, the stock of a fish species is a function of the entry flow of new fish (via natural fish reproduction) and the exit flow via fishing (and natural causes including the lifespan of fish). In this way, the fish stock is like the stock of biogenic CH₄ in the atmosphere – a function of inflow rate, outflow rate and atmospheric lifetime. One difference is that a large stock of fish in the ocean is generally a good

thing; a large stock of methane in the atmosphere is a bad thing. This is why the focus of the QMS is to control the outflows of fish while the focus of an MQS is to control the inflows of biogenic CH₄.

As with the fisheries QMS, clear and simple rules for quota trading would be needed to create an efficient MQS market (Kerr et al., 2003). Evaluations and assessments of the fisheries QMS offer a valuable resource from which to draw on to design the further aspects of the MQS. These wider aspects include the importance of setting the TAM in a rigorous manner and the potential social and economic consequences if the quota become concentrated in the hands of a few (Simmons et al., 2017; Slooten et al., 2017).

Figure 9-10 Potential structure of a methane quota system



Analysis of options

The NZ ETS works by requiring each emitter to have (and surrender) each year the same number of NZUs as the tonnes of CO₂e they emit in that year. Emitters can “bank” NZUs and so can choose to emit more now, and less later (or vice versa), depending on which is more cost-effective. If the overall goal is for New Zealand to cap its net emissions of long-lived gases between now and 2050, and for net emissions in 2050 and beyond to be zero (or lower), this ETS system with bankable NZUs is well suited. It simply requires that the government limit the number of NZUs it issues, net of forestry offsets, in relation to the target of total net emissions and for the units to have no validity beyond 2050. In practice, the government will issue the NZUs over time to meet the multi-year emissions budgets rather than issue them in one large lump.

Because long-lived gases accumulate permanently in the atmosphere, this is a suitable permit and pricing system where the target is to bring their net flow to zero in the desired timeframe. However, it is *not* well suited to a short-lived GHG such as biogenic CH₄ where the target is to stabilise the flow of emissions at a target level by a future specified date, and with emissions budgets that step down this flow to that target level from the current flow-level of emissions (Tietenberg, 1985). It is important to recall that both targets aim to achieve the overarching goal of limiting the steady-state stocks of short and long-lived gases in the atmosphere thereby limiting peak warming to no more than 2°C (Figure 9-3).

To achieve the goal for biogenic CH₄ therefore calls for a permit and pricing system that will cost-effectively control its flow over time to eventually reach a target flow and then stabilise at that level. This could be a separate permit system to the NZ ETS that entitles the emitter to emit a constant average *flow* of the gas over several years (eg, for five years, if that is the specified period of an emissions budget), with this constant average flow then stepping down in the next emissions budget (option 3 above). Or it could be achieved with separate caps and separate NZUs for biogenic CH₄ within the NZ ETS (option 2 above). The caps for the short-lived NZUs would be set to achieve the same pattern of constant average flows of emissions over time. Banking of units would be restricted to within the emission-budget periods.

Common to both these options is the principle of needing two instruments to achieve two targets. On the face of it, option 1 has only one instrument – the single cap on the all-gas NZUs – and therefore cannot provide the control necessary to achieve two separate targets. But a second potential instrument exists in the form of the exchange rate between the gases (Box 9.8).

Box 9.8 Amending the exchange rate for GHGs within a single-cap NZ ETS

Currently, the NZ ETS uses the GWP₁₀₀ exchange rate from the IPCC's Fourth Assessment Report which is 25.¹¹⁶ This means that it requires the surrendering of 25 NZUs to emit a tonne of CH₄ compared with one NZU to emit a tonne of CO₂. If it were found that, within the overall cap, CH₄ emissions were not declining fast enough, then the exchange rate "price" could be increased to, say, 34 (and vice versa).

In analysis prepared for the Parliamentary Commissioner for the Environment, a group of New Zealand researchers argued to reduce the GWP₁₀₀ value for CH₄ to below its current value until such time as CO₂ emissions are declining towards zero (Hollis et al., 2016). However, they also noted that the exact figure to choose is not agreed, as the arguments put forward for different values depend on the specific policy goal and "reflect judgments about politics, economics and the intersection of policy and science" (Hollis et al., 2016, p. 33).

As DCANZ notes (on the assumption that the exchange rate is fixed), "[p]ricing methane and carbon equally, would...not drive the right policy tension for relative mitigation efforts" (sub. DR380, p. 2). Because exchange rates between gases are well established in international GHG accounting rules, it would be controversial for New Zealand to "play around with them". Also, even with the exchange rate as a second instrument, option 1 does not make it as transparent as the other options that there are separate and different types of target for CO₂ and CH₄ reflecting their different atmospheric properties.

Because of the incompatibility of a single-cap NZ ETS with the nature of the end-goal for biogenic CH₄, and the problematic issue of amending exchange rates within an NZ ETS, the Commission does not recommend option 1 of including biogenic CH₄ in the NZ ETS under a single cap.

So, this means that option 2 (a dual-cap NZ ETS) and option 3 (an MQS) should remain under consideration. There are considerable similarities between these options, but also some differences. Key design aspects to examine include their economic effect (ie, how they incentivise mitigation of each type of gas in line with the marginal social benefits and costs of doing so) and their likely political and social acceptability and durability.

In terms of economic effect, both are quantity instruments – that is, they specify a quantity of allowable emissions, and emissions reductions are driven according to either the decreasing cap in the NZ ETS, or by the decreasing TAM (both of which are directly linked to the biogenic CH₄ emissions budget). Holders of short-lived NZUs or quota may decide to reduce their emissions because they will be better off from selling their permits (eg, to a more-efficient producer) and exiting either scheme entirely. This sort of transaction is possible because both short-lived NZUs and MQS quota are tradeable. This promotes an efficient allocation of permits across all emitters of biogenic CH₄.

¹¹⁶ Note that the Fifth Assessment report of the IPCC has updated this exchange rate to be 28 (eg, as shown in Figure 9-1).

A key economic effect is how closely the relative price of each type of permit will match the marginal social cost of emitting a tonne of each type of gas. Estimating social costs is immensely complex since the causation goes through several steps:

- a one tonne pulse of each type of gas causes a time profile of radiative forcing, temperature increase, and subsequent climate change events (eg, extreme weather events);
- climate change causes economic, social and environmental damage over time;
- these impacts cause varying losses in wellbeing over time (that can be valued in dollars discounted to the present).

While some estimates along these lines exist, they are not a practical basis for pricing emission units. Rather, the problem is simplified by setting quantity limits on emissions over time to achieve an intermediate (but vitally important) goal – limiting global temperature rise to well below 2°C. To achieve this, the key issue for both short- and long-lived gases is the same – to first stabilise and then reduce the atmospheric stock (recalling that negative emissions of long-lived gases are likely to be necessary to achieve this temperature goal).

New Zealand's quantity targets for long and short-lived gases should reflect the relative marginal social costs that they each cause. Ideally, the price of each type of permit should reflect the harm from a unit emission of a long-lived gas (which will raise its stock by one unit) relative to the harm from whatever increase in the steady-state stock of biogenic CH₄ will arise from a unit increase in its constant flow. For example, if the lifetime of CH₄ is 12 years, a one tonne increase in yearly emissions of CH₄ will result in an increase of 12 tonnes in its steady-state stock in the atmosphere. Accordingly, the prices of the permits should reflect the relative potency of the different GHGs in the atmosphere (tonne for tonne) and the lifetime of the short-lived gas. GWP* incorporates both these factors and could be used to check whether the relative price of the permits (determined in the market) is in this ballpark. If it is not, then the quantity caps should be adjusted to bring them closer to this desirable ratio.

Other design issues to carefully consider include:

- **The quantity of free allocation.** How many short-lived NZUs or quota should be freely allocated?¹¹⁷ In a dual-cap NZ ETS, the questions would be a) the percentage of NZUs freely allocated initially and b) how the free allocation would reduce over time. In an MQS, it would be how much quota to freely allocate at the beginning of the scheme. In an MQS, allocation only happens once because the quota is a right to emit an ongoing (albeit reducing) flow of biogenic CH₄.¹¹⁸ For example, if quota were freely allocated at the beginning of the MQS, a new entrant wishing to join either the waste or agriculture sectors (eg, a new landfill operator, or a new farmer) would need to purchase quota from existing quota holders. An exception may be needed if wastewater treatment plants entered the MQS (Chapter 15). In both a dual-cap NZ ETS and an MQS, the political acceptability of the quantity of free allocation would be important (particularly in terms of perceptions of fairness as compared to other sectors also facing the need to reduce their emissions).
- **The structure of free allocation.** As explained in Chapter 5, the rule for how many freely-allocated NZUs an NZ ETS participant receives can make a big difference to their incentives to reduce emissions. A lump-sum allocation (eg, allocation based on historical levels of output of the participant) would give a strong incentive of the full NZU price for each tonne of emissions avoided by reducing output. In an MQS, quota could be allocated to the waste sector in proportion to average historical emissions over a specified period (eg, emissions between 2015 and 2017). In agriculture, quota could be allocated in proportion to average production levels over a specified historical period (eg, average production between 2015 and 2017). Free allocation in a quota system is almost inevitably lump sum because allocation is one off. A lump sum allocation provides a strong incentive for farmers to sell their quota if

¹¹⁷ Free allocations would go only to agricultural producers because agriculture is an emissions-intensive, trade-exposed sector. Waste would not receive any free allocations, as under the current NZ ETS design.

¹¹⁸ A one-off free allocation might avoid ongoing controversy and enhance the durability and acceptability of an MQS compared to the NZ ETS. However, arguments about the withdrawal of free allocation over time would no doubt be replaced with arguments about the rate of reduction of the TAM.

they wish to change from animal farming to a different (low-emissions) form of land use.¹¹⁹ The rationale for basing the allocation of quota in the agriculture sector on historical production levels (rather than historical emissions) is to not penalise producers who have already gone further than others to reduce their emissions intensity.

- **The point of obligation.** Large landfill operators are likely to remain the point of obligation in the waste sector in either the NZ ETS or an MQS. The point of obligation in the agriculture sector is less clear-cut for either scheme. As discussed in Chapters 5 and 11, it will be important to locate the point of obligation for emissions where it achieves the best balance between incentivising mitigation and minimising administrative complexity and compliance costs.
- **International trading.** While the NZ ETS is not currently linked with any international schemes, this could occur in the future. Being aware of how a dual-cap NZ ETS or an MQS could enable international trading will be a necessary component of any policy analysis.

As well as scheme design, the political and social acceptance and durability of either a dual-cap NZ ETS or an MQS is relevant. As noted throughout this report, establishing stable and credible climate policy to drive action is critical. An MQS potentially has greater durability because it could receive more support from affected parties (ie, scheme participants) compared to a dual-cap NZ ETS. Although the dual caps within the NZ ETS would signal that short and long-lived gases are different, an MQS would make this even more explicit. No potential for confusion would exist, whereas confusion could be possible between the elements of the NZ ETS such as how the caps or free allocations work for short- and long-lived gases.

An MQS may also prove more acceptable because it is not the NZ ETS (ie, it represents a clean slate and way forward compared to historical contention around agriculture entering the NZ ETS). However, while it is based on the fisheries QMS and thus may be well-understood by some parts of the community, an MQS comprises an entirely new scheme over and above the NZ ETS. Transaction costs and administrative complexity will be important factors to consider (eg, in relation to the point of obligation as noted above).

On balance, the Commission does not have a strong preference between an MQS or a dual-cap NZ-ETS. Since reforming the NZ ETS to have dual caps and trading units, or establishing an MQS, would each be major reforms that have extensive and long-lasting implications, both options require further consideration and discussion with interested parties. This work programme fits the remit of the Interim Climate Change Committee, due to report back to the Government on recommendations for policy relating to agricultural GHG mitigation at the end of April 2019.

F9.6

Biogenic CH₄ is unsuitable for inclusion in a single-cap NZ ETS due to the difficulty such a scheme would have in driving emissions reductions in a manner that recognises the different atmospheric properties of short- and long-lived gases. A dual-cap NZ ETS with separate trading units for biogenic CH₄ and other GHGs, or a methane quota system, are two suitable alternative permit and pricing mechanisms for incentivising mitigation of biogenic CH₄.

R9.6

Biogenic CH₄ should be included in an emissions pricing mechanism that recognises its different atmospheric properties compared to long-lived gases. The Interim Climate Change Committee should assess both a dual-cap NZ ETS and a methane quota system in its report to the Government on recommended policy for agricultural GHG mitigation due at the end of April 2019.

¹¹⁹ The incentive to sell quota if free allocation is based on output (as it is currently in the NZ ETS) is very much weaker. But free allocation based on output has merit if the objective, as in export manufacturing, is to stop emissions leakage. Nevertheless, biogenic CH₄ leakage is unlikely to be a major problem with lump-sum free allocation because any farmer cutting output will probably have to sell their quota to another farmer or waste operator who wants to expand output. Quota is very unlikely to be tradeable internationally.

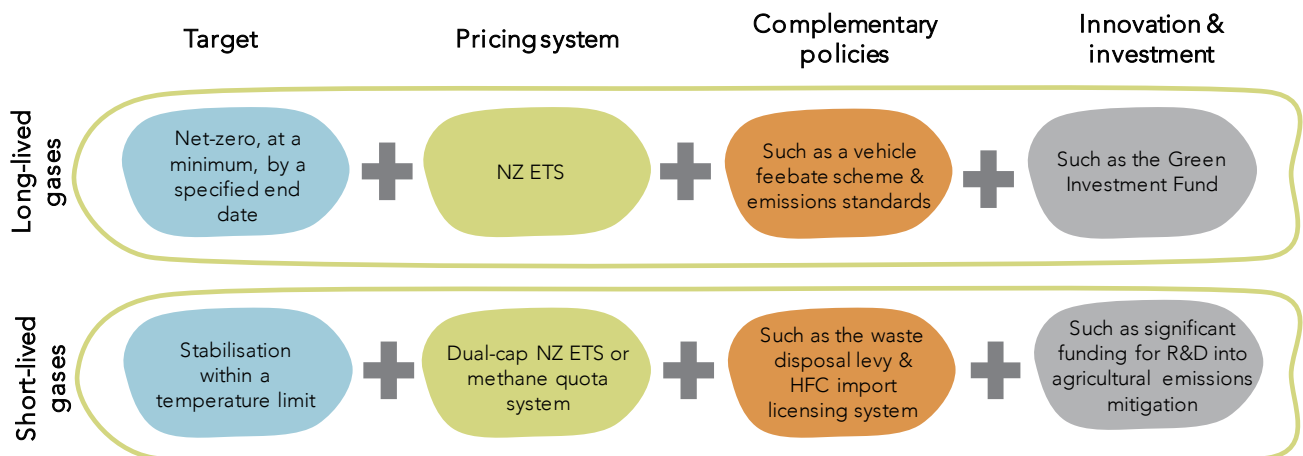
9.7 Conclusion

Because of the different atmospheric lifetimes of GHGs, emissions of long-lived gases need to reach net zero (or below) to limit peak warming to well below 2°C. Yet emissions of short-lived gases do not need to reach net zero to limit peak warming. The case for putting greater relative priority on mitigating long-lived gases is strong because emissions are irreversible. While this is well-understood within the scientific community, less policy attention has been paid to this issue globally. One reason is that the emissions profiles of most other developed countries are dominated by CO₂. As such, their focus is on mitigating long-lived gases.

Because a relatively high proportion of New Zealand's emissions are short-lived gases, the question of how best to prioritise between emissions reductions of short- and long-lived gases is of greater interest. The Commission recommends that the government seeks to enact separate long-term domestic targets for short- and long-lived gases to provide status and permanence for them. These targets should be supported by separate emissions budgets. It also recommends the inclusion of all long-lived gases in the NZ ETS, and the establishment of a pricing mechanism (either a dual-cap NZ ETS or an MQS) for biogenic CH₄.

These targets, emissions budgets and core pricing mechanisms will need to be supported by complementary policies, innovation and investment (Figure 9-11). The Commission considers that this "two-baskets" approach would provide for a distinctively New Zealand solution to its emissions profile. It would align New Zealand's mitigation policy more closely with the underlying science of warming, address the country's distinctive emissions profile, and could become a world-leading policy exemplar.

Figure 9-11 A New Zealand approach to short- and long-lived gases



10 An inclusive transition

Key points

- A well-paced transition should give firms and households predictability about the direction of change and the time to identify and take the opportunities that the transition offers. This depends on well-established emissions budgets, stable governance and the provision of free allowances with a measured phase-out to ease the transition. A well-functioning, high-productivity economy should provide the flexibility to allow businesses and households to innovate and grasp emerging investment opportunities.
- Central and local government agencies have an important role in providing or funding investments to complement those being made by firms and households as they adjust to the transition. These investments include support for innovation, skills acquisition and infrastructure. Building coalitions to share information and intentions will help coordinate these investments and consolidate support for the transition.
- Building on the co-benefits of mitigation efforts (such as improved water and air quality) and avoiding off co-harms (such as reduced biodiversity) will help maintain support for the transition.
- Effective action depends on changes in attitudes and values to favour climate-change mitigation. Better information on the emissions embodied in consumer goods and services will contribute.
- Interventions to address significant shocks to communities resulting from emissions-reduction policies (eg, the loss of a major employer) should focus on the labour market and skills needs of individuals, and should be targeted to those who will have the most difficulty gaining new employment. Yet the Commission has found that the current education and training system is not well set up to meet the needs of people seeking mid-career retraining.
- Mitigation policies may raise energy and food prices. These items make up a significant share of expenditure in lower-income households. A disproportionate burden of the transition to a low-emissions economy may therefore fall on these households.
- The focus of any public assistance to individuals should be on lower-income households who have a limited ability to substitute towards less emissions-intensive consumption, and those facing large shocks, such as individuals suffering a loss of employment opportunities.
- A combination of welfare benefits and tax credits to help lower-income households is preferred, as such benefits and credits are well-targeted and affordable, and existing policies can be used. The Government should monitor energy, food and transport price trends to ensure that benefits and tax credits are being appropriately adjusted over time.
- Lower-emissions vehicles, particularly electric vehicles, could soon deliver significant welfare gains by reducing transport costs. However, this transition will take longer for lower-income households who tend to buy older, cheaper vehicles in the second-hand market. Emissions pricing and a feebate scheme will increase the cost of purchasing and running fossil-fuel vehicles, which could disproportionately affect lower-income households in the short term.

Chapters 3 and 4 set out the scale of the economic changes needed to transition to a low-emissions economy and lay out the sectors that look likely to play the largest role, particularly land-use change, and the electrification of light transport. Chapter 4 also depicts the particular developments that are likely to occur in the transport, land use and electricity sectors and possible implications for employment, the demand for skills and effects on communities where these sectors are based. Key elements for a successful transition,

such as effective price signals, support for innovation and a stable and credible policy foundation are discussed in Chapters 5, 6 & 7.

Many submitters thought that the Commission should take a broader approach to an inclusive transition than that in the draft report, which focused principally on the employment and cost-of-living impacts on low-income households (eg, Trustpower, sub. DR249; Auckland Council, sub. DR249; New Zealand Council of Trade Unions, sub. DR321; Scion, sub. DR366).

This chapter first sets out a broad approach to assisting businesses, regions and rural communities to make a successful transition, and building support for such a transition. In a well-functioning, high-productivity economy, business and households should be alert to, and have the flexibility to grasp emerging opportunities. Yet central and local government also need to make investments to complement those being made by businesses and households (sections 10.1). Importantly, government agencies can work with other actors to build support for and lower barriers to an inclusive transition (section 10.2). Government also has a role in building greater support among consumers for climate change mitigation action (section 10.3).

Even in a well-paced transition, some businesses, some workers and some communities will face abrupt changes in economic activity (Chapter 4; section 10.4). There is likely to be a disproportionate impact on lower-income households (section 10.5). A well-designed and properly functioning social safety net should work to support vulnerable households through the transition and enable them to participate fully in a “post-carbon” society (section 10.6).

A well-paced transition

Previous chapters have set out the preconditions for a well-paced transition to a low-emissions economy. These include predictable emissions budgets, stable governing institutions, and free allowances to be withdrawn over time according to an established timeline. Te Rūnanga o Ngāi Tahu valued policy certainty and time for adjustment:

A ten or twenty year timeframe for certain change is the kind of window that should enable any business or household to make necessary adjustments without radical economic shocks. (sub. 83, p. 12)

One key to a measured and prosperous transition is the provision of free allowances to emissions-intensive, trade-exposed businesses (Chapter 5). Allowances should be phased out over time in a predictable way that is consistent with meeting emissions reduction targets; and at a pace that gives landowners, processors and manufacturers time and the incentive to adjust.

10.1 Coalitions to coordinate investments for the transition

Firms and households will be the main decision makers in the shifts in economic activity motivated by emissions mitigation policies. This will involve decisions about what to consume and what to produce, how to produce goods and services, and the investment strategies needed to bring this about profitably. Existing firms or start-ups may need new skills, and to develop new supply lines and distribution chains. Students coming into the workforce and current workers will decide what skills to acquire for a prosperous life working in a low-emissions economy.

Central and local government hold many of the levers that directly or indirectly complement the choices made by firms and workers. Government funds education and training for new and existing workers. Government can direct some support for innovation to promising areas of research (Chapter 6). Central and local government make decisions about roads, rail and other public transport infrastructure. They also make regulatory decisions that impact the viability of various private investments.

Coordination of government and private investments

The transition (like economic growth more generally) will be built on a complex web of private and government investment (and regulatory) decisions. Adding to the complexity, the value of some investments will obviously depend on whether other investments are made. For instance, if skills are not available, a change in land use may not be productive. If suitable infrastructure is not available to transport logs to mills or port, forestry investments may face a low return. Investors will likely not make investments at all, unless

they are confident that other investors (including government and government-funded agencies) will make the required complementary investments. It is easy to see how coordination of investment intentions could play an important role in shaping the cost, speed and success of the transition.

How are government investment decisions coordinated with those of firms and workers? Some government investment decisions are made centrally; yet for reasons of efficiency and responsiveness to emerging needs and local conditions, many are devolved.

- What tertiary educational providers teach, to an extent, is in their own hands.
- Investment in roads is an amalgam of decisions made by a central government agency (the New Zealand Transport Agency) and local government.
- Government support for research and development (R&D) and innovation is administered by the Tertiary Education Commission (mostly non-directive funding for universities) and the Ministry of Business, Innovation and Employment (MBIE). MBIE uses a variety of mechanisms to channel R&D funding mostly to Crown Research Institutes, businesses and universities and other public and private sector organisations. Some of this funding is directed (Chapter 6).

When decisions are devolved, achieving effective coordination of investments then raises questions of institutional design and responsiveness. For instance, current tertiary education policy does not provide well for mid-life retraining for workers (section 10.4). Local government funding arrangements make it difficult to provide transport and land-development infrastructure in a timely manner (NZPC, 2017a). The design of resource management regulation may unduly hinder new investments in renewable electricity generation and electricity transmission (Chapter 13).

Good information flows and collaboration can help align investment intentions

Sharing information can help to coordinate investments. This includes information on emerging opportunities, and the technology, practices, business models and skills required to put them into place. Market intelligence for new (or new to a region or district) products, and information on supply and distribution channels can help shape investments. Lack of this sort of information is one of the reasons that a shift to horticulture has been slower than expected (Box 10.1).

Box 10.1 A slower than expected shift to horticulture

The land devoted to horticulture and the value of horticultural production and exports (particularly fruit and wine) have been steadily increasing over the last decade or more, and are projected to continue to do so. Ample additional land is available that is biophysically suitable for horticulture, though economic suitability would depend on a combination of commodity prices, water resources, and availability of skills.

Yet Andy Reisinger (sub. 28) notes that while, on paper, opportunities to move into horticulture from dairying seem profitable in some parts of New Zealand, a large shift is not happening. He argues that a better understanding of barriers and how they may vary by region is needed.

[W]ithout a clearer long-term horizon point, the status quo with its aligned institutions and support mechanisms will be difficult to change. A targeted and objective analysis is necessary to better understand whether the status quo simply reflects the most economically viable form of land-use in most of New Zealand, or whether it largely reflects social and institutional lock-in that prevents genuine opportunities from being realised. (sub. 28, pp. 3–4)

Inquiry participants identified barriers to landowners moving to horticulture, including:

- limited understanding of how to go about making the change;
- uncertainty about the hidden costs of change;
- difficulties in accessing skilled labour;

- unfamiliarity with supply chains and processing, distribution and marketing arrangements;
- uncertainty about access to international markets; and
- difficulties in accessing financial support.

Dr Tanira Kingi, of Scion, told the Commission that, in regions or districts where horticulture was currently not a prominent land use, or a novel type of horticulture was being considered, lack of information about cultivation practices, markets, and distribution was a barrier for Māori landowners changing.

Source: Morgan Foundation, sub. 127; Horticulture New Zealand, subs. 41, DR394; Clothier et al. (2017); Dr Tanira Kingi (pers.comm., 16 July 2018).

Building coalitions

Building coalitions for climate-change mitigation action not only has immediate benefits in solving coordination problems. Coalitions also form a base for enduring action over time (Levin et al., 2012). Coalitions act to expand the population committed to climate-change mitigation and put in place a series of interventions that build on and reinforce each other, entrenching support over time.

For example, central and local government agencies may usefully play a part, with industry organisations and iwi, in developing information-sharing mechanisms. This could extend to collaborative mechanisms to align investments in a particular region to take up low-emissions business opportunities. Coalitions could involve industry, iwi and other Māori organisations, local and central government agencies and research and educational institutions, for instance. The scope could include a range of co-benefits of climate-change mitigation (section 10.2).

Action will often be centred on particular regions where economic change triggered by mitigation policies is gathering pace (and where significant effort to adapt to climate change may also be underway). While section 10.4 cautions against the efficacy of place-based interventions to reverse economic decline, this section focuses on coordination to realise the benefits of emerging opportunities. DairyNZ is providing an example of a place-based approach to identifying such opportunities. DairyNZ is

developing a rural planning tool which will examine the suitability of different land types across catchments and regions to reduce a range of contaminants [including GHGs]...The intention of this tool is to identify the adaptive capacity in different catchments and regions to maintain the ecosystem health. This will help us identify how to drive land use change in an efficient and effective manner across New Zealand. (sub. DR365, p. 7)

Coalitions to mitigate climate change can take different forms. For instance, in 2017, local Government leaders made a climate change declaration in which they together committed to a range of local actions to reduce greenhouse gas (GHG) emissions, guided by a set of agreed principles (LGNZ, sub. 36). Te Rūnanga o Ngāi Tahu has been working with its constituent marae, local government and businesses to develop both mitigation and adaptation responses to climate change (sub. 83). Te Rūnanga notes that, as a post-settlement iwi, “[w]e are well equipped to partner with central and local government, as natural agents of change and intergenerational investors within the Ngāi Tahu takiwā and nationally” (sub. 83, p. 5). Industry, iwi and research institutions have been working together on ways to reduce emissions in pastoral agriculture (Box 10.2).

Box 10.2 Building coalitions for action – reducing emissions in pastoral agriculture

The pastoral agricultural sector, through industry organisations and leading companies, is developing a strategic approach to climate-change mitigation. For instance, in June 2017 DairyNZ, in partnership with Fonterra and with the support of government agencies, launched the Dairy Action for Climate Change initiative (which builds on a similar strategy to address water quality issues). The initiative addresses barriers to emissions reductions by building the capability of rural professionals through professional training courses, raising the awareness of farmers, and undertaking GHG pilot case studies on dairy farms (DairyNZ, 2017).

Beef + Lamb New Zealand in May 2018 released its *Environment Strategy and Implementation Plan 2018-22* (Beef + Lamb New Zealand, 2018). The plan sets out a goal of a carbon-neutral sheep and beef sector by 2050 along with other environmental goals. The plan provides for farmers working together in catchment communities, progressing research for evidence-based action and policy, developing action plans for each farm, enabling farmer leadership on environmental issues and representing the industry in global forums. Beef + Lamb New Zealand will partner with “the dairy sector, scientists, environmental NGOs and Tangata Whenua to support farmers and bring about change.” (p. 4).

Te Rūnanga o Ngāi Tahu reinforced the role that iwi can play in supporting the transition for pastoral farming:

These [Southland and Waikato with a lot of dairy] are regions falling within the tribal boundaries of two of the longest-settled and best-resourced iwi, Ngāi Tahu and Waikato Tainui (pers. comm., 22 March 2018).

Building coalitions including primary sector industry and environmental organisations, local government and iwi will help identify and put in place strategies to support adjustment. (sub. 83)

Māori landowners have also asked for Māori-specific approaches to lowering emissions from land use (CCILG, 2016a; Harmsworth et al., 2010; Insley & Meade, 2008). The New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) now has a dedicated Māori research programme, which includes initiatives to:

- characterise 29 Māori farms and to monitor their GHG emissions (Kingi et al., 2015); and
- reduce emissions on four farms while improving profitability, and to disseminate the results through on-farm field days (NZAGRC, 2017).

The programme is now undertaking case studies of low-emissions practices on two large and diversified farming entities, in conjunction with DairyNZ, Beef + Lamb New Zealand, the Federation of Māori Authorities and Te Tumu Paeroa (the Māori Trustee) (Dr Kingi Tanira, pers. comm., 16 July 2018).

Many submitters saw an important role for government in helping to coordinate collaborative approaches to climate-change mitigation and managing the effects of mitigation policies (eg, New Zealand Council of Trade Unions, sub. DR321; and Tauranga Carbon Reduction Group sub. DR278). Christchurch City Council pointed to the role that local government could play in coordinating efforts and setting an example through its own practices (sub. DR284). The New Plymouth District Council identified its district’s strong foundations in the oil and gas and agricultural sectors. The Council pointed to work that it is engaged in with other local stakeholders and central government to “minimise the negative impacts and maximise the opportunities in a timely manner” of a transition to a low-emissions economy (sub. DR359, p. 1).

Te Rau Aroha Trust, a Māori-owned entity, with interests in developing horticulture, submitted:

Government has an obligation to work closely with Māori landowners and communities towards policies that are fair, equitable and inclusive of all the diverse and significant impacts and opportunities arising from climate change...

...we are poised to begin practically creating the numerous new green jobs for our whanau, working on otherwise under-utilized Māori land, in very high value and growth horticulture sectors linked to high value markets of the world. While transitioning to a low emissions economy...

[This] will require a strong leadership diligent focus and partners committed to the kaupapa (task) especially out over the medium to long term. We and other Māori stand ready to immediately begin the work on the ground and in our communities. (sub. DR207, p. 18)

Other examples (among a great many) of voluntary initiatives to mitigate climate change include:

- Air New Zealand providing customers with an option to offset the emissions from their air travel, by contributing to forestry initiatives;
- The Climate Change Iwi Leaders Group (CCILG), for at least a decade, leading work to develop Māori responses on climate change adaptation and mitigation, and providing advice to Government in support of effective action (CCILG, 2016b); and
- Local Government initiatives, for example, providing charging infrastructure for electric vehicles (EVs) (LGNZ, sub. 36).

F10.1

Central and local government agencies and providers of state-funded research, education and training services have a significant role in a transition to a low-emissions economy by making investments to complement those being made by businesses and households. Government provides or funds support for innovation, education and training and infrastructure. Building effective mechanisms to coordinate these investments will help reduce the costs and smooth the path of the transition.

Being alert to emerging opportunities

Emissions-reductions initiatives and other emerging economic trends will produce new opportunities for businesses across New Zealand and in particular regions. Businesses will assess the prospects and associated risks as they make new investments to take advantage of these opportunities. But, as discussed above, central and local government also have a role in sharing information and coordinating investment intentions.

On the one hand, government agencies should avoid making investments (such as favouring particular technologies) that risk being rapidly overtaken by better technologies (Chapter 13 discusses this risk in relation to electricity generation technologies). On the other hand, government agencies need to be nimble in matching the investment intentions of businesses, so that governmental support for innovation, education and training and provision of infrastructure does not act as a brake on realising new opportunities. While good information and exchange of analysis and understanding of opportunities will help, inevitably some uncertainty will emerge about which initiatives will prosper.

In some areas of government provision, such as support for innovation, a portfolio approach will help reduce risks. In other areas, such as education and training, shifts in provision will be shaped to some extent by changing student and industry demand. In this case, the key is how responsive or not education providers are to changes in demand.

Examples of possible opportunities identified by inquiry participants include:

- a large expansions of forests may make particular downstream industries using forest products more viable (Box 10.3);
- New Zealand could use its global lead in technologies and practices to mitigate agricultural biological emissions to make a major contribution to global climate-change mitigation efforts, so raising its international profile and possibly reaping some commercial benefits through the sale or licensing of technology (Box 10.4); and

- New Zealand businesses could leverage the food-technology science base and New Zealand's advantages in food processing, distribution and marketing to take advantage of emerging synthetic food technology and changing consumer preferences (both by shifting to higher-value natural produce and, more speculatively, shifting some production to plant-based and synthetic alternatives) (Box 10.5).

Box 10.3 **Downstream opportunities from large-scale forestry**

Some submitters saw potentially significant downstream opportunities from large-scale afforestation.

The restriction of the role of forestry to only carbon sequestration misses the multisectoral role of this ecosystem, and the major opportunity to provide alternative feedstocks to petroleum and coal. (Scion, sub. DR366, p. 2)

Peter Hall, a senior scientist at Scion, separately submitted:

The clear support [in the Commission's draft report] of forestry as a means to sequester carbon is welcomed. What is concerning is that there is little acknowledgement of the substantial role that the forest resource could play in the long term as supply of low carbon bioenergy that could be used to generate process heat, electricity and liquid fuels for transport. (sub. DR205, p. 3)

Scion also referred to new laminated timbers for construction and to bio-based manufacturing and products developed to produce "new fibre-based materials" to replace plastics and other petrochemical products, based on "new cropping forests and manufacturing processes" (sub. DR366, p. 2). Scion is working to develop these technologies.

Several inquiry participants saw potential for building regulation to stimulate more use of timber in construction (subs. DR194, DR246 and DR304). Chapter 16 considers the case for re-examining building standards to ensure they enable the use of low-emissions building materials.

Which downstream uses of wood emerge in the future will depend on a variety of factors, including the changing costs of technology, the price of logs and the economics of different cropping systems. A large expansion of global forests may depress prices, but an expansion of competing end uses (favoured by emissions pricing) could raise prices. New technologies or falls in the cost of existing technology could make some end uses economically viable, when they currently are not viable. Keeping options open through ongoing research makes sense as part of a wider portfolio of research into emissions-reducing technology (Chapter 6). Overall, realising downstream opportunities for wood products requires a concerted effort in research, connected to a commercial strategy with local and international partners of substance.

Box 10.4 **Leveraging New Zealand's lead in reducing agricultural emissions**

New Zealand could make a much larger contribution to reducing global agricultural emissions reductions than it can achieve in domestic reductions alone. The emissions intensity of agriculture in New Zealand is much lower than the emissions intensity of many large, but inefficient, global producers. As a highly productive producer, New Zealand possesses technical expertise that could assist other countries to reduce their emissions intensity through large efficiency gains. The successful development of mitigation technologies in New Zealand will also benefit agricultural producers globally.

New Zealand already promotes lower global agricultural emissions through the Global Research Alliance on Agricultural Greenhouse Gases (GRA) (Chapter 11). Under the GRA, New Zealand co-funds the Global Partnerships in Livestock Emissions Research, which provides funding for collaborative mitigation projects between New Zealand and international researchers. Through the Ministry of Foreign Affairs and Trade's Aid Programme, New Zealand also assists agricultural producers in several

developing regions to become more competitive and productive (in 2013/14, funding equalled about \$40 million).

New Zealand, by helping other countries to achieve reductions in agricultural emissions beyond business as usual, could potentially gain credits to meet its international climate-change mitigation commitments. This would likely involve setting up co-operative arrangements with individual countries or regions, to exclude double counting of emissions reductions. The Government is currently investigating potential mechanisms for obtaining international credits.

In 2017, the Government also joined the Koronivia Joint Work on Agriculture under the auspices of the United Nations Framework Convention on Climate Change. The agreement aims to develop and implement new strategies for adaptation and mitigation in the agriculture sector globally. It has a focus on improving soil health and fertility, improved nutrient use and livestock management systems, while attending to socio-economic and food-security dimensions of climate change in the agricultural sector.

Some new technologies, such as a methane vaccine, may also yield a potentially large commercial benefit, given the global scale of the potential emissions reductions (Chapter 11).

Source: MPI (2017a); GRA (n.d.); COP23 Fiji (2017); UNFCCC (2017); Fonterra, sub. DR355).

Box 10.5 **Alternative protein products – an opportunity or a threat?**

New Zealand farms face a growing threat from emerging plant-based and lab-grown alternatives to milk and meat products. These could massively disrupt traditional agricultural markets and New Zealand's part in them.

Alternative protein products are typically developed in biotech laboratories and factories rather than farms, using plant proteins such as soy and split peas, or animal cells. Producing alternative protein products has a substantially smaller environmental impact and is more resource efficient compared to traditional farming (Bosworth, 2015). One producer found that synthetic beef produces 87% fewer GHG emissions, and uses 95% less land and 74% less water, compared to traditional beef produced in the United States (Impossible Foods, 2017).

Investment in these technologies has accelerated in recent years and the products are falling in price (RSNZ, 2016). Bosworth (2015) expects synthetic technologies to soon become cost competitive with traditional agricultural products, and eventually outcompete in cost. Consumer responses will depend on price, acceptability of the technology and its environmental effects, and taste. The views about the prospects of alternative protein products to cause disruptive change for New Zealand firms vary widely (Beeby, 2017; Bosworth, 2017; Mcbeth, 2017). In a recent speech, Sir Peter Gluckman, the then Prime Minister's Chief Science Advisor commented:

The environmental numbers associated with these technologies are such that it will have a major impact, perhaps not in the next five years, but in the next 10 to 15 years, particularly if the impact of climate change continues to grow and the world becomes more conscious of the need for everybody to be responding to it. (Reported in Grieveson, 2017)

Steven Carden (2018), the Chief Executive of Pāmu Farms of New Zealand, believes that New Zealand could use its reputation as a producer of agricultural products, to compete in a remaining niche market for traditional agricultural products.

New Zealand's pastoral sector will only survive if our animal products are niche and premium. To achieve that our farms need to produce food that is different – and different in a way that's better for consumers. And not just because it's from New Zealand. But because it has scientifically-verified advantages that consumers trust. So they'll pay more for it. Our investments in new

businesses and products like sheep dairy and deer dairy products are examples we think have a future.

...our reality is that we will need fewer animals on our land in the future and more plants. We will need to shift our land uses from farming animals to more forestry and plant products. And to avoid replacing the production of an animal commodity for a plant commodity, our land uses must focus on producing unique plant cultivars that have particular functional health benefits.

Essentially Carden is asking his industry to turn the threat from synthetic proteins into an opportunity, drawing on existing strengths. In similar vein, the Waikato Regional Council noted that developing a low-emissions rural economy offers opportunities for New Zealand. For instance, “low-emissions” and “environmentally-friendly” branding of primary produce may afford growing market advantages in a carbon-constrained world (Waikato Regional Council, sub. 48).

Given its strengths in food technology and food production, New Zealand may even be able to find a place in global value chains for synthetic protein, although it has no comparative advantage in producing or marketing these products at this stage.

Different investors working together to ensure a fit between their plans has obvious benefits. Creating coalitions also helps build enduring action to reduce emissions. The next sections look further at strategies to consolidate wider support for climate-change mitigation.

F10.2

Opportunities for new types of economic activity will arise during the transition. While these cannot be anticipated with certainty, industry sectors and government agencies can keep options open and work together on support for innovation, skills development and infrastructure that enable these opportunities to be realised when they arise.

10.2 Building support around co-benefits of mitigation policies

The Commission sees emissions pricing (guided by emissions budgets and supporting regulatory initiatives) as the main lever to shift producer and consumer choices onto an efficient path to a low-emissions economy (Chapters 5 and 7). Yet other strategies can reinforce pricing and speed progress. This section discusses how attention to the co-benefits and potential co-harms of climate-change mitigation action can secure wider support. Section 10.3 looks at policies to shape consumer preferences in favour of low-emissions choices.

Leveraging co-benefits to broaden and consolidate the constituency for emissions reductions

Attention to the co-benefits of emissions-reduction efforts can build wider and enduring support for the transition. Lord Stern argues:

We can be confident that if we show commitment and foster innovation we will make rich discoveries along the way. Importantly these alternative paths, involving the transition to a low-carbon economy, look very attractive, over and above the reduction in climate risk that they bring...with...many co-benefits in terms of cleaner, quieter, fairer, safer, more energy-secure, more biodiverse ways of living and working. (Stern, 2015, p. 33)

Many submitters echoed the importance of harnessing interest in co-benefits, often with a particular focus on things such as the health of waterways (eg, Whakatane District Council, sub. DR317; SAFE, sub. DR216; Fonterra, sub. DR355), reducing erosion (eg, Taranaki District Council, sub. DR188), and improving air quality with resulting health benefits (see below, and see Venture Southland, sub. DR366; and New Zealand Centre for Sustainable Cities, sub. DR311). Others emphasised the fit between climate-change mitigation and adaptation, and with the benefits of a circular economy (eg, Sustainable Business Network, sub. DR254 and O-I New Zealand, sub. DR296).

Protecting freshwater quality and reducing emissions

Livestock farming causes nitrates to leach into waterways, reducing water quality, harming aquatic life, and reducing the value of waterways for the wider community (Monge et al., 2015; Yao et al., 2017). Many submitters pointed to the benefits for water quality that would result from a shift from intensive dairying to other land uses. Some argued that if the costs to the community of effects of agriculture on water quality (principally through nutrient leaching) were appropriately priced or regulated, more land would move from high-emissions agriculture to other uses (eg, Oji Fibre Solutions, sub. 71; NZIF, sub. 73).

Under the provisions of the Resource Management Act (RMA), the National Policy Statement on Freshwater Management sets out how local authorities should manage freshwater quality. In turn, regional councils take a variety of approaches to giving effect to these provisions (Box 10.6). The Government intends to update the National Policy Statement on Freshwater Management to apply stricter standards and ensure a more consistent approach across the country (Mitchell, 2018). Improving water quality is one of the key environmental outcomes sought by farm-focused initiatives, led by DairyNZ and Beef + Lamb New Zealand (Box 10.2).

Box 10.6 Examples of regulations introduced by regional councils to address water pollution

The quality of many of New Zealand's rural waterways has deteriorated, partly because of increasingly intensive farming (PCE, 2013). Nutrients in fertilisers, such as nitrogen and phosphorus, not taken up by plants can leach into nearby waterways as a result of rain and irrigation. These nutrients promote the growth of aquatic plants and toxic algal blooms. Increases in animal stocking rates, mostly for dairying, and the use of fertilisers increased rates of nitrogen leaching by 29% between 2000 and 2012 (StatsNZ, 2017c). In response, several regional councils have imposed limits on nutrient loss in their Regional Plans. Policies encourage farmers to optimise their nitrogen inputs and constrain their production. They also discourage landowners, such as foresters, from converting their land to farming.

Environment Canterbury

In 2014, Environment Canterbury (ECAN), in its Land and Water Regulatory Plan (LAWP), introduced caps on the nutrient loss of a farm equal to an individual farm's average losses between 2009 and 2013, to control leaching. This effectively caps yearly nutrient losses within the Canterbury Region at these historic levels. To obtain a resource consent, farmers must complete a Farm Environment Plan to demonstrate that their farming activities will comply with Plan regulations.

In mid-2017, ECAN notified Plan Change 5 to the LAWP. That Plan Change will make limits on nutrient discharges more stringent to reflect best management practices. Limits will depend, in part, on the nature of the farm, and the catchment where it is located. The regulatory change requires modifying the OVERSEER tool for estimating a farm's nutrient losses, to capture the changes in practice that farmers implement.

Waikato Regional Council – Lake Taupō

Responding to evidence of declining water quality in Lake Taupō, the Waikato Regional Council introduced a nitrogen cap and trade programme, as part of the Council's 2011 Regional Plan Variation Five. The programme's objective is to mitigate the effects of discharges in the catchment so that by 2080 the water quality of Lake Taupō is restored to 2001 levels.

The policy establishes a catchment-wide cap on nitrogen losses by allocating farmers individual nitrogen discharge allowances. Landowners may exceed their allowance provided that any nitrogen losses above their allowance are offset by a corresponding decrease in nitrogen losses elsewhere in the catchment. This creates a nitrogen trading system in which landowners facing high costs to reduce nitrogen may choose to buy nitrogen allowances from other landowners, and vice versa.

Source: Barns and Young (2012); Duhon et al. (2015); Environment Canterbury (2018).

Regulating nitrate leaching would reinforce the effects of an emissions price on land-use change. Monge et al. (2017) describe the effects of the Bay of Plenty Regional Council's regulation of nitrate discharges into the Rotorua lakes:

Dairy farmers will face the dilemma of complying with environmental regulations by either de-intensifying current operations, by including forestry, or by paying for the right to operate above the assigned NDA [nitrogen discharge allowance]. (p. 20)

Monge et al. (2017) show that, if nitrate leaching was priced at the rate implied by incentives to reduce nitrate leaching into the Rotorua lakes and carbon sequestered was priced at the then current price of \$7 for a New Zealand Unit (NZU), forestry could be at least as profitable as dairying on typical land in the central North Island. Regulation of water quality by regional councils had a significant effect on reducing deforestation intentions in the same region (Manley, 2017).

Benefits from native forests and reducing emissions

Native forests offer biodiversity and cultural benefits not afforded by exotic forests. Yet native forests are more expensive to plant and slow growing, so purely commercial considerations are likely to favour exotic forests for carbon sequestration (Chapter 11). On the other hand, native forests will keep sequestering carbon over a much longer timeframe than exotic species such as *pinus radiata*, potentially extending carbon sequestration from current planting well into the second part of the century. Pure Advantage submitted:

[o]ur own project work 'Our Forest Future' for example, a discussion paper that helped develop the initial concept work for the Trees That Count movement, identified a range of personal, material and economic benefits that can be created by planting native trees including improvements to soil and water quality, longer term sequestration of carbon, enhancement of personal wellbeing as well as a range of commercial activities like tourism. (sub. DR239, p. 2)

Dame Anne Salmond submitted that it is feasible to establish native forests at lower cost by relying more on natural regeneration, rather than on planting alone.

As we have learned by practical experience in a major regeneration project on the East Coast, (www.longbushreserve.org), strategic plantings of groves of berry-bearing native trees provide habitat for native birds that then disperse the seed into adjoining land, free of charge! Reversion can happen very quickly and economically under these circumstances – from pasture to closed canopy in 8-10 years in our direct experience. (sub. DR135, p. 2)

Recognising the additional benefits of native forests, firms are sometimes willing to offset their emissions through planting native forests, often in association with Māori landowners. Māori landowners may favour native planting for cultural reasons, a better fit with an intergenerational kaitiakitanga perspective, and because it can be a useful part of a diversified portfolio of land uses that benefits local communities (Dr Kingi Tanira, pers. comm., 16 July 2018; Garth Harmsworth, pers. comm., 26 July 2018). Te Rūnanga o Ngāi Tahu proposed additional incentives for native planting (sub. 83) and noted that the "value in indigenous forestry is multi-dimensional incorporating both regenerating native forests and potential for commercial indigenous forestry" (pers. comm., 22 March 2018).

Carver and Kerr (2017) identify policy options to increase native afforestation, such as:

- improving information on how much carbon is sequestered through native afforestation, to enable more reliable estimates of emissions credits to be earned from planting;
- allowing natural native regeneration to be eligible for Afforestation Grants Scheme (AGS) grants; and
- credibly verifying that carbon credits have been generated by native forestry, which would give companies a way to certify that their offsets come from native forestry.

Carver et al. (2017) also recommend research to identify land suitable for native regeneration, investigation of cheaper planting options for natives, and planting natives on riparian agricultural land being retired to protect water quality.

The Government has announced that a significant proportion of the one billion trees it intends to see planted over the next 10 years will be native trees (Jones, 2018b).

Health co-benefits through improved air quality

Reducing emissions of carbon dioxide (CO₂) from sources such as coal-fired power plants or diesel engines often has the co-benefit of mitigating pollutants such as particulate matter. Reductions of these pollutants globally could avoid up to 5 million deaths from air pollution each year (Shindell et al., 2012). Kevin Rolfe makes the point that mortality in New Zealand from poor air quality exceeds that from vehicular accidents by a wide margin (sub. DR187).

Benefits of climate-change adaptation

Action on adaptation around the regions will be happening at the same time as mitigation policies are causing shifts in economic activity. Te Rūnanga o Ngāi Tahu and Local Government New Zealand (LGNZ) emphasised the importance of climate-change mitigation and adaptation together (subs. 36, 83, DR248, and DR362). This reflects the reality that many marae and local communities face immediate threats from climate change, and actions taken to adapt can also mitigate emissions. For example, Te Rau Aroha Trust is siting its new horticulture venture in the eastern Bay of Plenty on land that will not be vulnerable to the effects of sea-level rise (sub. DR207).

The Department of Conservation pointed out that

[n]ative ecosystems can often provide benefits for mitigation and adaptation simultaneously. For example, wetlands and mangroves can sequester carbon, and provide natural defence against inundation and extreme weather events. Reducing loss of these ecosystems and enhancing their restoration would provide many climate change benefits as well as co-benefits for biodiversity. (sub. DR370, p. 1)

Adaptation effort will provide new opportunities for people dislodged by mitigation policy. For instance, Awatere (2018) used kaupapa Māori, bio-physical and economic assessment tools to understand and evaluate different land-use decisions in Te Tai Rawhiti. He also identifies the potential role of native planting in increasing resilience to extreme weather events.

F10.3

Actions to reduce greenhouse gas emissions have many associated benefits such as improved quality of waterways, reduced air pollution, and better adaptation to climate change. Attention to these co-benefits can help build support for the transition. For this reason, alternative approaches (such as promoting planting of native forests) will sometimes be more effective than approaches that focus only on climate-change mitigation.

Anticipating and covering off co-harms

Some mitigation initiatives can cause harm. For instance, residents may be concerned about the visual effects of and noise from wind farms. Many people prefer a more varied landscape than that offered by large-scale exotic forestry, and, as noted above, many people value a variety of benefits offered by native forestry. Harvesting forests may leave debris that clogs waterways and exacerbates the harm caused by storms. Highly erodible land is particularly vulnerable in the half-decade or so between harvest and the roots of replacement planting becoming well established. Sections 10.5 and 10.6 discuss potentially damaging effects of mitigation policies on vulnerable households, and how these effects should be addressed.

Addressing these concerns is important. Large-scale forestry and a big expansion of renewable energy generation are crucial to meeting New Zealand's mitigation targets (Chapters 3 and 13). Leaving aside potential harms, exotic forestry is the most efficient way to sequester carbon over the next thirty years. To build and maintain support, central and local governments need to effectively manage the potentially harmful effects of mitigation initiatives. The Sustainable Business Council submitted:

Investing in a just transition will help ensure that all New Zealanders and their communities are able to keep supporting the ongoing economic, social and environmental changes that will be required.

In many cases, with care, these harms can be mitigated without unduly reducing the benefits of climate-change mitigation. In other cases, a balance needs to be found between the legitimate concerns of local communities and the wider benefits of emissions reduction. In the case of land use, it is local authorities (guided by the RMA and associated national instruments) that must find a balance. In turn, the resource management decisions of local authorities are subject to oversight from the Environment Court. Chapter 13 discusses the operation of the RMA in relation to renewable energy generation and transmission. Using the RMA to manage the effects of plantation forestry is discussed below.

Managing the effects of large-scale exotic forestry – protecting landscape values

Planting large areas of exotic forests likely reduces biodiversity compared to native alternatives and can increase the risk of wildings spreading into sensitive landscapes (Karpas & Kerr, 2011). Other avoidable harms of plantation forestry include harvesting costs imposed on local communities through deteriorating infrastructure and debris and sedimentation in waterways (Salmond, 2017b; sub. DR 135). Large-scale forestry may lower water tables and reduce availability of water downstream (Otago Regional Council, sub. DR323). Increased forestry may also lead to a decline in the rural population and loss of associated infrastructure, such as schools (Federated Farmers, sub. 39; Beef + Lamb New Zealand and DINZ, sub. 98; Rangitikei District Council, sub. DR200; LGNZ, sub. DR248).

Recent storm events on the east coast and the Nelson-Takaka area have demonstrated the risks associated with accumulation of harvest debris, and planting particular species (often *pinus radiata*) on unsuitable land (Macfie, 2018; Dame Anne Salmond, sub. DR135). The Department of Conservation pointed to risks for native ecosystems (such as sedimentation in estuaries and sea grass habitats) caused by inappropriate siting of forestry (sub. DR370).

While it is not possible to avoid all the possible negative effects of large-scale exotic forestry, many can be mitigated by planting the right trees in the right place and at the right scale; and anticipating and providing for the downstream effects on, waterways, infrastructure and local communities. Ralph Sims, for instance, points to the benefits of

the integrated harvesting and chipping of forest residues at the same time as log extraction. Such an approach has already been undertaken in central New Zealand in the past and if carried out more frequently, would help to avoid the recent problems in Nelson and Tolaga Bay of the discarded forest residues being washed into rivers under high rainfall events causing greater flooding and damage to structures. (sub. DR199, p. 2)

Some land may be unsuitable for plantation forestry because it is too susceptible to erosion during planting and harvesting, or it creates an undue risk of spread of wildings, or it may have environmental and aesthetic values that planting would compromise. The National Environmental Standards for Plantation Forestry (NES-PF), administered by local authorities under the RMA, provides for the management of potential environmental harms of plantation forestry. Under the NES-PF planting on certain classes of land requires resource consent, and councils can apply conditions to protect waterways and prevent erosion during the vulnerable period after harvest (MPI, 2017e). The NES-PF came into force on 1 May 2018, so it is too early to judge how effective it will be in managing the potential harms of large-scale exotic forestry.

F10.4

Actions to mitigate climate change can sometimes have harmful effects (such as erosion of vulnerable land after forests are harvested, debris from harvests clogging waterways, or distress from the visual and noise effects of wind farms). Local and central government will need to manage these effects effectively to maintain wide support for a transition to a low-emissions economy.

Should the Resource Management Act be used to directly regulate for low-emissions land use?

Many of the co-benefits and co-harms of land use vary according to local circumstances. It is appropriate that local authorities are responsible for regulating these co-benefits and co-harms under the RMA in a way that acknowledges them. National resource planning instruments such as the NPS-PF and the National

Policy Statement for Renewable Energy Generation provide guidance to local authorities on regulating these matters.

Some submitters argued that the RMA presents an opportunity, more broadly, to influence land-use choices in a transition to a low-emissions economy (eg, ADLS, sub. 7; Te Rūnanga o Ngāi Tahu, sub. 83). The Commission, on the other hand, sees an effective emissions price as the best way to reduce emissions across the economy in a fair and efficient way (Chapter 5). A single emissions price cannot, though, reflect the varying range of co-benefits and co-harms associated with different land uses. As discussed above, additional incentives or regulation, often catchment specific, are needed to secure co-benefits and avoid co-harms. Incentives may take the form of pricing or subsidy of benefits (for instance the biodiversity benefits of native afforestation); levies to compensate for harms (such as the negative effects of harvesting forests on local infrastructure); and regulation of standards to secure benefits or avoid harms.

10.3 Increasing demand for a low-emissions economy

Social scientists are developing an understanding of the factors (in addition to emissions pricing and regulation) that can shift behaviour towards low-emissions production and consumption (eg, Creutzig et al., 2018). Shifting social norms and creating tipping points in attitudes and values is central – with changed acceptability of smoking a good example (Nyborg et al., 2016). In turn, many factors may influence norms and values and create an expectation of change. Examples include:

- the existence of policies to regulate emissions, and commitment to costly measures to implement them (such as public provision of charging stations for EVs);
- the development of visible coalitions of interest committed to reducing emissions (as described above), combined with leadership from public figures;
- the visible adherence of family members, neighbours and associates to low-emissions practices (which may also make those practices – such as diet - more convenient to adopt); and
- direct messaging with information about what others do to adopt low-emissions practices (which could be targeted on relevant peer groups).

Raising awareness of climate change mitigation opportunities

Concerns about the effects of climate change and a desire to mitigate those effects as part of global action are widespread in New Zealand. Awareness that a consensus supporting more stringent action is growing has motivated others to consider effective responses in their industries or communities. As described above, voluntary action to mitigate climate change (for instance through consumption choices, planting trees, and choosing low-emissions production methods) complements government regulation such as an emissions price.

Consistent with this, the Tauranga Carbon Reduction Group pointed to the important and influential role of many independent organisations within society and the impact of societal attitudes and media influences. It thought that “Government needs to be open to and work in conjunction with such entities and play an important role in stimulating and legitimising such actors” (sub. DR278, p.1). In a similar vein, the Sustainable Business Council stressed that,

[i]f we are to bring New Zealanders along on the journey, we need to show how low emissions living can be aspirational and inspirational. This means placing a much greater emphasis on communicating the positive action being taken across all sectors of society and recognising the role this plays in inspiring others to do the same. (sub. DR289, p. 2)

Catherine Leining submitted that:

The [draft] report could do more to highlight the challenges of individual behaviour change and shifting social norms as well as enhanced education and training to prepare the current and future workforce for rapid change. More research is needed in the social sciences and behavioural economics to help inform policies and programmes. Both central and local government can play an important role in motivating behaviour change and supporting associated research. (sub. DR279, p. 2)

Dr Geoff Scott advocated support for a series of educational initiatives led by tertiary institutions, and with a focus on promoting inventive approaches to low-emissions technology relevant to New Zealand (sub. DR154). Similarly, Kerry Shephard pointed to the role of compulsory and tertiary education in promoting a change in attitudes. He pointed in particular to the national *Environmental education for sustainability strategy and action plan*, and its recent revision in 2016/17 developed by the Ministry of Education and the Ministry for the Environment with the Department of Conservation (sub. DR213, p. 3). GNS Science pointed to its “highly successful Earth science short courses in several communities and [proposes that] a similar model could be applied to climate change (sub. DR390, p. 1).

EMANZ argued:

Critical to breaking down [information and inertia] barriers is education around technology alternatives, the true life-cycle costs of investment options, understanding the emissions implications of investment options and adopting a long term investment analysis horizon. Again, adoption of these practices will come through education and it is a serious omission from the draft that the education of businesses is excluded. (sub. DR242, p. 12)

There are many dimensions on which government and other organisations can proceed to promote demand for low-emissions goods and services and practices. Some, such as media campaigns and interventions targeted to particular audiences, can be evaluated for their impacts, and refined over time. The energy efficiency initiatives of Energy Efficiency and Conservation Authority (EECA) are examples of this sort of approach.

Others, by their nature, are more diffuse in their impact, and so difficult to evaluate, but potentially valuable. For instance, Motu’s *Low-emission future dialogue* brought together diverse interests to share views and perspectives over almost two years to February 2016. The dialogue identified many feasible pathways to a low-emissions future, and identified processes to make progress, with the intention of stimulating a broader national conversations (Motu, 2017). Those conversations are clearly part of a process that will help change attitudes and values in support of a low-emissions future.

Promoting low-emissions consumption

The previous discussion suggests that better information on the emissions embodied in goods and services could help shape consumer choices towards low-emissions options. This could be embodied in product standards and labelling (Afionis et al., 2017; Ballance Agri-nutrients, sub. DR285). Greater awareness of consumption emissions also fits well with “circular economy” approaches aimed at waste minimisation and reuse of products, materials and resources (Chapter 15). The Sustainable Living Education Trust, for instance, provides materials (some aimed at local government) to promote waste minimisation, climate awareness and low-carbon living, and other environmentally friendly choices (Sustainable Living Education Trust, 2018).

Submitters suggested a range of approaches that could build demand for a low-emissions economy. Christchurch City Council proposed product labelling (voluntary at first) that shows the emissions emitted in the manufacture and use of priority consumer products. The Council also suggested the use of emissions ratings for products, to be used alongside current energy efficiency ratings (sub. DR284). The Energy Management Association of New Zealand (EMANZ) proposed that central government should take a lead in publishing the emissions performance of its departments and facilities, with similar requirements for local authorities and other public bodies (sub. DR242).

Consumer-level information on emissions embodied in carbon choices can be supported by greater awareness of consumption-based greenhouse gas emissions at a national level. This will help consumers better identify, and take into account, broad aspects of their consumption that drive the production of global emissions. The Sustainable Business Network submitted:

The global carbon accounting system is based on a production-based approach. It is much easier to account for emissions occurring within the national boundary. However, SBN thinks that the carbon 'conversation' needs to widen to include consumption-based emissions. Consumption-based emissions ...are the carbon emissions associated with producing the goods and services which we buy (including from overseas). We need to be more aware of the emissions associated with imported goods (and increasingly services) we use, so that action programmes are enhanced to look at reducing these

consumption-based emissions. For example, a recent study by the C40 Cities Climate Leadership Group has shown that consumption-based emissions in Oceania cities are the highest of the 79 cities in the study. (sub. DR254, p. 2)

The government of the United Kingdom regularly produces “experimental” estimates of emissions embodied in goods and services consumed in the United Kingdom. While the methodology is complex, essentially it adds the emissions embodied in the imports into the United Kingdom to production-based estimates, and subtracts the emissions embodied in exports.¹²⁰ Consumption-based emissions were 1.75 times higher than production-based emissions in 2013, and have been consistently higher over the entire data series beginning in 1997. Consumption-based emissions peaked in 2007, fell back during the global financial crisis of 2007–2008, but, unlike production-based emissions, are now rising again (Committee on Climate Change, 2017b).

National contributions to GHG emissions reductions are currently based on production (and so ignore the effects of imports and exports). It is conceivable that, in the future, countries will pay more attention to consumption-based emissions, as this will highlight the role that demand in the developed world for emissions-intensive goods and services plays in driving emissions. Also, in the absence of internationally consistent emissions pricing, countries may wish to make border adjustments for imported emissions to provide a level playing field for domestic producers.

F10.5

Consumption-based emissions accounting helps identify the role that consumption of emissions-intensive goods and services play in driving global greenhouse gas emissions. Better information on consumption-based emissions will materially contribute to reducing global emissions.

R10.1

Stats NZ working with the Ministry for the Environment and the proposed Climate Change Commission should evaluate the benefits of a system of consumption-based emissions accounting that recognises emissions embodied in the import and export of goods and services.

10.4 Addressing adverse impacts on firms and regions

Even in a well-paced transition, sudden shifts in economic activity will occur. This could result in a significant employer closing in a particular location, leaving redundant workers with few employment options without moving. This section considers the options for government support that are likely to be most effective in protecting the people affected.

Direct assistance to affected firms?

Financial assistance could be provided to industries or firms facing closure or decline as the result of policy change. New Zealand has provided such financial assistance in the past, though on a small scale. During the withdrawal of agricultural protection and subsidies in the 1980s, government provided assistance to farmers to restructure their debts and exit agriculture entirely, if their farms were no longer viable (Gouin et al., 1994). Similar types of assistance could, theoretically, be provided to firms affected by policies to mitigate climate change. For example, the Commission’s modelling of mitigation pathways (Chapter 3) suggests that rising emission prices will see the continued decline of sheep and beef farming, as increasing demand for forests and the low-profit margins from meat lead more farmers to convert their land to forestry.

In practice, however, providing such assistance would be risky and raise questions of fairness. The provision of assistance could encourage lobbying for wider forms of government support, and may distract affected employers, investors and workers from adjusting to changed circumstances. The broad-based nature of the transition to a lower-emissions economy means that it may be difficult to distinguish whether a specific firm

¹²⁰ Estimates are based on an analysis of inter-country input–output tables that track inter-connected supply chains across the world (Committee on Climate Change, 2017b).

has failed due to emissions mitigation policies, as opposed to other factors. This stands in contrast to the adjustment programmes of the 1980s, where affected parties were easily identifiable, and where government action (the withdrawal of protection) was the primary cause of financial stress.

It is also worth noting that the take-up of the 'exit' grants in agriculture was much lower than anticipated, with only 1% of farmers leaving the industry (Vitalis, 2007). The overwhelming majority of farmers changed their businesses and adapted. Similar adjustments are likely to occur in the future.

The futility of trying to retain struggling firms

Australia has a long history of providing assistance to regions or areas affected by economic decline or the loss of major employers. Beer (2015, p. 23) notes that there were "135 structural adjustment programmes operating [in Australia] between 2000 and 2012", which cost over A\$88 billion in total outlays. The Australian Productivity Commission (APC) has assessed many of these interventions over time, in particular through its annual *Trade and Assistance Reviews*.

One high-level conclusion reached by the APC is that interventions which aim to retain struggling firms or help them remain viable ultimately fail. In commenting on assistance provided in response to a steel company entering administration, the APC observed that "direct support to 'struggling firms' has demonstrated little long-term success, and the manufacturers and employers eventually exit" (APC, 2017a, p. 7). Short-term or even medium-term public assistance is generally not sufficient where economic circumstances have fundamentally shifted against a firm.

F10.6

Providing financial assistance to firms facing closure or decline as the result of policy change would be risky, encourage unproductive lobbying and raise questions of fairness. Assistance is also unlikely to be successful in retaining struggling firms or helping them remain viable.

Additional assistance to communities facing large shocks

A further question is whether place-based interventions are needed for communities facing shocks. The transition to a low-emissions economy may mean the closure of large, locally important firms. Particularly for some smaller communities, the loss of a major employer may create a large shock, spilling over into other areas (eg, leading to smaller businesses closing as unemployment rises and consumer spending falls). Some stakeholders have argued that this economic change and disruption requires additional targeted support. Drawing on international work on the 'Just Transition' to a low-emission economy, the New Zealand Council of Trade Unions has argued for a range of initiatives to promote community and sector resilience and adjustment, including the initiatives noted below.

- New job opportunities in the low carbon economy and the transformation of existing jobs and industries should be promoted through public and private investment in low carbon development strategies and technologies
- Formal education, training, retraining, and life-long learning should be promoted for working people, their families, and their communities
- Organised economic and employment diversification policies should be developed for sectors and communities at risk
- Re-deployment of workers affected by transition should be promoted, including through industry-wide multi-employer pooling to match workers with new jobs
- Social protection measures, including active labour market policies, should be developed to support workers in industries undergoing change. (New Zealand Council of Trade Unions, 2017, p. 5)

The New Zealand Council of Trade Unions reiterated these points in its submission on the draft report (sub. DR321).

The Commission has made recommendations about supporting the development of new, lower-emissions technologies elsewhere in this report (Chapter 6). The potential to work with firms and industries to identify

pathways to lower-emission production is discussed above (section 10.1). This could include local and central government and their agencies coordinating provision of education and training, sharing information on investment intentions and putting in place new infrastructure. To the extent that such approaches are successful, the need to intervene when firms fail and workers are dislocated will lessen.

As noted above, the Commission also agrees that strong social protection measures, such as welfare benefits and tax credits, will play an important part in ensuring an inclusive transition (section 10.6).

Labour market and skills-based assistance is preferable, but needs to be designed well

There is some agreement around the benefits of labour market and skill-based adjustment schemes, though with some limitations. Workers with low or no qualifications are more at risk of displacement, and more likely to experience longer periods of unemployment (OECD, 2017a). The APC (2017b, p. 181) has argued that labour market assistance should be “reserved for those who would have the most difficulty becoming re-employed”, to avoid unnecessary expense or crowding out other job seekers. The APC (2017b, p. 179) has also highlighted problems where training provision “does not align with contemporary business needs or where displaced workers are encouraged to transition ‘into well-known industries and employment opportunities rather than sectors with long-term prospects’”.

Labour market assistance should be centred on the needs of *individuals*, rather than *regions*. Daley and Lancy (2011) highlight the poor outcomes and low value for money of regional job-attraction schemes, which subsidise business expansions in particular areas as a way of reducing unemployment or responding to the loss of large employers. In fact, tension is likely between the labour market needs of individuals and regions. As Beer (2015, p. 28) notes,

[p]erhaps perversely, labour market programmes can be seen to carry risks for regions. If successful, they may provide an avenue for the accelerated departure of skilled workers to other communities or cities.

As the NZPC (2017a) has noted in its earlier work on urban planning, mobility within and between regions helps to avoid labour market shortages, improves skills matches and is an important way of ameliorating the negative effects of unemployment. Looking at the experience of freezing works closures in New Zealand, Grimes and Young (2011) similarly found that, where communities facing the loss of a major employer are located close to urban areas, displaced employees are able to find work more easily. The aim should be to facilitate labour movements where improved opportunities are likely, rather than inhibit them. The New Zealand Council of Trade Unions agreed that relocation assistance should be part of a more comprehensive package of measures in a just transition plan (sub. DR321).

F10.7

Interventions that respond to the “shock” of the loss of a major employer in a region should focus on the labour market and skills needs of individuals, and should be targeted to those who will have the most difficulty gaining new employment. This may include helping people move out of the affected region to areas where employment prospects are stronger.

Current re-training provision is unhelpfully constrained by policy

The ability of individuals to acquire new skills over their lifetimes is likely to take on greater importance, not just because of the economic changes resulting from climate change but wider technological advancements, such as automation (NZPC, 2017b). However, the current education and training system is not well set up to meet the needs of people seeking mid-career retraining. The (OECD, 2017a) has commented that the training and career guidance system in New Zealand is heavily skewed towards “young people moving to the job market, while services available to guide adults in need of (re-)training are limited” (pp. 18-19).

The Commission noted in its inquiry into *New models of tertiary education* (2017b) that the barriers to mid-career retraining include:

- funding and regulatory settings that focus on younger, full-time learners completing full qualifications;

- limits on student support (ie, loans and allowances) that particularly affect people aged over 40; and
- funding rules that make recognition of prior learning difficult.

The Commission also observed weak connections between industry and tertiary education providers, and learner assessment practices by providers that limit the transfer of job-relevant skills.

F10.8

The current education and training system is not well set up to meet the needs of people seeking mid-career retraining.

10.5 Impacts of emission-reducing policies on households

Even given the natural dynamism of the economy, an ambitious policy target for emissions reduction that involves an *intentional trajectory* likely to result in a significant social and economic transformation will be challenging for current and future governments (Patterson et al., 2018).

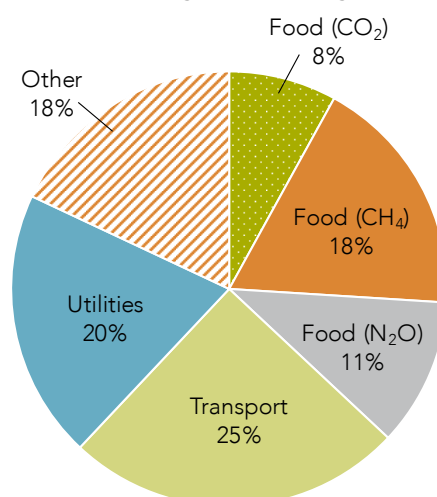
The Parliamentary Commissioner for the Environment argues that understanding the distributional consequences of setting emission reduction targets is likely to improve the durability of any system of carbon budgets (PCE, 2018). Also, as found internationally, perceptions of fairness can influence citizens' acceptance of any burdens associated with climate-change policies (Adger et al., 2016; B. Anderson et al., 2017; Klinsky et al., 2012).

This section considers the impacts of emission-reducing policies on households in New Zealand. A large number of submitters agreed that effective measures are needed to address the impact of emissions-reduction policies on low-income households (eg, Toyota New Zealand, sub. DR177; Eroad Ltd, sub. DR182; LGNZ, sub. DR248; Meridian Energy, sub. DR253; Sustainable Business Network, sub. DR254; Hill Young Cooper, sub. DR272; Wellington City Council, sub. DR276; Vector, sub. DR287; Sustainable Business Council, sub. DR289; Whakatane District Council, sub. DR317; and Motor Industry Association, sub. DR342).

Food, energy and transport make up the bulk of household emissions

According to Allan et al. (2015), food, transport and energy (utilities) made up around 82% of the average New Zealand household's emissions in 2012/13 (Figure 10-1).

Figure 10-1 Average New Zealand household greenhouse gas emissions by source, 2012/13



Source: Allan et al. (2015).

Some of these emissions are not currently captured in the New Zealand Emissions Trading Scheme (NZ ETS) or reflected in consumer prices. For example, as biological emissions from agriculture sit outside the ETS, the methane (CH₄) and nitrous oxide (N₂O) emissions from food production (eg, livestock) are not subject to an emissions price. However, the carbon dioxide (CO₂) emissions that result from the processing of food – eg, drying of milk – are within the ETS, and therefore already feed into consumer prices.

Household emissions do not rise proportionally with growing incomes

Allan et al. (2015) investigated the relationship in New Zealand between household characteristics and GHG emissions from consumption. They found that:

- emissions rise less than proportionately with income, as wealthier households devote a larger fraction of their income to relatively less emissions-intensive services;
- emissions tend to rise with age, possibly reflecting a greater need for heating or greater disposable income;
- household emissions are higher in the South Island (due to colder temperatures and associated heating requirements) and Auckland (due to traffic congestion and a higher share of migrants, who may fly more often);
- homeowners emit more, perhaps reflecting greater wealth and a greater propensity for international travel; and
- expenditure elasticities vary widely between different types of consumption: emissions from household energy do not change much as household expenditure increases, but transport emissions (particularly from air travel) grow in response to rising household expenditure.

For the lowest-expenditure decile of New Zealand households, food and utilities accounted for 70% of emissions. In the highest-expenditure decile households, these items made up just over 50% of emissions (Allan et al., 2015).

Pricing emissions can be regressive as lower-income households spend a greater proportion of their income on food and household energy

As discussed in Chapter 5, a price can be placed on GHG emissions through a variety of mechanisms, particularly taxes or trading schemes. Literature indicates that both taxes and trading schemes can have regressive impacts.

Shammin and Bullard (2009, p. 2432) conclude that in the United States, consistent with other studies, “a traditional cap-and-trade policy is regressive and would cause the cost of reducing GHG emissions to fall disproportionately on low income households”. In a comprehensive analysis of studies that investigate the distributional impacts of carbon taxes on households, Q. Wang et al. (2016) found that emissions pricing is regressive in developed countries such as the United States, the United Kingdom, Denmark, the Netherlands, Ireland, France, China, Cyprus, Sweden, Taiwan and Singapore. However, when domestic energy for cooking and heating is distinguished from transport fuels, they found that, while taxing domestic energy use is regressive in many countries, taxing transport fuels places a higher burden on middle-expenditure deciles.

In New Zealand, households in the lowest income quintile devote a higher share of their income to food, transport and household energy than other households (Figure 10-2). Expenditure share in household energy is the reason for most of these differences (Figure 10-3).

Figure 10-2 Percentage of expenditure devoted to food, transport and household energy, by household type



Source: Productivity Commission analysis of data from Stats NZ household living-cost price index (HLPI).

Figure 10-3 Percentage of expenditure devoted to household energy, by household type



Source: Productivity Commission analysis of data from Stats NZ HLPI.

In comparison, the highest income quintiles spent more in absolute and relative terms on transport. This aligns with the studies discussed above and the findings of Creedy and Sleeman (2006) on the effects on consumer prices of imposing a \$25 for each tonne of CO₂ carbon tax in New Zealand. Creedy and Sleeman found that although low-expenditure households spent

a proportionately greater amount of their income on carbon intensive commodities such as petrol and domestic fuel and power...the distributional effect of the carbon tax was not unambiguous, in view of the substantial price increases for several commodity groups on which households with relatively higher total expenditure spend proportionately more. (2006, p. 344)

Other studies analysed by Q. Wang et al. (2016) have focused on the impact of emission prices on urban and rural households and between households from different regions. Rural and suburban households have higher carbon tax burdens or welfare losses compared to urban households in Ireland, China and the United Kingdom, France, Indonesia, the Philippines and Thailand. No significant differences were found between households living in rural and urban areas in Denmark and Canada. In Cyprus and Malaysia urban households were more affected than rural households. Carbon tax incidence across regions in the United States are modest, but the impacts across regions in China and Canada are significant.

Analyses based on lifetime, rather than yearly, incomes or consumption tend to find less regressive impacts, reflecting the fact that people's incomes and spending patterns change over time.

F10.9

A large number of studies have analysed the impact of emissions pricing policies – such as cap-and-trade or carbon taxes – in developed countries. While the results vary depending on the sources of emissions and the characteristics of household expenditure, emissions-pricing policies are commonly found to be regressive in their impact.

F10.10

In New Zealand, low-income households spend a greater proportion of their income on food, transport energy and household energy. This suggests that emissions pricing may impact more heavily on low-expenditure households. But emissions pricing also leads to price increases for commodities on which households with higher expenditure spend proportionally more.

Lower-income families may be unable to substitute to lower-emitting consumption

Households have different abilities to respond to higher emissions prices and change their consumption behaviour. Low income and socio-economic status often go hand in hand with older, poorly insulated housing, housing that is further away from jobs (often with a lack of access to public transport), and the associated use of older and less fuel-efficient cars. Reducing emissions requires things like investment in insulation and more fuel-efficient transport and household heating. If some households are unable to make these investments, they must bear the burden of higher prices. They can become “locked in” to their emissions (Feng et al., 2010; Meade, 2017). In New Zealand, a significant share of affected households will be Māori – a point emphasised by Te Rūnanga o Ngāi Tahu and the CCILG.

Low-income households, which are disproportionately Māori, should be top of mind when considering where costs fall, and also where investment may provide significant co-benefits, for example in terms of better employment and health outcomes. (Te Rūnanga o Ngāi Tahu, sub. 83, p. 12)

Māori households are much more vulnerable to downstream costs created by any ETS. They are less likely to be able to absorb these costs and are unable to easily invest in alternatives to reduce their own costs to offset the ETS. We see the cost of energy increase as the transport and energy sectors will need to adjust their pricing models to pass on costs. Affordability of any policy shift will of course be significant for Iwi Māori. (CCILG, 2016b, p. 10)

F10.11

Lower-income households are less able to make investments that enable them to reduce the emissions intensity of their consumption.

The possible scale of impacts on consumer prices

As discussed in Chapter 3, many possible pathways lead to a low-emissions economy. The pace of change and the degree to which emissions prices rise depend on the speed of expected and actual technological change, whether existing industries are significantly disrupted, and on the level of emissions reduction being pursued (ie, whether the target is ‘net zero’ or a low level of emissions by 2050).

Where the expectations of technological change are high, existing industries are disrupted by technology, and the government pursues a less stringent emissions goal (ie, 25 megatonnes of GHG emissions by 2050), the pace and range of emissions prices increases will be comparatively slow and low, meaning that the direct flow-on impacts to food, energy and transport costs will be muted. Food price impacts may also be moderated to the extent that they are influenced by international commodity prices and the extent to which free allowances continue to be available to domestic agricultural producers.

If a net zero emissions target is preferred and existing industry structures largely survive, government policy – and especially emissions pricing – will play a much more significant role in driving the transition. For example, under the Commission’s “stabilising-decarbonisation, net zero” scenario, emissions prices rise from around NZ\$20/tCO_{2e} now, to possibly up to NZ\$250 by 2050. This would see a large impact on

consumer prices. Previous modelling and empirical studies have estimated the possible impact of emissions prices on fuel and electricity prices.

- Infometrics (2017) estimated that a NZ\$100 a tonne emissions price would raise retail petrol prices by 28 cents a litre.
- Stevenson et al. (2018) investigated the impact of rising emissions prices on the electricity market, and found that, based on current technologies including the use of gas peakers, average annual wholesale electricity prices rose from around NZ\$80 a megawatt hour (MWh) at a NZ\$20 a tonne emission price to just over \$100/MWh at a NZ\$80 a tonne emissions price.

10.6 An inclusive transition – households

One key way to counter the regressive impacts of emissions pricing and other climate change policies is to provide financial assistance to affected individuals and households (eg, through transfer payments or the tax system). Assistance can be delivered in various ways, with different impacts.

Focus on those who have a limited ability to substitute or who face large shocks

Higher emissions prices will affect a wide cross-section of the community, as they flow through to consumer and producer prices, business revenues and returns on capital. However, for the purposes of providing public assistance, the focus should be on those individuals or households with little ability to substitute to lower-emitting activities or those facing significant shocks as a result of rising emission prices. Everything considered, these people will mostly be in lower-income households.

What types of assistance are available for households?

Nolan (2007) notes four main mechanisms are available through which family incomes can be lifted. Each mechanism has its advantages and disadvantages (Table 10.1).

Table 10.1 General advantages and disadvantages of income assistance programmes

Minimum wage	Personal income tax schedule	Family & employment tax credits	Main welfare benefits
<ul style="list-style-type: none"> - Supports concepts of fairness of reward and socially acceptable incomes. - Reduces demand for low-wage labour. - Has low (static) fiscal cost to government, but increases costs faced by businesses. - Is effective at lifting incomes reduced by poverty traps. 	<ul style="list-style-type: none"> - Is simple. - Is broadly received. - Is fiscally costly (rate changes more costly than threshold changes and has minimal effect in reducing poverty). - Reduces (although often small) poverty traps. 	<ul style="list-style-type: none"> - Have a complex design. - Can target assistance on basic criteria (eg, joint taxable income, numbers and ages of children). - Are a cost-effective way to provide moderate levels of assistance to many households. - Are seen as rewarding work effort, but creates poverty traps. 	<ul style="list-style-type: none"> - Have a complex design. - Can target assistance narrowly. - Are a cost-effective way to provide a lot of assistance to relatively few households. - Can respond to fluctuations in need or family circumstances. - Create poverty traps.

Source: Nolan (2007).

Given the Commission's preferred focus on those with limited ability to substitute or those facing large shocks, neither the minimum wage nor changes to the personal income tax schedule are recommended. As noted above, income tax changes are fiscally expensive, poorly targeted and not very effective at easing

poverty. The international literature that examines tax-based compensation only for carbon or emissions pricing similarly finds that the effects of such compensation can be regressive, as higher-income households receive a significant share of the compensation (Mathur & Morris, 2014; Rausch et al., 2011).

Minimum wage increases will not be the most targeted or effective way of reaching low-income households. Although minimum-wage workers in New Zealand

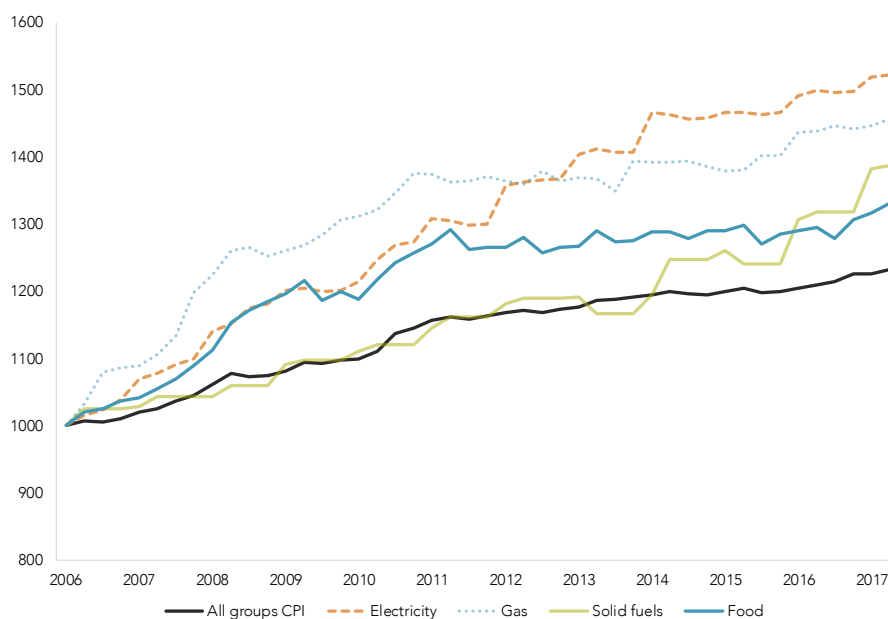
are more likely to live in the poorest households, they are relatively widely dispersed throughout the income distribution. This is particularly true of teenage minimum wage workers. Furthermore, low-income households often do not contain any working members. (Maloney & Pacheco, 2012, p. 648)

Reflecting this wide dispersion, Maloney and Pacheco (2012, p. 648) estimated in 2012 that a 10% increase in the minimum wage, “even without a loss in employment or hours of work, would lower the relative poverty rate by less than one-tenth of a percentage point”. Nolan (2007, p. 23) also notes that an increase in the minimum wage “may translate in little extra take home pay as wage increases reduce the income assistance that people on low and middle incomes may be entitled to”.¹²¹ Minimum wage adjustments also do not provide any assistance to people out of work.

This suggests some combination of targeted tax credits and adjustments to benefits would be the best targeted and lowest-cost option for meeting the income needs of affected households. Combining the two would ensure that both employed and unemployed households are covered. The existing suite of welfare benefits and tax credits appears to cover off most, if not all, households likely to be especially affected by an increase to their cost of living due to an increase in emissions prices.

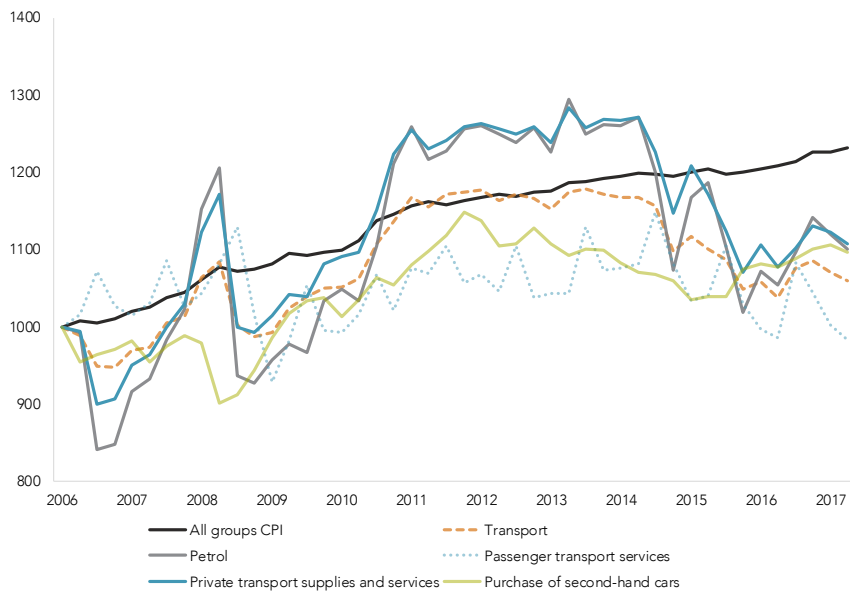
Benefits are automatically adjusted each year to reflect changes in the Consumer Price Index (CPI). Electricity, gas and food prices have risen faster than the general CPI in recent years (Figure 10-4), but most transport-related costs have tracked close to, or below, the general CPI.

Figure 10-4 Changes in the CPI and selected household energy and food prices, 2006–2017



Source: Productivity Commission analysis of Stats NZ data.

¹²¹ This withdrawal of other assistance in response to higher wages is known as the “poverty trap”.

Figure 10-5 Changes in the CPI and selected transport prices, 2006–2017

Source: Productivity Commission analysis of Stats NZ data.

Adjustments based on the main CPI may misrepresent the impact of price changes on lower-income households, who consume a different “basket” of goods and services (as can be seen in Figure 10-2 and Figure 10-3). Stats NZ produces a regular household living-cost price index (HLPI), which measures the impact of price changes on different household types (eg, by their income or expenditure levels or beneficiary status). The December 2017 HLPI results showed that the annual cost of living had risen faster for the lowest-spending households than the highest (Stats NZ, 2018d).

Yet much of this increase was due to rises in the cost of items not directly affected by policy to mitigate climate change, especially rents. Over a longer period, food and energy prices across the different household groups broadly track each other (Figure 10-6 and Figure 10-7). Transport prices are slightly more variable, but this volatility is more significant for higher-income households (Figure 10-8).

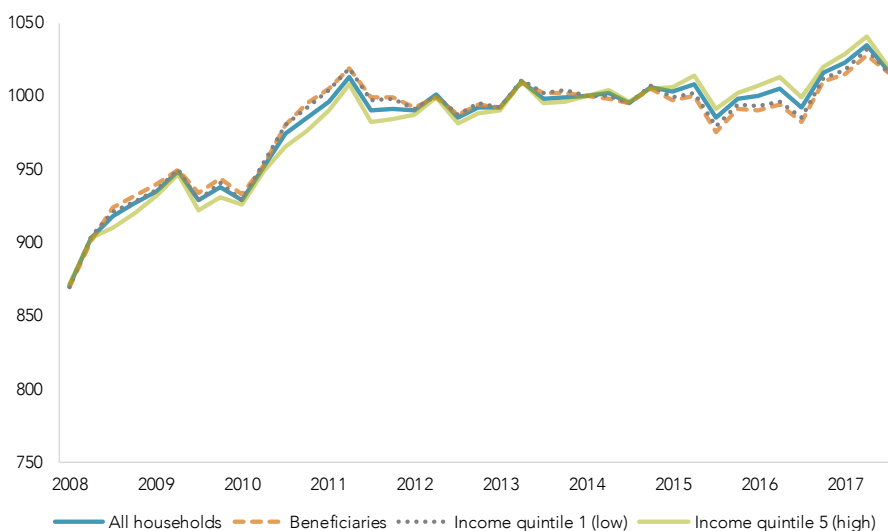
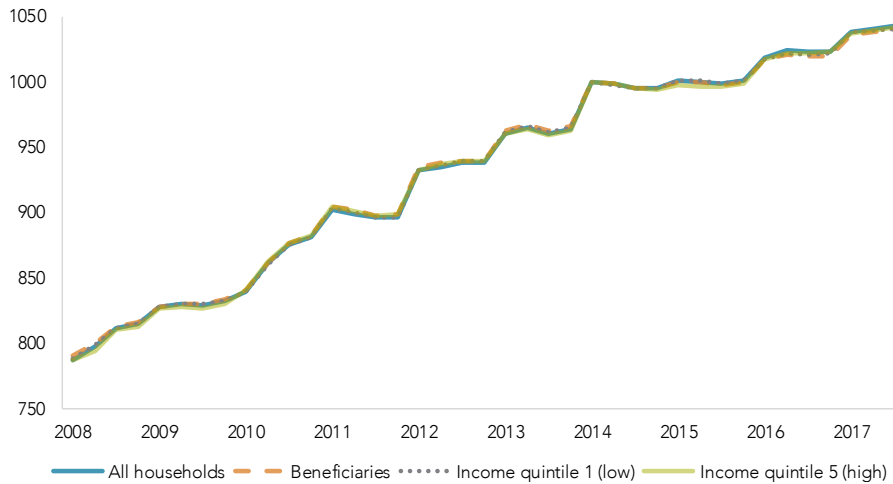
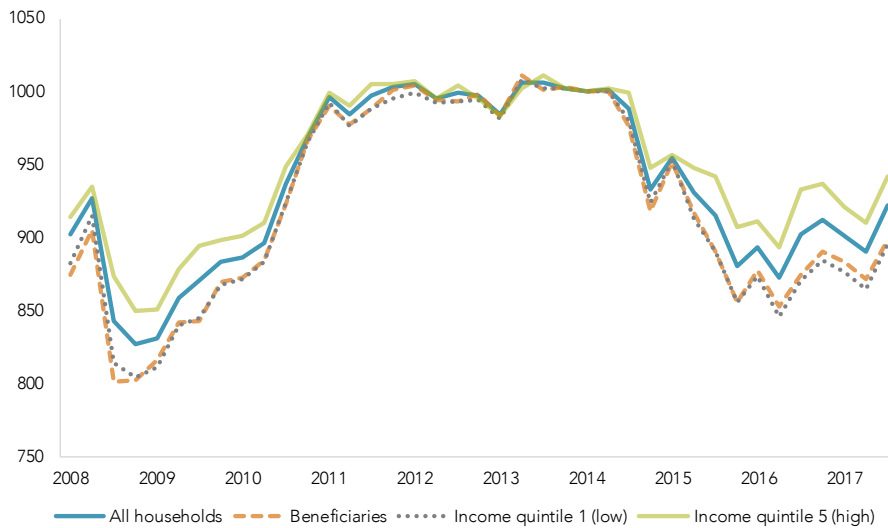
Figure 10-6 Food price index by selected household type, 2008–2017

Figure 10-7 Household energy price index by selected household type, 2008–2017**Figure 10-8 Transport price index by selected household type, 2008–2017**

Source: Productivity Commission analysis of Stats NZ data.

In practice, therefore, for the purposes of compensating lower-income households for *emissions-reducing* policies, adjustments based on CPI appear adequate.

Working for Families and other tax credits are not automatically adjusted for changes in the cost of living, although they have been periodically updated by governments through the annual budget process.¹²² The most recent adjustment was in December 2017, with increases to per-child payments and abatement thresholds and the reinstatement of a credit for 'independent earners' (individuals in employment on low to moderate incomes, without dependents). Such adjustments come at a significant fiscal cost,¹²³ but will be important for ensuring that tax credit-based assistance adequately offsets the financial impact of emission reductions for lower-income households.

F10.12

The existing suite of benefits and tax credits should be adequate for offsetting direct impacts of emissions-reducing policies on the cost of living for lower-income households, provided tax credits are regularly adjusted for inflation.

¹²² NZ Superannuation is often adjusted annually by more than the CPI (in particular when average weekly earnings rise faster than the CPI).

¹²³ The most recent (December 2017) adjustment to Working for Families cost an estimated \$2.003 billion over five years.

Assisting households to substitute away from high-emissions consumption

Housing

Income-based assistance delivered through benefits, tax credits or both may not be sufficient to allow lower-income households to make the sorts of investments in energy efficiency needed to offset the impact of rising energy or transport costs. The high one-off costs of, for example, installing better heating or household insulation may be beyond the means of these families. This may be a particular issue in rental accommodation, where landlords do not pay the electricity bills and so may have weak incentives to invest in insulation or more efficient appliances such as heaters (Barton, 2012). US and Australian research indicates that tenants are much less likely to use or own more efficient appliances (Australian Bureau of Statistics, cited in APC, 2005; L. W. Davis, 2011; Gillingham et al., 2012).

The Government currently provides insulation subsidies targeted towards landlords and lower-income households, reflecting the significant health benefits associated with warmer and drier housing (Grimes et al., 2012a). Changes to rental standards will require ceiling and underfloor insulation (where feasible) from 2019 and may increase landlord efforts to improve the quality of their housing. Stronger incentives may be necessary to encourage behaviour change by landlords, if the current rental standards regulation proves inadequate.

One risk with such investments is that they may encourage greater energy use, leading to an increase in emissions – the so-called “Jevons paradox”. This effect is named after 19th century economist William Stanley Jevons, who observed that technological efficiency improvements which enabled more economical use of resources actually increased their overall consumption.

It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth...[every] improvement of the engine, when effected, does but accelerate anew the consumption of coal. (Jevons, 1865, cited in Alcott, 2005, p. 12)

In theory, therefore, better-insulated and more efficiently heated homes could lead to greater energy use and higher emissions. However, empirical research suggests this risk may not be significant. An evaluation of the Government’s earlier home insulation scheme (which was available to all households) found “[e]lectricity savings and total metered energy savings...for houses that had insulation retrofitted” (Grimes et al., 2011).

Our preferred estimate (based on a cleaned dataset) finds that 0.96% of average annual household electricity use is saved as a result of having insulation retrofitted, while 0.66% of average annual total metered energy is saved. Some other estimates (based on broader samples) show greater savings, with up to 1.41% electricity savings and 1.03% total metered energy savings. (Grimes et al., 2011, p. 8)

F10.13

Public interventions to promote investments such as home insulation have a number of benefits, especially for individual and household health.

Transport

Given the prominent place of transport in household emissions and living costs, a second area where additional targeted support could be considered is assistance for low-income households to replace an emissions-intensive vehicle. New Zealand has one of the highest rates of car ownership in the developed world, reflecting the important role that private vehicles play in enabling people to be mobile.

Chapter 12 discusses opportunities to reduce emissions in the transport sector, and makes recommendations to increase the uptake of lower-emissions vehicles, including:

- feebates (rewarding low-emission practices through rebates and penalising high-emission practices through fees);
- other support for the development of underpinning infrastructure (eg, charging stations for EVs); and
- emissions standards for fossil-fuel vehicles entering New Zealand.

The uptake of lower-emissions vehicles across the population should have some benefits for lower-income households, such as reduced exposure to noise and air pollution and less associated health damage. This will especially be so for those who live close to major roads and highways, where noise and air pollution may be concentrated and land (and housing) is often cheaper (reflecting the lower amenity value). Yet the benefits from lower pollution may not accrue entirely, or even largely, to lower-income households. If lower-income households living near roads and highways are renting, some of the benefits will be capitalised into land values and therefore captured by landlords.

However, shifting from fossil-fuel vehicles to low-emission vehicles is likely to be challenging for some lower-income households, at least in the short term. Currently, the price premium for EVs over fossil-fuel vehicles is significant, effectively putting them beyond the reach of these households. In general, low-income households tend to purchase older, less fuel-efficient vehicles.

The introduction of feebates and emissions standards may therefore have some negative impacts on low-income households. A feebate will raise the cost of high-emitting vehicles entering the fleet, while standards will likely increase the cost of these vehicles to some degree, as the efficiency of the overall fleet improves (more fuel-efficient vehicles are broadly more expensive). While these policies will not directly affect vehicles in the second-hand market (where most households purchase vehicles), the existence of these policies would likely have an indirect effect¹²⁴ on the resale price of vehicles already in the fleet. Feebates also tend to penalise larger vehicles, such as vans, which has equity implications for families who require a larger vehicle. On the other hand, feebates would make higher-efficiency vehicles (eg, hybrids) more affordable, while the impact of standards on fuel efficiency would likely deliver fuel savings for many households.¹²⁵

Chapter 12 also envisages a more “mode neutral” government planning and funding system for land transport, implying greater support for and access to public transport. Some submitters supported more assistance for affordable public transport (eg, OraTaiao: New Zealand Climate & Health Council, sub. DR378). Such assistance may ease constraints for some low-income households, although it is unlikely to meet all such households’ needs. For example, comparatively high concentrations of lower-income households are located in Northland and East Cape; yet population densities are low, making it hard to create or maintain viable public transport links.

In the longer term, the shift towards lower-emission vehicles will likely deliver significant welfare gains for low-income households through lower transport costs (Chapter 4). Already, the cost of fuelling and maintaining an EV is much cheaper than a conventional vehicle, while the upfront cost of an EV is falling steadily. Bloomberg New Energy Finance expects that the upfront cost of an EV will hit parity with a fossil-fuel vehicle during the 2020s (Chapter 12). The (uncertain) pace at which the cost of an EV will reduce will heavily influence the scale of shorter-term impacts on low-income households caused by mitigation policies.

To limit the shorter-term costs of transport policies felt by low-income households, compensatory policies may be appropriate. Yet, designing compensatory policies for transport is a good example of the challenges created by uncertainty. Rapid technological and consumer change may lead to a fast and reasonably smooth adjustment. For example, greater uptake of low-emission vehicles may see faster ‘filtering’ of the existing fleet of EVs and hybrid vehicles into the second-hand market, reducing their price premium over fossil fuel vehicles. In this case, the need for government intervention to assist low-income households may be minimal in the longer term.

However, rapid change may also complicate the process of adjustment. If the global transition away from fossil fuels proceeds quickly, and therefore demand for petrol declines, then this could lead to falls in the price of petrol. Such an outcome would, in turn, make continuing to run fossil-fuel vehicles affordable and could discourage switching to low-emissions vehicles.

Given these uncertainties, the Government should continue to monitor the uptake of low-emission vehicles by different household types and any impacts on the mobility of lower-income households. Where significant

¹²⁴ For instance, if large high-emitting vehicles become more expensive to import (ie, because of a feebate scheme), then the demand for large, high-emitting used vehicles already in the fleet will increase. This will raise the price of these vehicles.

¹²⁵ Chapter 12 found that manufacturers choose to provide less-efficient model variants into the New Zealand vehicle market rather than into markets where standards apply.

and negative impacts on mobility are identified, the Government could intervene through targeted subsidies to affected households or additional investments in public transport. Chapter 12 identifies two policy options – incentives for scrapping older high-emitting vehicles and higher EV rebates for low-income households – and recommends that the Ministry of Transport further considers the merits of these policies.

F10.14

The shift to low or zero-emissions vehicles may be difficult for some low-income households, given the current high price premia for electric vehicles and hybrid vehicles over fossil-fuel vehicles. Compensatory policies may be appropriate to assist these households in the short term. Yet, depending on the rate of change in technology and consumer demand, the price premium may fall rapidly, minimising the need for government intervention in the longer term.

10.7 Conclusion

Like previous economic transformations, the shift to a low-emissions economy will create both opportunities and risks. Even in normal times, some existing firms and jobs regularly disappear, while new business and occupations emerge. In a broader transition, impacts on particular regions and industries are likely to be larger and possibly more abrupt at times. Risks can be minimised and opportunities maximised if government and private investments in innovation, skills and infrastructure are well coordinated and responsive to emerging opportunities. Alertness to and flexibility to take opportunities on offer is inherent to a well-functioning and high-productivity economy

Attending to co-benefits and co-harms of reducing emissions will maintain wide support for the transition and encourage the changes in attitudes and values that will complement other initiatives such as pricing and regulation of emissions. The position of vulnerable workers will be protected if they are able to easily acquire new skills and move between jobs.

Some of the emissions-reducing policies discussed elsewhere in this report may increase the cost of some essential household goods and services, such as food, transport and energy. These items make up a larger share of expenditure for people on lower incomes. So these individuals could disproportionately feel the burden of adjustment. Yet a well-designed and properly functioning social safety network should be able to assist with this adjustment. The transition for vulnerable households can be eased by existing policies, such as the benefit and tax credit system. Other existing policies, such as targeted subsidies for household insulation and regulatory interventions to raise the quality of rental housing, may also assist such households to substitute away from higher-emitting forms of consumption (as well as creating other benefits, such as better health).

Where the impacts from climate change mitigation policies create significant 'shocks' to communities – eg, through the loss of a major employer – these interventions should focus on the skills and labour market needs of the affected individuals. This focus will require some retooling of the current education and training system, to better meet the needs of people seeking retraining.

Part Four:

Emission sources and opportunities

Part Four looks across the New Zealand economy at the specific emitting sources including land use, transport, electricity, heat and industrial processes, waste and the built environment. It identifies the opportunities and challenges for reducing emissions from these sources and recommends a range of complementary regulation and policies for achieving emission reductions.

11 Land Use

Key points

- Land use will need to change substantially if New Zealand is to transition to a low-emissions economy by 2050. In particular, land planted in forests will need to increase by between 1.3 million and 2.8 million hectares, mostly converted from marginally profitable beef and sheep land. Rapid growth in horticulture (from a relatively small base) could also play a significant role in reducing agricultural emissions. The needed rate of change is comparable to the rate at which beef and sheep farming converted to forestry, dairying and other uses, over the last 30 years. Yet the transition requires a sustained rate of forestry far higher than in the past.
- Horticulture is already (without an emissions price) more profitable than dairying on some land types and locations. Yet barriers to land change exist. The need for investments in upstream supply capacity, new on-farm productive capacity, and downstream processing, distribution and marketing capacity; and time taken to acquire skills and knowledge, may delay changes in land use. Policy uncertainty is also a cause of delay.
- Agricultural emissions have risen over recent decades because output has risen much faster than the emissions intensity of output has fallen. Scope exists for further modest reductions in emissions intensity, using a combination of higher productivity and wider adoption of current low-emissions practices (such as stand-off pads and selective breeding). Research into new technologies has an uncertain potential to further reduce agricultural emissions in the medium to long term. Yet the potential payoff to successful research justifies scaling up current efforts.
- Agricultural emissions (including those from horticulture and cropping) should be fully covered by emissions pricing. The Commission recommends that biogenic methane emissions should be treated separately to long-lived gases such as biogenic nitrous oxide (N₂O) emissions (Chapter 9). N₂O emissions, at least, should be covered by the New Zealand Emissions Trading Scheme (NZ ETS).
- For emissions covered by the NZ ETS, agriculture, like other emissions-intensive trade-exposed sectors, should receive free allocation of New Zealand Units (NZUs). An emissions price will incentivise farmers to use management practices and current and emerging technologies to reduce emissions. Incentives will be stronger if the point of obligation is at the farm level. The Commission recommends a mix of farm-level and processor-level point of obligation to surrender NZUs.
- While, on paper, ample land is available for accelerated afforestation, the economics are less clear. The current price of NZUs in the NZ ETS should encourage more afforestation, but suitable land is likely to become more expensive over time to plant (as lower cost options are used up). More certainty around the NZ ETS and a more predictable emissions price path will help. In the meantime, the Government is, through its one billion tree programme, taking a more active approach than in the past to afforestation. Planting should include native forests, especially on more remote and less valuable land.
- Māori own and control a significant and growing proportion of land in New Zealand. Legislation recognises and protects their ancestral relationship to land, which encourages a multigenerational approach to how it is developed. The resources and experience that come with Treaty settlements have strengthened land-use governance arrangements. Yet barriers remain, particularly as a result of multiple ownership and land tenure limiting access to investment capital.

This chapter investigates:

- the role of land-use change, particularly afforestation at scale, in New Zealand’s transition to a low-emissions economy;
- barriers to changing land use;
- opportunities to reduce emissions within the agricultural sector, and the practices and technologies that will reduce emissions;
- the role of emissions pricing in encouraging adoption of low-emissions practices and technologies; and a shift to lower-emissions land uses;
- the potential to sequester carbon through forestry (and through other carbon sinks) and the role of emissions pricing in encouraging afforestation; and
- the potential contribution of Māori landowners to a low-emissions transition.

Box 11.1 explains the land-use categories and terms used in this chapter.

Box 11.1 **Land-use categories and terms used in this chapter**

The New Zealand Greenhouse Gas Inventory classifies agriculture as a major sector for reporting emissions. This includes emissions from pastoral farming – the farming of livestock; and from horticulture (growing fruit, vegetables and flowers) and cropping (arable farming). This chapter uses the term “agriculture” to include pastoral farming, horticulture and arable farming. “Pastoral farming” refers to livestock farming, mainly dairy, beef and sheep farming.

The GHG Inventory classifies forestry as one of a number of land use categories (which also include, for instance, cropland, grassland and wetlands). In this chapter, “forests” primarily refers to planted forests, whether exotic or native. Forests may be planted for harvest, or be permanent.

A substantial part (29%) of New Zealand’s land area is covered by naturally established permanent native forests. These forests are generally protected from deforestation and so do not feature in greenhouse gas (GHG) emissions accounting. Nor are these forests, unless deforested, included in the New Zealand Emissions Trading Scheme (NZ ETS).

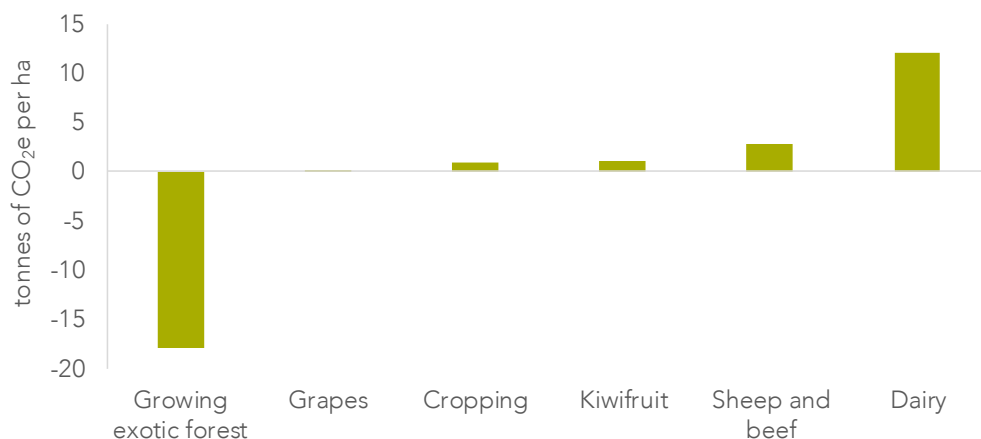
Carbon sequestered in naturally establishing exotic trees (sometimes classified as “wildings”) does not count towards meeting New Zealand’s international emissions reductions targets.

Source: MFE (2017f).

11.1 A low-emissions transition requires land-use change

Biological emissions from agriculture make up nearly half of all New Zealand’s GHG emissions – far more than any other industry. Forestry, on the other hand, currently offsets just below 30% of gross emissions. This makes land use and land-use change a central part of New Zealand transitioning to a low-emissions economy.

The way land is used has a big impact on emissions. For instance, agriculture, especially dairying, is typically much more emissions intensive per hectare than horticulture and cropping (Figure 11-1). As a result, moving to a very low-emissions economy will require both adopting practices and technologies that reduce emissions from agriculture; and some shift from agriculture to lower-emissions land uses.

Figure 11-1 Indicative yearly biological emissions per hectare from different land uses

Source: Clothier et al. (2017); Reisinger et al. (2017); Tate et al. (1997).

Notes:

1. Emissions vary considerably within particular land-use types. The estimate of emissions from sheep and beef farming are an average of Reisinger et al.'s (2017) estimate for North Island and South Island farms. Clothier et al. (2017) estimate average horticultural and arable emissions based on the calculation protocols of the Intergovernmental Panel on Climate Change. The Ministry of Agriculture and Forestry estimated GHG removals from forests as the overall average carbon sequestration rate for exotic forests during a rapid growth phase.
2. The data cover only emissions from biogenic sources. Adding emissions from fossil fuel use would have only a small impact on the relative emissions intensity across land uses. The data does not include differences in carbon sequestered in soils.

Chapter 3 reports the results of modelling of pathways to net zero or very low net emissions by 2050. All the scenarios require a substantial shift in land use. For instance, between 1.3 million hectares and 2.8 million hectares of new forest will need to be planted; land devoted to sheep and beef farming will fall by similar amounts; and horticultural land could double or even triple in area. At the same time, improved farming practices and technology will reduce emissions from animals, fertiliser, urine and dung.

Accelerated afforestation would buy New Zealand time to put in place economically and technologically more difficult options to lower emissions (both in land use and in other parts of the economy). The knowledge, technologies and resources for afforestation already exist. Yet, the time offered by afforestation to find new technologies may be no more than several decades (David Evison and Euan Mason, sub. 27; Scion, sub. 67). At some point beyond 2050, carbon sequestration through afforestation will reach a limit as economically viable land for new forests is used up (RSNZ, 2016; Vivid Economics, 2017a).¹²⁶ A great many submitters supported land-use change as a main route to a low-emissions economy (Box 11.2).

Box 11.2 Submissions on land-use change and a transition to a low-emissions economy

A great many participants saw changing land use as a key to meeting New Zealand's climate change mitigation targets, particularly by increasing afforestation and decreasing areas for agriculture.

The transition to a low-emissions economy will take decades. In order to achieve net emissions reductions, increased carbon sequestration through afforestation is essential in the short to medium term. A clear policy in relation to the contribution forestry will make in terms of this transition is crucial and required as a matter of extreme urgency. (Oji Fibre Solutions, sub. 71, p. 2)

Land use change is essential [for meeting New Zealand's Paris commitments] in the absence of wholesale change in the use of fossil fuels or farming practices. (The Forestry Leadership Group – Climate Change, sub. 1, p. 1)

Land-use change is of fundamental importance if the land sector is to be part of New Zealand moving towards a low-emissions economy. (Andy Reisinger, sub. 28, p. 2)

¹²⁶ The Sustainable Energy Forum (sub. DR251) points out that, to the extent that harvested wood products sequester carbon for long periods of time, plantation forests can sequester additional carbon over time, even if not expanding.

... a barrier [to reducing emissions] in recent times has been economic strategies which depend on growing the volume of primary production and lead to neglect of environmental harms and limits. Better opportunities for New Zealand in an emissions-constrained future lie in diversification of land use and food production, and a focus on environmental excellence. (The Morgan Foundation, sub. 127, p. 2)

Without a significant reduction in national livestock numbers, particularly cattle, any measures intending to reduce agricultural GHG emissions are likely to have very limited effect. Therefore incentives and/or penalties must be implemented to encourage diversification into low GHG-emitting land-use including horticulture and/or forestry. The current decline in forestry must be reversed. While mature forests are effectively carbon-neutral, a major programme of planting over the next, crucial decades will enable NZ to sequester a considerable amount of carbon. Once again, this cannot simply be left to the invisible hand of the market. (Graham Townsend, sub. 105, p. 1)

... given the widely acknowledged limitations of existing technology and approaches for reducing livestock emissions, it is clear that diversification of land use represents a primary opportunity, and that heavy reliance on the dominant industry model is a major barrier. In other words, pursuing growth potential in companion or alternative land use activity must be given high priority for a low-emissions economy pathway. (Te Rūnanga o Ngāi Tahu, sub. 83, p. 8)

F11.1

Land use will need to change substantially if New Zealand is to transition to a low-emissions economy by 2050. In particular, the transition will require a large and sustained increase in afforestation.

Are the required rates of land-use change feasible?

The transition pathways in Chapter 3 require substantial changes in land use. Forest land will need to increase by up to 2.8 million hectares, with a corresponding shift out of beef and sheep farming. A smaller area of land (up to 1 million hectares) may also need to shift to horticulture (including cropping). Some of the shift to horticulture will be from dairy farming. For most pathways, the shift out of pastoral farming is substantially less than the fall of roughly 3 million hectares between 1990 and 2015 (Chapter 4). Yet a large proportion of this fall was a shift to non-farming uses and a significant proportion was the transfer of very low intensity high-country leasehold land into the conservation estate.

The transition pathways will require an average of between 44 000 and 90 000 hectares of new forests to be planted each year over the 32 years to 2050. This is far higher than the average net 18 000 hectares planted each year between 1990 and 2015 (Chapter 4). New planting did reach a brief peak of 100 000 hectares in 1994 and averaged around 50 000 hectares over the decade from 1990 to 2000 (MPI, 2017h). While planting at the modelled rates is technically feasible, availability of suitable land for planting, and profitability are key determinants of further afforestation (section 11.5). Models always involve some uncertainty, especially when they are extended far into the future and beyond the historic price ranges of the data on which they are based.

The modelled increase in horticulture land (100% – 200% under some scenarios) is also substantially faster than the 44% (or 38 000 hectare) increase in horticulture land between 1990 and 2015. Also, while ample land suitable for horticulture is likely available, apparently profitable opportunities are not currently being taken up (Clothier et al., 2017; Reisinger et al., 2017; Box 10.1).

Overall, the rates of change in land use required to move to a low-emissions economy are comparable to the rates of change New Zealand has experienced over the last 30 years (Chapter 4). While circumstances are different, this suggests that the changes are feasible and that the rural economy will likely have the capacity to adjust positively to new opportunities as they emerge.

F11.2

The rate of land change needed to transition to a low-emissions economy over the next three decades is comparable in magnitude to the overall rate of change over the last three decades. Yet high rates of afforestation will need to be sustained for a much longer period in the future than happened in the past; and the past movement into horticulture may need to accelerate.

Barriers to land-use change

Private landowners are guided by the prospective profitability of alternatives in deciding how to use their land. This will depend on factors such as the price of the land, the availability of upstream supply of inputs to on-farm production, downstream processing and distribution infrastructure and marketing capacity; the availability of knowledge, skills and technology to support the alternative land use; and prospective prices in world markets. Adequate cashflows are also an issue, especially for forestry where revenue may be deferred for decades.

Uncertainty about the returns to alternative uses will also influence land-use decisions. Landowners may decide to hold their land in its current use until the factors affecting future profitability become more apparent (Kerr & Olssen, 2012; Schatzki, 2003). Similarly, the need to make investments in new production and in upstream and downstream capacity, and to develop knowledge and skills, may slow land-use change. New Zealand's existing sunk investments in highly productive pastoral farming capacity and the support of a secure buyer in the form of Fonterra (with a growing number of other dairy processors), weigh against change. Fonterra notes that the levels of required investment and potential debt held in dairy farms, the risk of stranded on-farm and processing assets, and effects on employment, are barriers to alternative land uses (sub. 88). Finding ways to address these barriers will help ease the transition (Chapter 10).

Andy Reisinger observed several factors that may slow the uptake of promising horticultural opportunities:

On paper, horticultural enterprises appear to have higher profitability than dairying in parts of New Zealand, but horticulturalists are not buying out dairy farms in large numbers. This is likely to be influenced by hidden costs, skills barriers, infrastructure, investment costs, risks, along with more systemic influences in terms of attitudes of banks, international markets, export and training mechanisms. (sub. 28, p. 2).

Where price signals are particularly strong (such as the relative rise in dairy commodity prices in the last two decades) land conversion can be faster. Yet the full effect of an increase in commodity price differentials may play out over 15 to 20 years (Kerr & Olssen, 2012). Factors that could speed change, in addition to strong price signals, include certainty about policy settings that may affect profitability, the availability of skills and knowledge that reduce the risk of making a change, and the availability of funds to support both on-farm and off-farm investments in new productive capacity.

Planting forests for harvesting or carbon sequestration means that land will be unavailable for other uses for many years or permanently. Owners may instead hold land in expectation of increases in land value (eg, driven by rising commodity prices). The Forestry Leadership Group (FLG) submitted: “[f]armers avoid afforestation because it reduces farm income, reduces land use flexibility and ties up capital for unacceptable lengths of time” (sub. 1, p. 6).

Foresters also worry about the risk of regulatory changes (such as those that regional councils might put in place) that will prevent conversion from forests to other uses (FLG, sub. 1; Beef + Lamb New Zealand & DINZ, sub. 98). Uncertainty around a future emissions-price policy will add to the uncertainty around future commodity prices and production costs and so increase the option value of delaying land conversion.

F11.3

The need for investments in upstream supply capacity, new on-farm productive capacity, and downstream processing, distribution and marketing capacity; and the time taken to acquire skills and knowledge, may delay changes in land use, even when they otherwise appear profitable. Policy uncertainty affecting future profitability is also a cause of delay.

11.2 Land use emissions and emissions trends

This section briefly sets out trends in emissions from land use. It focuses primarily on biological emissions – mostly methane (CH₄) and nitrous oxide (N₂O) from pastoral farming. Other emissions, for instance from the use of fossil fuels for transport, milk powder drying and heat for greenhouses, are covered in Chapters 12 and 14.

Importantly, agricultural emissions are both short-lived in the atmosphere (mostly CH₄) and long-lived (N₂O). N₂O comprises around 21% of agricultural emissions. To stabilise global warming, net emissions of long-lived gases need to stop, but a flow of short-lived gases can continue, though at a reduced level (Chapter 9). Urine and dung deposited by grazing animals account for over 75% of N₂O emissions from land use. Most of the remaining N₂O emissions result from using fertilisers and from crop residues (MfE, 2017f). Prioritising a substantial fall in N₂O emissions will, as a result, likely require shifts in farm practice (eg, better fertiliser application, using herd houses or stand-off pads), a reduction in stock numbers and a shift in land use.

Land use provides an opportunity to offset gross emissions by sequestering carbon in forests. Forests currently sequester around 23 megatonnes of carbon dioxide (CO₂) each year, compared with almost 30 megatonnes sequestered in 1990 (MfE, 2017g). Soils also sequester very substantial amounts of carbon (section 11.6). Yet, because of measurement difficulties, the New Zealand GHG Inventory only accounts for carbon in soils when land use changes (MfE, 2017f).

Agriculture and GHG emissions

Farming livestock to produce food is emissions intensive – New Zealand's pastoral farms emitted over 35 megatonnes of carbon dioxide equivalent (CO₂e) in 2015. About 73% of these emissions were CH₄ from ruminant digestion. Over 20% was N₂O emitted from soils.¹²⁷ The two main emissions sources are:

- **Enteric fermentation** – Ruminant animals such as sheep and cattle produce CH₄ when digesting food. In the process of *enteric fermentation*, microbes break down carbohydrates in the rumen (a stomach chamber). Some of these microbes (methanogens) produce CH₄. The animals burp out CH₄ as a result of regular contractions of the rumen.
- **N₂O emitted from soils** – The urine and dung that livestock deposit on soils and the synthetic fertiliser that farmers apply to pasture contain nitrogen. Microbes in the soil interact with excess nitrogen not used to fertilise pastures to release N₂O into the atmosphere. Urine and dung are the biggest source of New Zealand's N₂O emissions, and account for over 75% of N₂O emissions from land use.

Another 3% of emissions is CH₄ produced by decomposing manure on pastures or held in effluent ponds. Unlike many other countries, New Zealand's animals graze on pasture rather than being fed grains using feed lots. So, they spend relatively little time off pasture (MfE, 2017f).

New Zealand's GHG Inventory includes emissions from horticulture and cropping as part of agricultural emissions (and does not account for them separately). Horticultural and cropping emissions are less than 3% of all agricultural emissions, and are mostly N₂O from fertiliser use. A minor amount comes from crop residues (Reisinger et al., 2017).

¹²⁷ Processing agricultural outputs (eg, generating heat to dry milk) and transporting produce and inputs also produce emissions, although a much lower amount than direct on-farm emissions. Horticulture also produces emissions to heat greenhouses, for instance. Mitigation of these non-biological emissions is addressed in Chapters 12 and 14.

Agricultural emissions have risen, mostly due to dairying and use of nitrogen fertiliser

Between 1990 and 2015, agricultural emissions rose by about 16%, largely driven by the intensification and growing overall volume of dairying as well as by the increasing use of synthetic fertilisers. With a larger number of dairy cows and more intensive production, emissions from dairying rose by 130% over this period. This increase was partially offset by lower beef and sheep emissions, mainly due to herd numbers dropping. As a result, CH₄ emissions from enteric fermentation only rose by 4%, between 1990 and 2016 (Figure 11-2). A fivefold increase in the use of nitrogen-containing fertilisers helped contribute to a 28% rise in N₂O emissions (MfE, 2017e). Increasing fertiliser use has contributed to gains in farm productivity. But it has also generated greater nitrate leaching (Chapter 10).

Due to these trends, dairy farming’s share of total agricultural emissions more than doubled from 23% to 50% between 1990 and 2016 (Figure 11-4). While New Zealand is home to far more sheep than cows, cows (especially dairy cows) are much more emissions intensive than sheep. A dairy cow produces on average roughly seven times more CH₄ than a sheep (MfE, 2017f).

Figure 11-2 Change in emissions across sources, 1990 and 2016

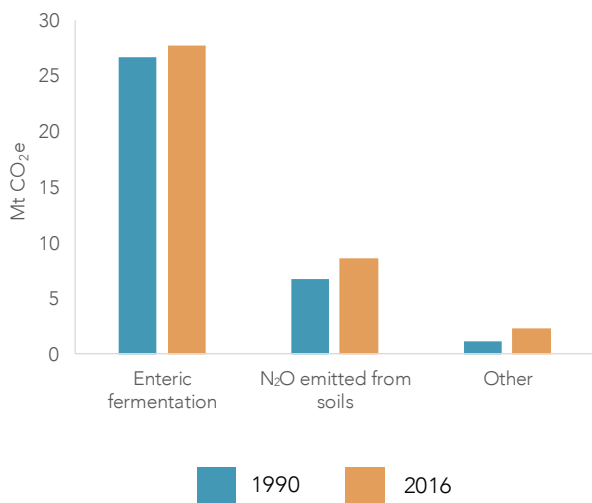


Figure 11-3 Percentage change in production, livestock, and emissions, 1990-2016

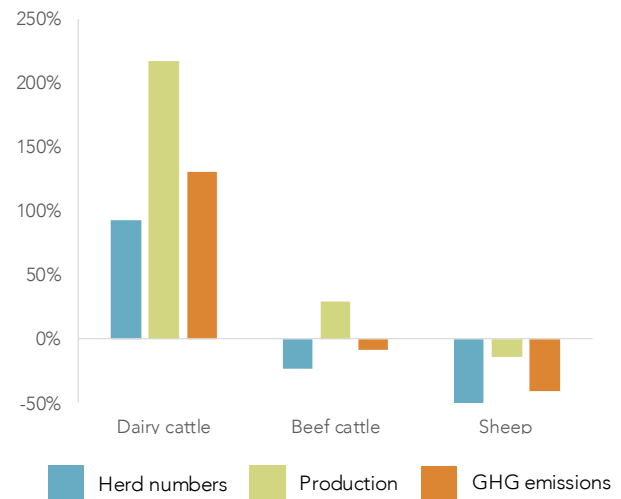
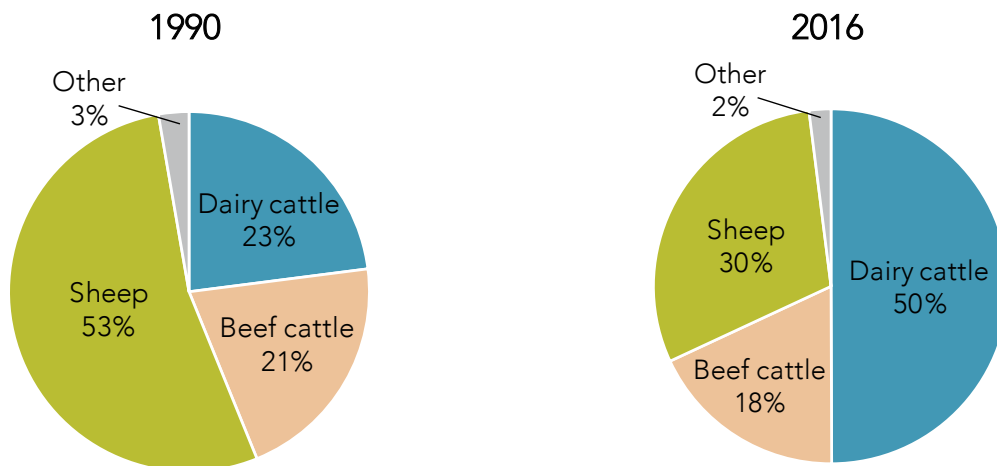


Figure 11-4 Contribution to New Zealand’s agricultural emissions across sectors, 1990 and 2016



Source: Productivity Commission analysis of MfE (2017g), LIC and DairyNZ (2016), and Stats NZ (2017b) data.

11.3 Opportunities to reduce emissions in agriculture

This section assesses the availability and technological feasibility of options to mitigate emissions from pastoral farming, and their potential impacts on profitability and suitability to New Zealand's farming system. It also briefly discusses options to mitigate biological emissions in horticulture and cropping.

Reducing emissions behind the farm gate

Pastoral farming plays a major role in New Zealand's economy. The sector contributes about 6% of New Zealand's GDP, and about 40% of New Zealand's goods exports. Close to 40% of New Zealand's land is used for pastoral farming. Even under the more ambitious pathways to a low-emissions economy, pastoral farming is likely to remain a large part of the rural economy (Chapters 3 and 4). To meet New Zealand's targets, it is imperative that the sector continues to reduce its emissions intensity and gross emissions. Vivid Economics (2017b) estimates that agricultural emissions must reduce by 30% for New Zealand to achieve net zero emissions by 2050. This will come from a combination of lower stock numbers, reduced emissions intensity using currently available practices, and from new technologies as yet unproven.

Current mitigation options

Currently, options suitable for a majority of New Zealand farms do not exist to make big reductions in biological emissions while maintaining production. Smaller reductions (up to 15%) are possible by increasing productivity and more widely adopting existing lower-emissions management practices (Anastasiadis & Kerr, 2013).

Emissions vary widely across New Zealand's farms. For instance, the highest-emitting farms produce roughly twice as much CH₄ emissions and three times as much N₂O emissions as the lowest-emitting farms per hectare of farm (Kingi et al., 2015). Much variation is due to factors such as climatic and soil conditions. However, the way the farm is managed is also important. As a result, the main current options to reduce emissions are:

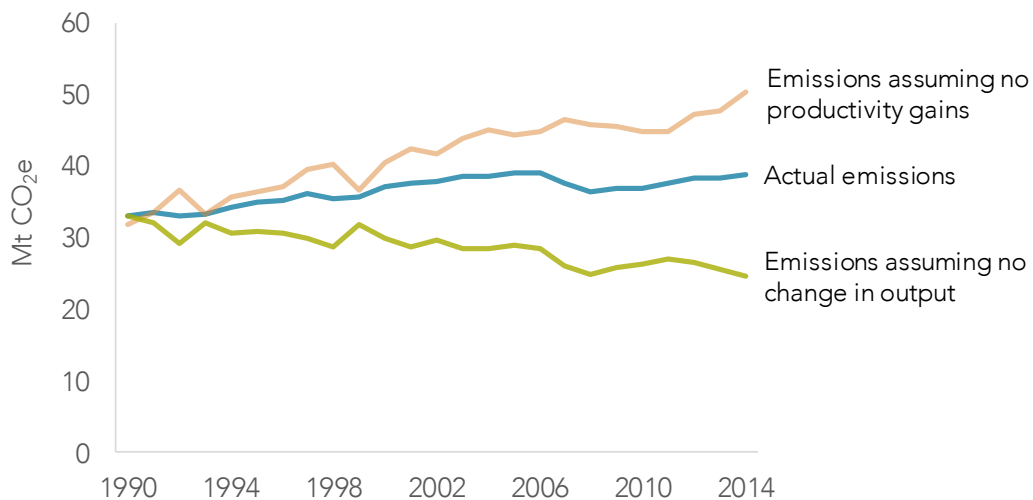
- productivity gains that improve profitability while lowering emissions (eg, continuing genetic gains);
- reducing stocking rates;
- reducing nitrogen inputs; and
- other farm practices that lower emissions (such as milking once a day, and using stand-off pads).

Mitigation options to reduce on-farm emissions do not necessarily improve farm profitability and are generally more likely to reduce farm profits (Vivid Economics, 2017b). Yet Reisinger et al. (2017) conclude that mitigation options that would not reduce farm profits are available for some farms (even though some reduce total production).

Gains in productivity can continue to limit the rise in agricultural emissions

In general, the output of higher productivity farms is less emissions intensive. A more productive animal produces more output of milk or meat, but is also likely to produce more emissions (Reisinger et al., 2016). Even so, a more productive animal produces fewer emissions per unit of production.

Steady gains in pastoral farming productivity since 1990 have enabled New Zealand to maintain or increase production, even though animal numbers have fallen overall (section 11.2). Lamb production in 2015 nearly equalled 1990 levels with only half the number of sheep, while beef farming increased production, with fewer cattle. The national dairy herd doubled in numbers, while milk production tripled, as the average cow produced over 40% more kilogrammes of milk solids in 2015 compared with 1990.

Figure 11-5 New Zealand's agricultural GHG emissions trends, actual compared to potential

Source: RSNZ (2016).

Notes:

1. Emissions data has been adjusted to reflect the downward revision of agricultural emissions in New Zealand's 2015 GHG Inventory.

As a result, the productivity gains achieved over the last 25 years helped to curb the increase in agricultural emissions (Figure 11-5). Without gains in productivity (and assuming production grew at the same rate), total agricultural emissions would have increased by about 58% rather than 16% between 1990 and 2015. On the other hand, if total agricultural output had stayed constant at 1990 levels, emissions would have fallen by about 25% (with the productivity gains). Factors driving these efficiency gains include improved management of pasture, more efficient use of fertiliser, more optimal stocking rates and improved breeding (NZAGRC & PGgRC, 2016).

F11.4

New Zealand's agriculture sector achieved steady productivity gains over the last 25 years, leading to a reduction in emissions per unit of milk and meat produced. Yet, because dairy cattle numbers and total production rose substantially, absolute emissions have risen.

Reisinger et al. (2016) expect farm productivity to continue to improve though at a declining rate, leading to ongoing falls in emissions intensity on the average farm, even without new initiatives. Raising the performance of less efficient farms, would likely further reduce emissions intensity.

Reducing stocking rates

Reducing stocking rates (number of animals per hectare) directly reduces emissions and can improve profitability and productivity in some circumstances. Reisinger et al. (2017) estimate that lower stocking rates can reduce emissions by up to 10% on dairy farms and by 2% to 5% on sheep and beef farms, while maintaining production and improving profits. In some cases, reducing stocking rates can be profitable even without productivity gains (PCE, 2016).

Reducing nitrogen inputs

Reducing nitrogen inputs into farm production is the main avenue for reducing N₂O emissions. The major sources of nitrogen are from the supplementary feeds that animals eat, and the nitrogen fertilisers applied to pasture. New Zealand's animals consume much more nitrogen than they need for their optimal growth and productivity (Reisinger et al., 2016). Use of supplementary feeds and nitrogen fertilisers for sheep and beef farms is typically low (Beef + Lamb NZ & Deer Industry New Zealand (DINZ), sub. 98), so opportunities to reduce nitrogen inputs are mostly limited to dairying.

Modelling suggests that removing the use of nitrogen fertilisers reduces N₂O emissions by 6% to 14%, though with reduced production and varying impacts on profitability across regions (Reisinger et al., 2017).

The use of precision technologies can also help to optimise the use of fertiliser. DairyNZ (sub. 18) notes that “[r]educing the nitrogen fertiliser applied per hectare requires significant skill and careful feed budgeting” to ensure pasture production is not affected (p. 6).

Another way to reduce nitrogen inputs on farms is by using supplementary feeds that contain less nitrogen (such as maize silage). An animal’s diet heavily influences the nitrogen content of their excrement, and therefore their N₂O emissions. Emissions reductions of over 10% are achievable in some regions (Reisinger et al., 2017). However, the benefits of reducing emissions by using low nitrogen feeds are partially offset by the N₂O emitted by the fertilisers used to grow the feeds (DairyNZ, sub. 18).

Reducing nitrogen inputs has the co-benefit of reducing nitrate leaching into waterways and improving water quality (Chapter 10).

Other farm practices to lower emissions

Applying nitrogen inhibitors, such as dicyandiamide (DCD), to pasture has the potential for minor N₂O reductions in aggregate. The cost of emissions reductions, at roughly \$650 per tonne of N₂O, makes DCD use economically viable for only a small proportion of dairy farms (Reisinger et al., 2016). In any case, DCD sales ceased after traces of the compound were found in milk product. The product is currently unavailable in New Zealand. Given its high price, if DCD was reintroduced to the market, it would be more likely used to mitigate both emissions and nitrate leaching rather than for emissions alone.

Switching from milking dairy cows twice a day to once a day presents another mitigation option for dairy farmers, with potential emissions reductions of up to 10% while maintaining profitability (Reisinger et al., 2017). Another possible way of mitigating N₂O emissions is taking stock off pasture using stand-off pads, though this can involve large capital costs (DairyNZ, sub. 18). Also, Indigo Biozest (sub. 92) submitted that their product has been shown in trials to lift animal productivity, and reduce GHG emissions and nitrate leaching. Better understanding of its impact on emissions would require more comprehensive testing.

F11.5

Current options to reduce pastoral agricultural emissions are modest, without substantially reducing production. Farmers can achieve reductions of up to 15%, through productivity gains and shifting to low-emissions practices. Some approaches can also improve farm profitability. More options are currently available for reducing nitrous oxide emissions than methane. Options for sheep and beef farming are much more limited than for dairying.

Overall pastoral agricultural emissions are projected to remain stable or rise

Even with the current mitigation options available, modelling suggests overall pastoral agricultural emissions will at best remain stable or even rise (under current policy), given current patterns of growth in agricultural production. Based on Ministry for Primary Industries (MPI) projections of livestock numbers, Reisinger et al. (2016) estimate that agricultural emissions in 2030 will be roughly 5% to 11% higher than 2015 levels. They conclude:

Absolute emissions from agriculture will continue to rise, making any reduction target below 1990 or 2008–2012 levels highly challenging and, based on current knowledge, impossible unless the expansion of the agricultural sector itself were constrained or new, highly efficacious mitigation technologies successfully developed and rapidly and widely adopted (p. 53).

More recent modelling by the Ministry for the Environment projects agricultural emissions will stay relatively flat up until 2030, with an overall reduction of about 2% (MfE, 2018g).

F11.6

Despite the present opportunities for mitigating on-farm emissions, New Zealand's absolute pastoral agricultural emissions are projected to remain at least stable or to rise. Reducing absolute emissions will require a combination of constraining production and achieving significant breakthroughs in developing new mitigation technologies.

Emerging opportunities for reducing emissions from pastoral farming

New Zealand, along with many other agricultural-producing countries, has invested in developing breakthrough technology that can dramatically reduce on-farm emissions. Options such as selective breeding and a methane inhibitor are emerging. To have a meaningful impact on emissions, any new technology will need to suit New Zealand's farming system and be accepted by farmers, industry and consumers.

Breeding low-emitting animals

Some ruminant animals emit more CH₄ than others, partly due to their genetic make-up. For instance, high-emitting sheep produce up to 50% more CH₄ emissions than low-emitting sheep. In 2014, the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) began work on identifying genetic traits for low-emitting cattle (NZAGRC & PGgRC, 2016).

Selectively breeding low-emitting animals provides a clear opportunity to reduce emissions over time. Farmers already breed sheep and cattle to maximise their economic value. The breeding value of animals is largely based on factors related to their production efficiency, fertility and longevity. The inclusion of low-emission traits could be available in breeding indices for sheep and cattle within five years. Further, breeding low-emitting animals is unlikely to significantly affect production (NZAGRC & PGgRC, 2016).

If every sheep was a low emitter of CH₄, total agricultural emissions could be up to 5% lower than at present. For cattle, total emissions could fall by up to 10% (PCE, 2016). Yet, reaching the point where all livestock are low emitters takes time. For sheep, this process would likely take decades. Because all beef and dairy calves born each year come from a small number of bulls, distributing these traits throughout the national herd could be relatively faster.

Methane inhibitors

A methane inhibitor is a chemical compound fed to an animal to target the methanogens by either killing them, or depriving them of the hydrogen they need to produce CH₄. One inhibitor under development has been proven to reduce an animal's CH₄ emissions by 30%, and is planned to be released in 2019. However, the inhibitor is delivered by mixing it in with cattle feed, rather than applying it to pasture, so is not well suited to New Zealand's grazing system (particularly beef and sheep farming).

Delivering a methane inhibitor in New Zealand would likely require putting the chemical compound in a large tablet or formula that dissolves slowly in the rumen. As this would take considerable skill, time and labour to administer, the compound would need to be effective at low concentrations. Otherwise, the inhibitor would need to be administered frequently, which would come at a cost and would be impractical (PCE, 2016). Inhibitors will likely be more suitable for dairy cattle than other livestock, as milking enables more frequent contact with animals.

Even if a successful inhibitor was only available for dairy farms, it would potentially have a significant impact on agricultural emissions. Work is under way to develop a cost-effective inhibitor that reduces CH₄ emissions by more than 20% and can be used practically in New Zealand. Some compounds have shown promising results, although a commercially available inhibitor is not expected until after 2023 (NZAGRC & PGgRC, 2016).

A methane vaccine

A methane vaccine in theory would trigger an animal's immune system to generate antibodies that suppress the CH₄-producing methanogens in an animal's rumen. Prototype vaccines developed in New Zealand have proven successful in laboratory trials. Trials on sheep are under way to test their impact on animal emissions (NZAGRC & PGgRC, 2016). The partnership of the NZAGRC and the Pastoral Greenhouse Gas Research

Consortium (PGgRC) aims to develop a vaccine that delivers at least a 20% reduction in CH₄ emissions, without limiting production.

A vaccine would be ideal for New Zealand's pasture-based system. Farmers already vaccinate livestock to prevent disease, so adding another vaccine would be simple and cheap to administer and less likely to meet consumer resistance. A vaccine would also be unlikely to affect the quality of meat or dairy products (PCE, 2016). If the vaccine helped to increase an animal's production, the vaccine's net economic cost could be negative (Vivid Economics, 2017b).

The development of a methane vaccine is still in the early stages, and the emergence of such a technology is not guaranteed. Even given the huge potential benefits of a vaccine, as Andy Reisinger (sub. 28) submits, successfully developing an effective vaccine is "extremely challenging". A product will nearly certainly not be available before 2030 (PCE, 2016). Rangitikei District Council (sub. 35) emphasises the need to ensure a successfully developed vaccine has no unintended adverse effects (eg, reduced productivity, different product taste and compromised food safety).

F11.7

The development of an effective mitigation technology could have a significant impact on New Zealand's agricultural emissions. While options such as a methane vaccine and inhibitor show some promise, the prospects of a successful technology are highly uncertain and the benefits dependent on their suitability to New Zealand's farm systems.

Reducing emissions in horticulture and arable farming

Horticulture and arable farming currently account for less than 3% of biological emissions from agriculture (section 11.2). Yet, the Chapter 3 transition pathways envisage that horticulture and arable farming will expand two- or threefold up to 2050. If so, effective strategies to reduce horticultural and arable farming emissions will become more important for New Zealand's transition. This is particularly so, as biological emissions from horticulture and arable farming are mostly long-lived N₂O arising from the use of fertilisers.

Strategies to reduce arable and horticultural biological emissions vary by crop. They mostly involve more precise application of fertiliser; better crop rotation, tilling and ploughing practices; and avoiding soil compaction – particularly when conditions are wet. Some of these strategies would also improve farm profitability (Clothier et al., 2017).

Research into technologies to reduce agricultural emissions

Improved productivity and better farm management practices have been slowly reducing the emissions intensity of New Zealand's agricultural products over time and this is likely to continue (section 11.3). Even so, more substantial reductions depend on finding and adopting new technologies. Chapter 6 concludes that New Zealand's strategy for its transition to low emissions should have a strong focus on directed innovation, which will require significantly more resources devoted to it than the current allocation.

New Zealand is a "world leader in the science and technology of agricultural mitigation" (Fleming & Kerr, 2017, p. 17). Currently, the Government invests roughly \$20 million each year into researching mitigation technologies, most of which helps fund three research centres.

- The Pastoral Greenhouse Gas Research Consortium, set up in 2003, comprises industry participants, government agencies and the National Institute of Water and Atmospheric Research. The PGgRC focuses on the mitigation of CH₄ and N₂O emissions. It works in partnership with the NZAGRC. It is receiving \$37.8 million of funding between 2013 and 2019, half of which comes from the Ministry of Business, Innovation and Employment and the other half from industry.
- The New Zealand Agricultural Greenhouse Gas Research Centre, established in 2009, researches ways to reduce CH₄ and N₂O emissions and increase the carbon stored in soils. It is receiving \$48.5 million of Government funding between 2009 and 2019.

- The Government, working with other countries, helped establish the Global Research Alliance on Agricultural Greenhouse Gases (GRA) in 2009. The GRA researches, and seeks to develop, technologies to lower GHG emissions from food production. The GRA now has 49 members and is funded from voluntary contributions from member countries. Specific research projects also receive funding from other sources. New Zealand hosts the GRA's secretariat. The GRA's activities are receiving \$65 million of Government funding between 2010 and 2020.

Some submitters advocated increased funding for agricultural emissions mitigation research (John Crook, sub. 31; Federated Farmers of New Zealand, sub. 39; and Waikato Regional Council, sub. 48). J. Robert McLachlan (sub. 9) argued that the current level of government funding for research is “woefully inadequate compared to the size of the [agricultural] industry”, and a barrier to future emissions reductions (p. 6). The Parliamentary Commissioner for the Environment (PCE) argued that funding for a search for a breakthrough technology, such as a methane vaccine, should be increased (PCE, 2016). Andy Reisinger (sub. 28) recommended that the Commission “develop a framework for thinking about and quantifying the benefits of developing [mitigation] technologies, to better inform the quantum of research investment that can be justified” (p. 1).

Under current policies, continuing funding for agricultural emissions mitigation research is uncertain and small (at around \$16 million each year) in relation to:

- the size of the agricultural sector and downstream processing (about 6% of GDP);
- the proportion of total emissions that come from agriculture (almost half);
- the urgency of the risks arising from climate change and New Zealand's commitments to lower emissions; and
- the total size of Government's contribution of funding for innovation (in excess of \$1.5 billion each year).

Potential payoffs in terms of enhancing New Zealand's international reputation are possible, through the dissemination of a successful technology to reduce agricultural emissions (and possible commercial payoffs) (Chapter 10).

Chapter 6 concludes that arguments for increasing funding for emissions-reduction research are strong where New Zealand already has a solid research base and significant emissions, such as in agriculture. On reasonable assumptions, if a vaccine reduced CH₄ emissions by 30%, the annual value in New Zealand alone, at a carbon price of \$50 a tonne, would be over \$380 million. This suggests that, even if the chance of success from research into mitigation technologies is only in the order of 30%, a substantially higher level of funding than the current total level of around \$16 million each year would be justified by the potential returns.

One option to increase funds for research on agricultural mitigation technologies is to use some of the proceeds of auctioning NZUs (see Chapter 6).

R11.1

The Government should increase its yearly funding for research on agricultural mitigation technologies to a level that better reflects the potential value of successful outcomes. Funds could, for instance, be allocated from the proceeds of auctioning New Zealand Units (NZUs).

Overcoming barriers to the adoption of best farm practice

Reducing pastoral agricultural emissions will depend on a combination of innovative technology and farmers adopting best practice. Farm management practices that lower emissions, including some that improve productivity, have been known and available for decades. With the help of research and industry advice, farmers continue to identify and adopt new approaches to lowering emissions. Yet, across New Zealand, progress in reducing biological emissions has been slow and overall results modest. Even if a technological breakthrough occurs, it may still take many years for a majority of farmers to adopt it. Journeaux et al. (2017)

reported that farmers interviewed for their study thought that it could take between 6 and 10 years to achieve a 10% reduction in emissions and up to 15 years to achieve a 20% reduction.

Causes for slow adoption of new practices and technologies vary. Pastoral farmland comprises roughly 25 000 sheep and beef farms, and over 12 000 dairy farms. Farmers have a variety of world views and objectives. They often rely on other farmers as a key source of information to decide what to try, and so new ideas take time to percolate through (Journeaux et al., 2017). Conversely, many mitigation practices are complex and require a high capability to implement effectively. Beef + Lamb NZ and DINZ noted that “farm systems are not readily changed as they are based on biological systems, and planning is necessarily much longer term than typical industrial or manufacturing processes” (sub. 98, p. 5). Farmers may also perceive emissions reduction strategies as risky.

DairyNZ noted the absence of a “clear set of good management practices to guide appropriate behaviour”, low awareness of the issue of climate change, implications of the Paris Agreement and what it means for the dairy industry, and “a lack of capacity and capability within rural professional networks” (sub. 18, p. 10). The Morgan Foundation (sub. 127) identified a lack of relevant independent advice. Beef + Lamb NZ and DINZ argue for “access to expertise and advisory services that can assist farmers to identify practical and affordable changes and adaptations to their current business models” (sub. 98, p. 8). Waikato Regional Council (sub. 48, p. 8) pointed to the positive effect of peer and industry recognition to foster best practice in the pastoral farming sector, which would equally apply to emissions reductions efforts.

Yet industry organisations, such as Dairy NZ and Beef + Lamb NZ are rising to the challenge. They are working with farmers, food processors like Fonterra, research organisations and iwi to raise awareness of best practice and set timetables to lower emissions in their sectors (see Box 10.2 in Chapter 10). Similarly, Synlait, a dairy processor based in Canterbury, has announced a goal to reduce on-farm emissions by 30% over the next decade. The reduction includes 50% cuts in N₂O, 30% in CH₄ production and 30% in CO₂ (Howard, 2018).

F11.8

Based on past experience, adoption of low-emissions farming practices and technology could be slow and complex. Yet, the pastoral agricultural industries are putting in place peer and industry support for farmers to accelerate the adoption of new practices to meet ambitious emissions-reduction goals. The industries’ efforts to reduce biological emissions from pastoral agriculture will be central to sustaining the industries’ role in a future low-emissions economy.

11.4 Putting a price on all land-use emissions

Under current policy, the NZ ETS does not price biological emissions from agriculture (including horticulture and arable farming). On the other hand, foresters can earn NZUs for the sequestration of carbon. This section considers the merits of, and explores policy options for, introducing a price on agricultural emissions.

A transition to a low-emissions economy by 2050 will require both a substantial shift in land use (particularly towards forestry) and a reduction in biological emissions from remaining agriculture (section 11.1). An effective price on agricultural emissions (as in other sectors of the economy) would strengthen incentives to shift to land uses that produce lower emissions; and otherwise to develop and use technology and management practices that lower emissions. It would also provide a devolved mechanism to weigh the marginal costs of reducing emissions from particular land uses against the cost of lowering emissions elsewhere in the land sector and in other parts of the economy (see Chapter 5).

The merits of applying a price to agricultural emissions

When the NZ ETS was launched in 2008, the Government intended to include agricultural emissions from 2013, with 90% free allocation based on 2005 emissions. Allocations would phase out to zero by 2030 (Kerr, 2016). Since 2012, successive governments have deferred including agricultural emissions, pending economically viable and practical mitigation options being available, and New Zealand’s trading partners

making greater progress on mitigating emissions (MPI, 2017d). While exempt from emissions pricing, the sector is required to report its emissions each year.¹²⁸

The decision to defer the full inclusion of agricultural biological emissions into the NZ ETS has been highly contentious (DairyNZ, sub. 18; The Morgan Foundation, sub. 127). Some submitters from the agricultural sector recommended keeping the exemption on biological emissions (Fonterra, sub. 88; Beef + Lamb NZ & DINZ, sub. 98). They argued that pricing these emissions, without adequate ability to reduce them, unfairly disadvantages New Zealand farmers compared to international producers. In particular, they argued that pricing emissions would cause some agricultural production to shift from New Zealand to other countries, without reducing global emissions (“emissions leakage”).

On the other hand, a substantial number of submitters advocated bringing agricultural emissions into the NZ ETS.¹²⁹ Key arguments are that a price on on-farm emissions would:

- better incentivise mitigation as well as research and investment into future mitigation solutions;
- improve the efficiency of emissions reductions, as the NZ ETS would cover all emissions; and
- be more equitable, as it would mean all emitters face the same price for their emissions.

Potential response of farmers to an emissions price

Without a price on emissions (or other regulation), farmers are likely to adopt only mitigation measures that also improve their farm profits (and then quite slowly, given past experience). Many farms can achieve modest emissions reductions by changing their management practices (section 11.3). Some of these practices are productivity enhancing, and could therefore be profitable for farmers without an additional financial incentive. Yet, as (Kerr, 2016) notes, other practices currently require greater incentive to become viable.

[S]ome emissions efficiency improvements will not raise profit – they will come at a cost. For example, if a farmer immediately replaced their entire current herd with high-breeding worth animals, emissions intensity of the farm’s production would be lower but this would come at a high cost. These changes will not occur without encouragement or incentive. (p. 21)

The effect of an emissions price on farming practices is uncertain and will vary across regions depending on effects on profitability (Reisinger et al., 2017). Non-cost barriers will also slow change in practices (section 11.1).

Even so, an emissions price would make more mitigation options financially attractive.

An emissions price would also signal future policy directions and make farmers more aware of the link between different management practices and emissions. Introducing a price earlier rather than later would allow a more gradual (and therefore less costly) transition, especially given that required emissions reductions will become more stringent over time if delayed.

Pricing agricultural emissions also makes switching to alternative lower-emissions land uses a relatively more attractive option. The NZ ETS already provides incentives for farmers to convert their pasture to forestry. A rising price on agricultural emissions would provide an increasing incentive to convert farmland to horticulture and cropping.

Pricing emissions would encourage private investment to develop mitigation technologies

Pricing biological emissions would encourage private investment to develop mitigation technologies.

Ballance Agri Nutrients submitted:

Currently to develop a new product or service that can result in reduced emissions there is no ability to capture the value from the emission reductions except indirectly where there is a productivity benefit that is captured by the farmer. As a consequence there is a major deficiency in the ability to justify the

¹²⁸ Farmers do bear a direct cost for their emissions from using fossil fuels (eg, transport fuel), and likely some indirect cost passed on from milk and meat processors who consume fossil fuels (eg, burning coal to power milk processing plants) and from off-farm transport operators.

¹²⁹ See subs. 1, 25, 27, 29, 32, 36, 40, 51, 52, 56, 67, 71, 73, 78, 83, 122, and 129.

investment in developing mitigation technologies (as a non-industry good party) because the business case lacks a direct revenue line from that benefit. (sub. 34, p. 7)

Guardians of NZ Superannuation (sub. 32) noted that bringing agricultural emissions into the NZ ETS should “generate incentives for agricultural businesses, including suppliers to leverage government research programmes” (p. 8).

An all-sector emissions price would be more efficient and equitable

Pricing emissions and allowing landowners to work out the best way to reduce emissions (or to pay for reductions or carbon sequestration elsewhere in the economy) is likely to be more efficient than central direction through regulation. For instance, trading NZUs will encourage the lowest-cost emissions reduction options to be used first, and will let land-use choices respond flexibly to new opportunities as they unfold (Chapter 5).

Applying an emissions price to agricultural emissions means that the Government itself would not directly decide how private landowners use their land. An emissions price would be but one factor among many that shaped land-use decisions (section 11.1). Federated Farmers was sceptical about the Government potentially “picking winners” in relation to land use: “We would not be supportive of policies that would curtail the ability of landowners to use their land in an economically optimal manner” (sub. 39, p. 7). The Fertiliser Association of New Zealand also argued against “the prescription of particular land uses because of the risk of locking in uneconomic land uses and inefficiencies in production” (sub. 61, p. 9). Beef + Lamb NZ and DINZ made a similar point (sub. 98). Pricing biological emissions would allow a variety of land uses, though making some relatively more profitable than others.

Exempting agriculture from an emissions price also places a disproportionately (and inefficiently) high emissions reduction burden on other sectors in the context of meeting New Zealand’s emissions targets, especially since agriculture accounts for such a large proportion of total emissions. Foresters, in particular, argued that agriculture not being in the NZ ETS tilts the playing field against other land uses – especially forestry (eg, subs. 36, 48, 67, 71, 73, 83 and 97).

F11.9

Applying a price to agricultural emissions would give farmers more incentives to adopt mitigation options, though the size of the effect is uncertain. An emissions price would encourage more private investment in developing mitigation technologies and also improve the efficiency and equity of mitigation efforts across the economy.

Addressing impacts on international competitiveness and leakage

Introducing a price on agricultural emissions would make New Zealand the only country in the world to have done so. The main arguments for exempting agricultural emissions from pricing are the effect on the international competitiveness of New Zealand’s agriculture; the emissions efficiency of New Zealand agriculture compared to other agricultural producers; and the limited scope to reduce agricultural emissions.

Agriculture in New Zealand is highly exposed to trade, with more than 90% of produce exported (RSNZ, 2016); yet New Zealand is a price taker in international markets. A price on agricultural emissions could cause emissions leakage. Any leakage would, though, depend on other factors that vary across countries, such as labour and fuel costs and the cost of land. To date, the emissions price in New Zealand has been low compared to fluctuations in agricultural commodity prices – suggesting that other factors would likely be more important currently in deciding the location of production.

Some submitters raised the issue of emissions leakage, since New Zealand is the largest global exporter of dairy and sheep meat products, and among the least emissions-intensive producers in the world (DairyNZ, sub. 17; Federated Farmers of New Zealand, sub. 39; Fonterra, sub. 88; Beef + Lamb NZ and DINZ, sub. 98). Other submitters raised the tangential issue of global food security (Box 11.3).

Box 11.3 Emissions pricing and food security

Some submitters argued that global food security was an important reason for protecting agricultural producers from measures to reduce GHG emissions (DairyNZ, sub. 18; Federated Farmers of New Zealand, sub. 39; Beef + Lamb NZ & DINZ, sub. 98). They sometimes pointed to the Paris Agreement, which recognised the “fundamental priority of safeguarding food security and ending hunger” (UNFCCC, 2015b). This concern is particularly focused on developing countries, and in essence weighs food security against climate change mitigation.

Yet New Zealand contributes little to global food security. It produces around 3% of global dairy produce, 3% of sheep meat and 1% of beef (OECD, 2018c). Rising global demand for milk and meat products is linked to the world’s increasing middle-class population. Any reduction in supply from New Zealand will have little impact on markets for food for the poor in developing countries. According to Anders Crofoot, a former National Vice President of Federated Farmers of New Zealand, New Zealand’s agricultural sector does not “feed the poor” (cited in Kerr, 2016, p. 15).

Only a small amount of global agricultural production is traded internationally, and less than 1% of dairy products. Agricultural produce in developing countries is largely produced and traded locally, and food security concerns, in any case, focus on the supply of grains.

Ensuring food security is compatible with meeting climate change mitigation goals. As the Parliamentary Commissioner for the Environment (PCE, 2016) emphasises, “[t]he world will continue to need food. But the way in which food is grown and the types of food grown will have to change if biological emissions are to be reduced” (p. 77).

On emissions leakage, DairyNZ submitted:

If a policy framework was introduced which resulted in New Zealand’s milk production curtailment, it is likely a less efficient producer would fill the gap resulting in an increase in global emissions and carbon leakage. NZIER and NZAGRC estimates this could amount to 13 mega tonnes of biological emissions entering the atmosphere from 2020–2030 if New Zealand’s milk production is displaced (sub. 18, p. 17).

Any increase in global emissions resulting from a shift in production depends on the relative emissions intensities of production in particular countries. Some estimates suggest New Zealand’s emission intensity is one quarter of the average farm globally (DairyNZ, sub. 18).

Yet, the gap in supply resulting from reducing New Zealand’s production is more likely to be filled by its trading competitors than “average” farm producers. Comprehensive data on the emissions intensity of New Zealand’s trade competitors is lacking. Even so, output from high-productivity farms tends to be less emissions intensive than from low-productivity farms (Gerber et al., 2013; section 11.3). Productivity is also likely correlated with trade competitiveness. This all suggests that New Zealand’s trade competitors are likely less emissions intensive than the average global farm producer. In any case, New Zealand produces only a very small proportion of global agricultural production (Box 11.3); so any shift in production will have only a modest effect at most on global emissions.

Free allocations of credits within the NZ ETS are designed to protect trade-exposed industries and limit the risk of emissions leakage (see Chapter 5). Under a similar provision for agriculture, farmers would face the full incentive to mitigate emissions at the margin (since they would be able to sell any unused credits). Yet, initially, they would incur only a small part of the full cost of their emissions, protecting the viability of their business. In contrast, exempting agriculture from the NZ ETS (the current approach) removes incentives to lower emissions, and so is an inferior approach to dealing with emissions leakage (Chapter 5). New Zealand may also benefit from being the first to price agricultural emissions, by increasing the international credibility of its mitigation efforts and its reputation for agricultural innovation (Chapter 10).

New Zealand’s competitors in Europe and elsewhere will also eventually face the cost of their agricultural emissions. Many developed countries have set economy-wide targets to reduce emissions. As countries’

commitments become increasingly ambitious, they will likely start to regulate their agricultural emissions too (especially as they will make up an increasing share of their emissions).

F11.10

New Zealand's trade competitors do not yet face a price on their agricultural emissions. Given New Zealand's agricultural sector is highly trade-exposed, introducing a price for agricultural emissions without support would reduce the international competitiveness of New Zealand farms and potentially result in emissions leakage.

Yet, with adequate support for farmers (eg, provision of free allocations), pricing agricultural emissions will provide incentives to reduce emissions, while lessening any risk to the viability of New Zealand's agricultural businesses. Also, the risk may not be as severe as some suggest, since New Zealand's core competitors in international trade are likely eventually to face comparable regulation of emissions.

Providing free allocations would also protect individual farmers from the immediate effects of an emissions price on profitability. Otherwise, a farmer currently earning minimal profits or heavily indebted could face financial stress. Other policies could also assist vulnerable farmers and communities through their transition (Chapter 10).

Agricultural emissions should be priced

The Commission considers that the benefits of pricing agricultural biological emissions, including providing greater mitigation incentives and improved efficiency and equity, outweigh the costs. In particular, a substantial change in land use is required for New Zealand to transition to a low-emissions economy by 2050. As an emissions price will be factored into land values, this will provide a more even-handed signal favouring forestry and horticulture. Depending on the design, it could also encourage farmers to reduce their emissions from current land uses, beginning where it is easiest and least costly to do so.

A large majority of submitters on this issue thought that agricultural biological emissions should be priced (eg, Waikato Regional Council, sub. DR227; New Zealand Forest Owners Association, sub. DR246; Chris Livesey, sub. DR247; Motor Industry Association, sub. DR342; Ora Taiao – New Zealand Climate and Health Council, sub. DR378). Many added that free-allowances (discussed below) should be used to ease the transition for a period (Greater Auckland Inc., sub. DR 266; Ballance Agri-nutrients, sub. DR 285; Geoff Thompson, sub. DR304; Fertiliser Association of New Zealand, sub. DR322; New Zealand Farm Forestry Association, sub. DR338). Federated Farmers of New Zealand (sub. DR310), the Taranaki District Council (sub. DR188) and Venture Taranaki (sub. DR255) opposed pricing agricultural emissions at present, while DairyNZ (sub. DR365) preferred to work with the Interim Climate Change Committee to determine a policy.

Short-lived and long-lived agricultural emissions should be priced separately

Importantly, agricultural emissions are both short-lived in the atmosphere (mostly CH₄) and long-lived (N₂O). N₂O comprises around 21% of agricultural emissions. To stabilise global warming, net emissions of long-lived gases need to stop, but a flow of short-lived gases can continue, though at a reduced level (Chapter 9).

To properly recognise the difference in warming impacts between short-lived and long-lived gases in an emissions pricing system, the Commission recommended in Chapter 9 setting separate budgets and targets for the two types of gases. The Commission recommended that the NZ ETS should control the reduction in long-lived gases such as N₂O. Yet it found that a single-cap NZ ETs is unsuitable for controlling biogenic CH₄. It recommended, instead, that the Interim Climate Change Committee should assess both a dual-cap NZ ETS and a methane quota system for CH₄ and recommend a preferred approach in its report to Government due at the end of April 2019.

Free allocations for long-lived nitrous oxide (and for biogenic methane, if included in the NZ ETS)

As for other trade-exposed sectors, the Government should, to protect the viability of agricultural businesses during a transition period, provide free allocations within the NZ ETS for a large majority of long-lived agricultural emissions. This should also apply to biogenic methane if included in the NZ ETS.

Chapter 5 recommends that the Government should progressively withdraw free allocation to emission-intensive trade-exposed firms over the next two decades to a pre-announced schedule. Yet it recommends that the Government should be able to slow the withdrawal of free allocation, in the event that the proposed climate change commission finds that major competitors are not, actually or imminently, facing comparable emissions prices. This approach should apply to agriculture too.

R11.2

Agricultural nitrous oxide emissions should be fully included in the New Zealand Emissions Trading Scheme (NZ ETS). Agricultural methane emissions should be fully included in the NZ ETS if that is the option recommended by the Interim Climate Change Committee in its report to Government due at the end of April 2019.

Point of obligation for biogenic agricultural emissions

The impact of a price on agricultural emissions differs depending on whether the price is borne by individual farmers or by processors of agricultural products or inputs. The point in the supply chain obliged to report on and surrender units for emissions is known as the *point of obligation* (Chapter 5). Currently under the NZ ETS, agricultural emissions are reported at a processor level. This section considers the merits of setting the point of obligation for agriculture at the processor level, or at the individual farm level.

Making processors the point of obligation would require processors, both upstream and downstream of where the emissions actually occur, to bear the direct cost of emissions. For instance, this would include fertiliser manufacturers, who produce an intermediate good that when applied to pasture causes N₂O emissions; and meat and dairy processors, who process meat and milk solids that come from emitting animals. Estimates of emissions would be based on national averages (eg, the average N₂O emissions for a tonne of nitrogen fertiliser used).

Under this approach, processors could pass the cost of the emissions price to farmers, whose individual decisions affect the level of emissions. Farmers would then have incentives to reduce their levels of production (eg, reduce stocking rates where this is profitable, or shift land uses) or to reduce the amount of fertiliser they apply to pasture. Yet they would face little direct incentive to change management practices to reduce their emissions intensity. It is possible that processors could provide such incentives, for example by rewarding farmers who adopt good practices and penalising others.

Another option is setting the point of obligation at farm level. Under this approach, individual farmers would bear the direct cost of an emissions price based on a model of their on-farm emissions (rather than directly measuring emissions). This approach would incentivise the adoption of a much wider range of mitigation options compared to a processor level point of obligation, since farm modelling can capture differences in the way farms are managed. In this way, it provides a stronger price signal to reduce emissions. Farmers would benefit from changing to lower emissions practices, such as using low-nitrogen feeds and selectively breeding low-emitting animals, as well as reducing livestock numbers and changing land uses.

Key issues to consider in setting a point of obligation for agriculture

The key issues to consider in choosing the most appropriate point of obligation for agriculture include:

- the range of mitigation options incentivised;
- the types of mitigation options available to farms;
- the cost and complexity involved with estimating emissions and administering the system; and
- the fairness and acceptability of the system among the farming community.

Assuming a point of obligation at the farm level and at the processor level cost the same to implement, a point of obligation at the farm level is a more efficient option since it provides a stronger price signal to reduce emissions. Yet, in practice, making thousands of individual points of obligation at farm level would be much more difficult to administer compared to a processor level, with potentially high transaction costs.

These costs could outweigh the benefits of a farm-scale system, especially given that limited mitigation options are available. It is also not simple to accurately estimate a farm's emissions.

The rest of this section discusses some of the challenges in implementing a farm-scale system. It then identifies three potential approaches to setting the point of obligation.

Feasibility and practicability of measuring emissions at the farm level

It is infeasible to directly *measure* on-farm emissions accurately, since they are so diffuse. Instead, it is possible to *model* emissions at the farm level based on information about farm livestock, inputs and outputs, and emissions factors associated with these features. The OVERSEER nutrient budgeting tool is most commonly used for this purpose (Box 11.4).¹³⁰

Box 11.4 OVERSEER

Developed in the early 1980s, OVERSEER is a modelling tool used to estimate the nutrient flows in a farm system. It is jointly owned by the Ministry for Primary Industries, AgResearch Limited and the Fertiliser Association of New Zealand. The tool gathers a range of data inputs including animal characteristics, productivity and feed intake, soil type, slope and rainfall. It then produces nutrient budgets to advise farmers on how to use nutrients more efficiently, and so to improve their farm profitability. It also produces reports identifying risks of environmental impacts and how different practices will affect these risks.

The intended purpose of OVERSEER at its inception was as an advisory tool for farmers to use regarding their fertiliser use. Over time, the model has been developed and adapted, in part, as a response to growing concern about farming breaching environmental limits. Under the Sustainable Dairying: Water Accord, Fonterra requires each of its dairy suppliers to provide accurate farm information to model nitrogen loss and nitrogen conversion efficiency using OVERSEER. Now several regional councils have begun using OVERSEER as a tool to regulate nitrogen discharges on farms to address water pollution (Chapter 10). According to Hollis et al. (2016, p. 26), the model "has a mixed reputation within the farming community, especially in catchments where it has been used as a regulatory tool".

While it was not designed to model GHG emissions, OVERSEER can provide estimates of a farm's emissions. It does this by combining estimated emissions factors from the national GHG Inventory with data specific to an individual farm. This allows the model to capture a range of mitigation options for farmers.

Source: OVERSEER (2017); Fonterra (2016); Kerr and Sweet (2007).

A big advantage of using OVERSEER for emissions pricing is that most dairy farmers are already familiar with the model, as they use it for monitoring their nutrient losses. Views were mixed however among submitters about whether OVERSEER is currently a suitable tool for regulating emissions. The Fertiliser Association of New Zealand (one of the owners of OVERSEER) supported using it to estimate on-farm emissions:

FANZ considers that reliably modelling and estimating farm scale GHG loss is feasible, and that farm scale point of obligation provides for flexibility and innovation, and is the most likely way to successfully effect the required behaviour change. Furthermore, authoritative research reports and investigations confirm that OVERSEER operates at a suitable farm scale and is appropriate for estimating GHG emissions in a manner which is consistent with the National Inventory methods. (sub. 61, p. 7)

In contrast, Beef + Lamb NZ and DINZ considered that OVERSEER should not be used for estimating emissions in a regulatory setting, since the model does not capture the "real-time" variation in emissions that results from the dynamic nature of farm systems. They noted that

¹³⁰ MfE also models on-farm emissions at the national level for the purposes of reporting in New Zealand's annual GHG Inventory. The Inventory methodology uses national-level data on production and productivity to estimate feed intake and, in turn, estimate CH₄ and N₂O emissions.

[w]ork is needed to improve OVERSEER as an emissions modelling tool as it does not currently reflect the full range of on-farm actions that can be taken to reduce emissions, including an assessment of whether they can even be modelled. (Beef + Lamb NZ & DINZ, sub. 98, p. 4)

Fonterra also considers that it would be very difficult to successfully implement OVERSEER at a scale and accuracy required for a farm-level point of obligation (sub. DR355).

In 2017, the Biological Emissions Reference Group commissioned AgResearch (also an owner of OVERSEER) to review the suitability of using OVERSEER for reporting emissions at farm level. The study concluded that “the OVERSEER structure is suitable for farm-scale GHG reporting” (de Klein et al., 2017, p. 5). Even so, AgResearch identified ways to improve the transparency and accuracy of the model and therefore provide greater confidence to farmers in its use; and to refine the model to acknowledge a wider range of farm-level factors. The authors also recommended a process for ongoing alignment of the model with the national inventory model, since this model is used to estimate New Zealand’s emissions in the context of its international commitments.

OVERSEER Ltd submitted that it has recently significantly upgraded OVERSEER to make it more intuitive, simpler and faster to use; provided a centralised data base to increase efficiency in accessing and sharing information; and made it easier for farmers to visually assess the potential of different options (sub. DR300).

One advantage of a point of obligation at the farm level is that it provides stronger, sharper incentives for individual farmers to reduce their emissions. The extent to which this is effective (and justifies the increased cost of monitoring and reporting emissions) will depend on what mitigation options are captured by the farm-level emissions model. OVERSEER reliably models some livestock characteristics, stocking rates, types of feed and livestock productivity, all of which are associated with levels of emissions in well-established ways. With further adaptation, it should be capable of modelling and so incentivising other mitigation options that are at the farmer’s discretion. Use of OVERSEER as a regulatory tool will create pressure to refine it to better reflect current and emerging mitigation options. Horticulture New Zealand submitted that OVERSEER is unsuited to monitoring GHG emissions from Horticulture (sub. DR394).

Regardless of the point of obligation used, further work to improve OVERSEER would be beneficial. As an advisory tool, OVERSEER would “allow farmers to estimate their emissions and model changes to their farm systems and indicative changes in emissions that would be likely to occur” (Beef + Lamb NZ and DINZ, sub. 98, p. 4).

F11.11

The impact of a price on agricultural emissions differs depending on the point of obligation. A point of obligation at the processor level mostly incentivises reduction of output (either through reducing stock numbers where this is profitable, or through changing land use), and therefore provides a blunt price signal to reduce emissions. A point of obligation at the farm level provides stronger incentives for a farmer to change the way they manage their farm as well as to reduce their output.

F11.12

OVERSEER is currently the main tool for monitoring emissions at the farm level, and is already widely used by dairy farmers for nutrient management. While its overall structure is suitable for monitoring farm-level emissions, further work is under way to improve its transparency, the extent to which it captures a wide range of on-farm mitigation options, and to better align the model to the methodology used in preparing the national inventory.

R11.3

Unless and until there is a better alternative, the Government should use OVERSEER to monitor emissions at the farm level. The Ministry of Primary Industries should undertake work with AgResearch and the Fertiliser Association of New Zealand to further improve the capabilities of OVERSEER as a tool for modelling farm-level emissions. The improvements should capture as far as possible the full range of on-farm actions that can reduce emissions.

Even with a reliable tool for modelling on-farm emissions, the cost of monitoring, verifying, and enforcing compliance for many small emitters is likely to be high (Kerr, 2016). Each farm required to report emissions would need to know or learn (in the case of sheep and beef farmers) how OVERSEER works and the process of purchasing NZUs. Checking that every farm is providing accurate information would be impractical. The Environmental Protection Authority, which administers the NZ ETS registry, could check compliance of a sample of farms, with sanctions for non-compliance (as already provided for under the Climate Change Response Act 2002).¹³¹ Te Rūnanga o Ngāi Tahu submitted that the question comes down to cost and complexity; and noted that OVERSEER is already widely used in its takiwā (sub. DR362).

As part of the Dairy Action for Climate Change Plan, Fonterra is trialling the recording of CH₄ emissions for up to 100 of their suppliers, as part of the reports on environmental performance they already provide to these farmers (DairyNZ, 2017). At one trial farm, the accuracy of measurement using breath monitors compares well with the “gold standard” approach that uses respiration chambers. The monitors are being used to test the effects on emissions of breed, cow feed conversion efficiency and type of feed (DairyNZ, 2018).

BECA has prepared a report for the Biological Emissions Reference Group (BERG) on the costs to the Government and to farmers of processor-level and farm-level points of obligation (BECA, 2018)¹³².

- BECA estimates that the combined annual costs to Government and farmers of a farm-level point of obligation will be close to \$39 million, with \$30 million of this borne by farmers.¹³³ Of this, \$14 million is for brokerage fees to purchase NZUs (currently a minimum of \$500 a trade each year), and \$11 million for engaging certified nutrient management advisors (as is currently the case when OVERSEER is used for regulation of nutrient leaching into waterways).
- In comparison, BECA estimates that the total yearly cost of a processor point-of-obligation would be \$2.7 million.
- With 95% free allocation, the administrative costs to farmers of a farm-level point of obligation would be 78% of the “net emissions trading obligation”. The yearly administrative costs would be an average \$1 300 for each farm, while the obligation to purchase units would be a yearly average of \$1 600.
- BECA estimates for the total yearly costs of the farm-level point of obligation vary between \$16 million and \$61 million depending on assumptions about cost drivers. The lower-end assumptions involve developing a simplified version of OVERSEER (or alternative) that models only emissions and has a farmer-friendly interface (therefore reducing the need for advisory services); and brokers developing an on-line trading portal that would reduce yearly brokerage fees to farmers. BECA estimates that this could reduce the total yearly costs to farmers to something around \$6 million. Higher unit costs for advisory services drive the high-end estimates.

¹³¹ Similarly, under the Waikato Regional Council’s nitrogen trading programme, farms are audited each year to check farmers are complying with limits. Farmers cover this cost.

¹³² BECA also looked at the administrative cost of “non-price” based scenarios such as direct regulation of emissions per hectare, regulation of emissions mitigation technologies, and a government agreement with industry to support farmers to undertake emissions reduction activities. It also looked at price-based incentives to use emissions mitigation technologies. The study did not undertake “any investigation into comparative benefits between scenarios” (BECA, 2018, p. iv). The report (p. 40) acknowledges further work commissioned by BERG that assesses “the most effective mechanisms for driving farmer behaviour change and also [looks] at the wider economic costs and benefits of biological emissions mitigation options.”

¹³³ BECA estimates costs for the 24 000 “economically significant farms” (above 10 hectares in size for dairy farms; and above 80 hectares in size for sheep, beef and deer farms).

If only agricultural N₂O emissions are included in the NZ ETS (as the Commission proposes as an option in Chapter 9), the average farm-level ratio of unit costs to the administrative costs of participation would be even less favourable than the BECA estimates. N₂O constitutes less than 25% of all agricultural emissions (expressed in CO₂e). One third of these emissions are due to the use of nitrogenous fertilisers.

Even so, as free allocations are reduced and the value of obligations rises, the economics of using a farm-level point of obligation will improve. Also, if methane emissions are treated separately through a methane quota system (as proposed by the Commission in Chapter 9) advisory services may help farmers with modelling those and N₂O emissions at no extra cost (so reducing the ratio of administrative costs to the value of obligations covered).

To make reporting at the farm level a more practical option, one approach is to limit surrender obligations to farms with total emissions above a certain size threshold. As the BECA study shows, the relative cost of monitoring farms with low emissions is likely to be higher, and the potential emissions reductions lower. Reporting for smaller farms, and surrender obligations, could remain at the processor level.

F11.13

A point of obligation at the farm level would require monitoring, verifying, and enforcing compliance for a large number of small emitters. Carrying out this process for all emitters would likely be costly and difficult. Modifying this approach by, for instance, limiting a requirement for farm-level reporting to farms with total emissions larger than a certain threshold could help to minimise these transactions costs.

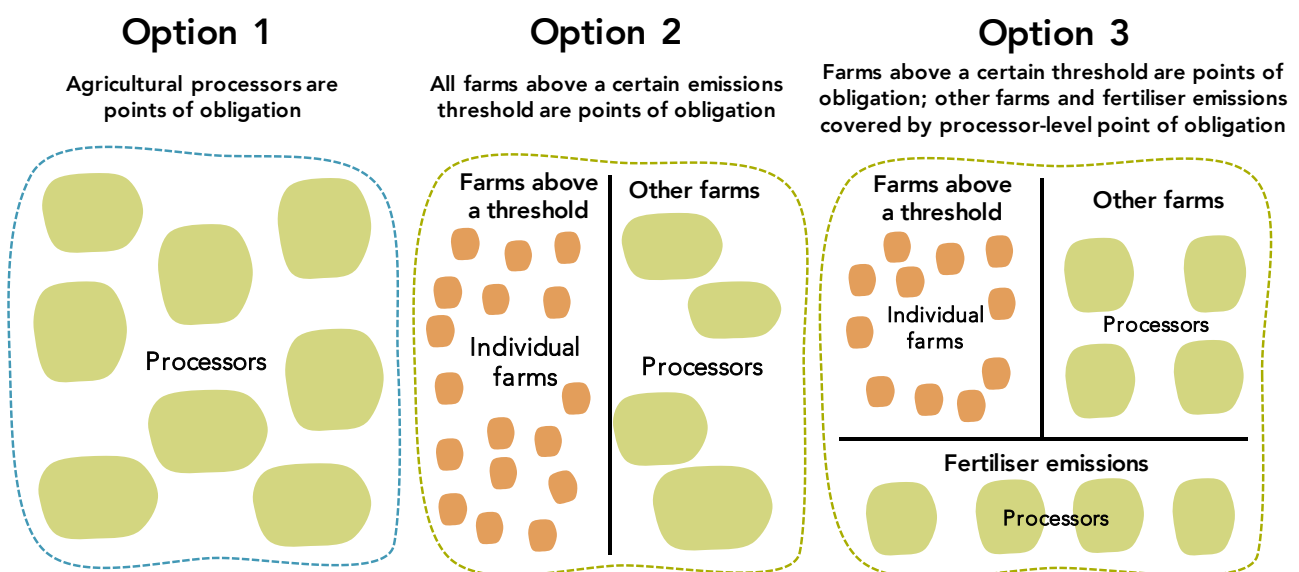
Point of obligation for N₂O emissions arising from fertiliser use

Currently, fertiliser manufacturers and importers report on N₂O emissions arising from the use of fertiliser. If agriculture is brought into the NZ ETS, it would be efficient for these businesses to be the point of obligation. In particular, this would cover the vast majority of biological emissions from horticulture and cropping. OVERSEER treats emissions from fertiliser use separately to those arising from livestock. So a point of obligation at the processor level for fertiliser emissions would be straightforward to administer in conjunction with a point of obligation at the farm level for livestock emissions.

Three broad options for agriculture's point of obligation

The Commission has identified three broad options for a point of obligation for agricultural emissions (Figure 11-6).

Figure 11-6 Options for agriculture's point of obligation for nitrous oxide within the NZ ETS



While Option 1 (processor level) would provide weaker incentives for reducing emissions intensity, it would be less costly to administer and for participants to comply with. It would require greater reliance on other policies to support adoption of on-farm practices and technology to reduce emissions (Chapter 10).

Option 2 (farm level above a certain size) would provide stronger incentives to change on-farm practices and could be more acceptable to the farming community, as it provides farmers with greater flexibility to respond to an emissions price (Emissions Trading Scheme Review Panel, 2011 Federated Farmers of New Zealand, sub. 39; Waikato Regional Council, sub. 48). Even so, some farmers who have higher than average emissions due to factors outside their control (eg, climate, soil type) may feel that a farm-level system is inequitable. Kerr (2009) points out that gaining broad acceptance among farmers of a farm-scale system would be critical for ensuring that the system operates effectively.

The Commission prefers Option 3. This combines:

- a point of obligation at the processor level (ie, fertiliser importers and manufacturers) for N₂O emissions caused by the use of fertilisers (processors would pass this cost on to farmers in proportion to the fertilisers used); and
- a mandatory point of obligation at the farm level for other N₂O emissions (above a minimum threshold); and
- a point of obligation at the processor level for farms that are below the emissions threshold for other N₂O emissions; farms below the threshold could opt for a farm-level point of obligation if they prefer.

The appropriate threshold above which farmers must adopt a farm-level point of obligation can only be determined once a scheme is designed in detail and a more rigorous assessment of costs is undertaken. Any initial threshold could be lowered over time as the value of obligations grows and as technology and business process changes reduce the costs of participating in a farm-level point of obligation. Te Rūnanga o Ngāi Tahu points out that there are precedents in other regulatory regimes (such as the Crown Minerals Act) for different approaches based on the scale of the regulated entity (sub. DR362).

Option 3 has a number of advantages.

- Option 3 will remove horticulture from a farm-level point of obligation as their N₂O emissions are largely due to the use of fertilisers. Yet horticulturalists will still have incentives to reduce fertiliser use taking into account these emissions, as the price will be included in the price they pay processors.
- For other N₂O emissions, farmers below the threshold will be able to opt for a farm-level point of obligation, as many prefer.
- The threshold for mandatory participation at a farm level can be adjusted over time to reflect changes in administrative costs.

BECA (2018) identifies a number of administrative and accounting issues that would need to be resolved in a system that combines farm-level and processor-level points of obligation. Downstream processors would need to account for farms that are in and out, and have to adjust payments to farms and processor-level emissions returns accordingly. Also, the processor-level emissions factors would need to be adjusted over time to take account of the characteristics of farms that had opted out of a processor-level point of obligation.

A large majority of submitters on this issue preferred either a farm-level or a hybrid point of obligation (eg, AgResearch Ltd, sub. DR191; Waimakariri District Council, sub. DR192; Greater Wellington Regional Council, sub. DR195; Rangitikei District Council, sub. DR200; Northland Regional Council, sub. DR226; Chris Livesey, sub. DR247; Sustainable Business Network, sub. DR254; Ballance Agri-nutrients, sub. DR285; Wood Search Marketing Ltd, sub. DR306; Federated Farmers of New Zealand, sub. DR310; DCANZ, sub. DR380; Beef + Lamb New Zealand, sub. DR389). Many acknowledged the trade-off between complexity and cost at the farm level and providing stronger incentives for farmers to adopt low-emissions practices (eg, Fonterra, sub. DR355). Some also pointed out that a minimum size threshold for a farm-level point of obligation could be adjusted over time (Environment Institute of Australia and New Zealand, sub. DR260; New Zealand Farm Forestry Association, sub. DR338).

R11.4

Fertiliser manufacturers and importers should be the point of obligation in the NZ ETS for nitrous oxide emissions caused by the use of fertilisers.

R11.5

The Government should establish a farm-level emissions threshold for the point of obligation for pastoral agricultural emissions not caused by the use of fertilisers.

- Farms with emissions above the threshold should have a farm-level point of obligation.
- Farms with emissions below the threshold should have the option of a farm-level point of obligation.
- Meat and dairy food processors should be the point of obligation for remaining pastoral agricultural emissions not covered by a farm-level point of obligation (and not caused by the use of fertilisers).

The threshold should be adjusted down over time as the cost to farmers of participating in a farm-level point of obligation falls relative to the value of obligations to surrender NZUs.

11.5 Sequestering more carbon in forests

Growing forests sequester carbon that currently offsets around 30% of New Zealand's gross GHG emissions. Accelerated afforestation will play a key role in New Zealand transitioning to a low-emissions economy (section 11.1). A substantial number of submitters supported accelerating afforestation (subs. 2, 12, 15, 19, 31, 67, 71, 77, and 97).

Mature native forests cover 29% of New Zealand's land area, while a further 8% is planted in commercial forests.¹³⁴ For the purposes of GHG emissions accounting, mature forests that replenish themselves naturally, and commercial forests that are harvested and equivalently replanted, are carbon neutral (on natural forests see Holdaway et al., 2016).¹³⁵

Which species, which planting regimes?

MPI told the Commission that it was important that the "right trees are planted in the right place for the right reasons" (pers. comm., 6 December 2017). This partly reflects past experience with bursts of planting for harvest in unsuitable, inaccessible terrain, far from ports and excessively subject to erosion.

Many areas of marginal land are unsuited to harvesting, but suitable for forests that are intended to be permanent and never harvested. The economics of permanent forests or "carbon farming" are very different to planting for harvest. Thinning and pruning may boost harvest values but not carbon sequestration. As a result, permanent forests sequester more carbon and over a longer period than forests planted for harvest (NZCFG, sub. DR293). Permanent forests do not need access to infrastructure for harvesting purposes and are suitable for establishing at scale (NZCFG, sub. 95).

On some marginal lands the most profitable approach, depending on the emissions price, may be simply to plant and leave *pinus radiata* to grow.¹³⁶ With a suitable seed source, unharvested exotic forests could eventually revert to native forests as native species re-establish naturally (M. Anderson, 2016; David Evison and Euan Mason, sub. 27; NZCFG, sub. 95; Forbes et al., 2016; G. M. J. Hall, 2001; E. G. Mason & Morgenroth, 2017). Even so, MPI advised the Commission that there is little evidence that this is a viable

¹³⁴ Of this, regenerating native forests are currently sequestering around 6 megatonnes of CO₂ a year (MfE, 2017f).

¹³⁵ In practice, the sequestration of carbon over time, and so carbon neutrality, will depend on what happens to wood once it is harvested, and, particularly, the durability of wood products.

¹³⁶ Scion submitted that researchers have identified areas in New Zealand suited to planting other species such as *eucalyptus fastigata*, *e. regnans*, *e. goboidea*, *cupressus lusitanica* and *sequoia sempervirens*. Scion noted that *Pinus radiata* is not suited to long-term carbon sequestration as it has a lifespan of less than 100 years (sub. DR366).

option, and that it might require manual killing of exotic species seedlings to prevent the establishment of a self-sustaining exotic forest (pers. comm., 22 December 2017). Carver and Kerr (2017) also note that work on this approach has been limited to date, and see a need for further research to see if this is a cost-effective way of establishing natives.

MPI later advised the Commission that it has identified some relevant research on this question (pers. comm., 7 August 2018). NZCFG submitted that it had established an independent scientific advisory group to examine this question (sub. DR293). Scion submitted that it is leading an MPI-funded research programme on this question, but that it considers that other options are better than planting *pinus radiata* in the hope that it will revert to indigenous tree species (sub. DR366). Dame Anne Salmond also submitted that using strategic planting of berry-bearing native trees to facilitate regeneration of native forest was a better and cheaper option (sub. DR135).

R11.6

The Ministry for Primary Industries (MPI) should review expert research into the potential for permanent exotic forests to convert to native forests and the conditions under which such conversion could reliably and economically occur. MPI should commission further expert research, if this is likely to resolve doubts about the efficacy or not of this approach to establishing native forests.

Some submitters and other commentators have strong reservations about large-scale planting of exotic forests, because of their effects on landscape and cultural values, and biodiversity (Contact Energy, sub. 29; Te Rūnanga o Ngāi Tahu, sub. 83; Wise Response Society, sub. 102; Salmond, 2017a; Timaru District Council, sub. DR396). The Environmental Defence Society (EDS) submitted on the 2016 Review of the NZ ETS:

EDS does not support an ETS configuration that would lead to a massive expansion of monoculture pine plantations across New Zealand's landscape. That can destroy landscape quality and diminish the experiences for our biggest export earner, tourism. (EDS, 2016, p. 2)

The EDS and a number of inquiry participants (eg, Graham Townsend, sub. 15) pointed to the related risk of wildings spreading: "The ETS must not incentivise the spread of these troublesome weeds" (EDS, 2016, p. 2).

The FLG has, on the other hand, suggested that the Government should consider, in some locations, farming wilding pines with a view to native forest eventually replacing them (sub. 1). MPI considers this would not be consistent with international agreements, because simply allowing wildings to grow would not meet the test of "human-induced conversion of land". The expansion of wildings also creates problems for productive or biologically and ecologically significant land, and can disrupt surface and aquifer flows of water (pers. comm., 22 December 2017). Yet, plantation forests also likely have effects on water flows which local authorities regulate; and managing wildings to eventually revert to native forest may meet the test of "human-induced conversion".

Based on current practices, native forests are more expensive to plant (than exotic) (Carver & Kerr, 2017) – though planting at scale could be less expensive (Te Rūnanga o Ngāi Tahu, pers. comm., 22 March 2018). Native forests, left to regenerate naturally, grow slowly and require pest control (RSNZ, 2016). In the first 30 years, native forests sequester only one half or a third as much carbon as *pinus radiata* forest (David Evison, pers. comm., 14 February 2014).¹³⁷ Yet native forests grow and sequester carbon for a much longer period than exotic forests (G. M. J. Hall, 2001). Most native forests are protected from harvesting under the Forest Act 1949 as amended in 1993; and under the New Zealand Forestry Accord (Karpas & Kerr, 2011).

While recognising the rapid uptake of carbon by plantation forests on the right sites, Philip McDermott submitted:

¹³⁷ Dame Anne Salmond submitted that she had looked for peer-reviewed research evidence on native species rates of sequestration but had failed to find any (sub. DR135). Rates will almost certainly vary by geographic area and by species. Other submitters agreed that generally native species sequester carbon at a substantially lower rate than exotics such as *pinus radiata* though potentially over much longer periods (eg, NZCFG, sub. DR293; Scion, sub. DR366).

The diversity of native forests, the slower progress towards maturity, and the adaptation of species and complexes to site conditions offers a more balanced and generally sustainable path to carbon capture and retention. This includes carbon capture throughout regeneration, moving from bracken/scrub, through nursery species (manuka) to semi-mature and mature forests, with a far greater prospect of carbon storage in the undercover than in a monoculture. (sub. DR153, p. 2)

Other types of forests not covered by emissions accounting

Forest & Bird (2018) points out that New Zealand's 7 million hectares of existing native forests store about three times as much carbon as pine forests do. Better pest control in existing native forests will greatly increase the amount of carbon they store. Based on past rates, Forest & Bird estimates that pest control in native forests could help sequester 85 megatonnes of CO₂ each year over the next five years (at much lower cost than alternative ways of reducing net emissions). The Department of Conservation submitted:

New Zealand native forests are a huge carbon reservoir. Investing in their long-term health is a way to ensure that these stocks are secured; and minimising the risk of future CO₂ release from land use change. This is a significant obligation in both the "Kyoto Protocol" and "Paris Accord." (sub. DR370)

To be counted towards meeting New Zealand's international commitments, planting to sequester carbon must meet certain conditions. These include a requirement that the carbon removals are anthropogenic and additional (in the sense that such removals would not otherwise have occurred). As a practical matter such removals must be able to be accounted for at a reasonable cost, and be able to be monitored over time to ensure their longevity. Such accounting conventions and practical considerations flow through to specific forest accounting rules for the purposes of the NZ ETS. For instance, only forest species that can attain a mature height of 5 metres or more are included (MPI, 2018a). This could exclude, for instance, mānuka grown for the purposes of extracting and harvesting honey.

Availability of land for forestry of different types

Suitability of land for different types of forestry depends very much on local conditions and the economics of alternative uses. Generally, forestry is not an attractive alternative to dairying (where land prices are high) and further conversions are much more likely on marginal land on sheep and beef farms, or marginal land not currently in production (Kerr et al., 2012; Reisinger et al., 2017). But if the land is to be used for harvest planting, it needs to be on suitable terrain, and accessible for logging and transport to ports or downstream processing. The economics of alternative uses will also depend on the prospective price of carbon over the growing period and at harvest and the price of timber at harvest. Small foresters also face cashflow challenges given the 25–30 year wait from planting to harvest.

Several broad analyses of land types in New Zealand conclude that ample land is available for further afforestation. E. G. Mason and Morgenroth (2017), for example, identify 1.3 million hectares of highly erodible land that could be used for planting forests.¹³⁸ Planting would require "minimal" livestock reductions and would have co-benefits in reducing erosion and siltation of waterways (p. 13).

New Zealand Carbon Farming Group (NZCFG) works in partnership with several large emitting companies and with iwi to plant permanent forests on its own and other land. It has raised the possibility of planting on government-controlled land. It estimates, from sub-block analysis, that the Government has 2.89 million hectares of marginal land under its ownership or control and urges the Government to show leadership in enabling planting on this land (sub. 95).

MPI has done initial work on potential afforestation on Crown lands, focusing primarily on Public Conservation Land. It has identified 59 000 hectares as possibly suitable for afforestation (pers. comm., 22 December 2017).¹³⁹ Even this is subject to establishing that the land would count as an eligible 'post-1989' forest under NZ ETS rules. In many cases, the land parcels are small and not likely to be economically viable as forests; some land is subject to Treaty of Waitangi settlements; pastoral leasehold land does not accord afforestation rights; and conservation land is managed for conservation purposes, which is likely

¹³⁸ Some land may be unsuitable for plantation forestry because it is too susceptible to erosion during planting and harvesting, or it creates an undue risk of spread of wildings, or it may have environmental and aesthetic values that planting would compromise. The National Environmental Standards for Plantation Forestry that came into force on 1 May 2018 set conditions around approval by regional councils and territorial authorities for planting on such land (MPI, 2017e).

¹³⁹ The Department of Conservation asked that this estimate should be caveated and noted that the purpose of Public Conservation Land is incompatible with exotic forestry (sub. DR370).

incompatible with planting exotic forests (pers. comm., 22 December 2017). MPI has been continuing to carry out analysis of land availability (pers. comm., 9 August 2018), with the involvement of the Department of Conservation (sub. DR 370). Scion submitted that it has the experience to contribute to this analysis, through its leading MfE's LUCAS (Land use and carbon analysis system) programme (sub. DR366).

F11.14

New Zealand has sufficient suitable land to greatly expand afforestation to sequester carbon. This land includes over a million hectares of highly erodible land unsuited to pastoral agriculture (though some of this is also unsuited to forestry). The land is both privately and publicly held. The availability of privately held land will depend on the economics, including the prospective price of NZUs over the growing period and at harvest. The availability of government-controlled land for further afforestation is uncertain.

R11.7

The Ministry for Primary Industries, working with Land Information New Zealand and Landcare Research, should undertake a complete audit of the availability of government-controlled land suited for afforestation (whether native or exotic), and develop policy options that would cost-effectively establish forestry on such land as is available.

11.6 Sequestering carbon in non-forest sinks

Carbon stored in soils accounts for a substantial part of global carbon stocks. Far more carbon is present in soils than in the atmosphere or in live plants and animals (Meduna, 2017; Schwartz, 2014). A small percentage increase in the amount of carbon stored in the world's soils (as little as 0.4% a year) could entirely offset fossil fuel emissions (see eg, Locke, 2015; Wise Response Society, sub. 102; Clare St Pierre, sub. 115). Historically, the cultivation of soils has led to a loss in soil carbon in many places (as much as 50% to 70% in the North American prairies and the north China plains, for instance) (Schwartz, 2014).

The amount of carbon present in soils is closely associated with the type of vegetation growing on it, and, when farmed, the regime used to manage successive crops and to maintain pastures. Global carbon stocks can be substantially increased by changing the way land is used, and by improving farming practices. The depth of plant roots and the associated mycorrhizal fungal activity influences the amount of soil carbon.

New Zealand pastoral soils already have relatively high levels of soil carbon (on average around 106 tonnes of carbon a hectare (McNally et al., 2017; Clare St Pierre, sub. 115; Reisinger et al., 2017). Yet scope exists to increase soil carbon on pastoral land, while raising productivity. This is achievable through better management (such as using deep-rooted pasture plants, optimising the use of fertilisers and reducing tillage) (Tony Banks, sub. 3; Ross Clark, subs. 24, DR209; Auckland Council, sub. 97; Wise Response Society, sub. 102; Clare St Pierre, sub. 115; Chris Hook, sub. DR157; Derek Parkes, sub. DR138). McNally et al. (2017) estimate a theoretical potential for increasing soil carbon under New Zealand pastures ranging from an extra 10 to 42 tonnes a hectare – enough to offset the increase in agricultural GHG emissions between 1990 and 2014.

Even so, Meduna notes that, while even increases of less than 1% in soil carbon could mitigate current emissions, “[i]t is always contingent on soil type, management practice and climate, and the costs of measuring soil carbon can be significant” (2017, p. 1). The effect of different practices in different situations on soil carbon is not well understood. Soil carbon increases over time on hilly sheep and beef farms with less intensive stocking, but tends to decline on flat-land pasture (Meduna, 2017). While McNally et al. (2017) and Ballance Agri-Nutrients (sub. 34) argue that irrigation can increase soil carbon by increasing the production of plant dry matter, other researchers have found that, at least in some circumstances, irrigation decreases soil carbon (Meduna, 2017; NZAGRC, 2017). The NZAGRC is undertaking research to better understand how farm management practices influence soil carbon (Dairy New Zealand, sub. 18; NZAGRC, 2017). Even so, Scion expressed strong scepticism about the ability to reliably measure changes in soil carbon (sub. DR366).

The New Zealand GHG Inventory (MfE, 2017f) accounts for soil carbon changes only when land use changes. The changes in soil carbon are estimated from a model based on representative soil samples and data on climate, rainfall and terrain. No credit is given in international GHG accounting, or in the NZ ETS, for increasing soil carbon within an existing land use (Meduna, 2017). The difficulties in understanding the complex interactions of different management practices and their effects on soil carbon, and of measuring changes in soil carbon at the farm level, pose challenges for recognising soil carbon sequestration through the NZ ETS.

Other submitters favoured non-forest carbon sequestering species such as miscanthus (GP International Ltd., sub. 20). The Bioenergy Association submitted on the NZ ETS review, “NZ experience is that Miscanthus dry matter production is two to three times that of radiata pine and hence up to ten times that of planted indigenous forest” (Bioenergy Association, 2016, p. 6).

Yet other submitters pointed to further ways to sequester carbon that currently are not accounted for in the NZ ETS nor in the New Zealand Greenhouse Gas Inventory. The Department of Conservation, for instance, pointed to carbon sequestered in wetlands, peat swamps and in estuaries and other marine environments such as mangroves and coastal wetlands (sub. DR370). The Department pointed out that such environments provide both mitigation and adaptation advantages. Wetlands and mangroves not only sequester carbon, but also provide a natural defence against inundation and extreme weather events.

11.7 Forestry in the NZ ETS

New Zealand is the only country that currently includes forestry in an ETS. Participation in the NZ ETS is mandatory for pre-1990 planted forests and voluntary for post-1989 forests. The main features of the NZ ETS for forestry are (Carver et al., 2017):

- at harvest, owners of pre-1990 forest land must surrender NZUs equal to the resulting reduction in carbon, but can avoid this obligation by replanting (including equivalently in another location) or facilitating natural regeneration (without earning credits for new growth);
- participating post-1989 forests earn NZUs for net carbon sequestered from the time they are registered, and must surrender NZUs (equal to the resulting loss of carbon) at the time of harvest (up to the value of the credits received); if the land is deforested, they must surrender any remaining NZUs earned; and
- forests of more than 100 hectares must use a field measurement approach to assess carbon stocks; smaller forests must use look-up tables.

To date, the NZ ETS has been largely ineffectual in stimulating more afforestation, mostly because of uncertainty around policy and a very low emissions price for much of the period (Carver et al., 2017; subs. 1, 13, 18, 27, 35, 40, 46, 48, 67, 73, 97, 102, 115, and 127; MfE, 2016c). Only around 45% of eligible post-1989 forest land is registered in the NZ ETS. In 2015 around 2 200 participants were registered, covering an area of a little over 300 000 hectares (Carver et al., 2017).

Should forestry remain in the NZ ETS?

Some participants have told the Commission that forestry should not be in the NZ ETS. They argue that because forestry offers a relatively low-cost way to mitigate emissions, this will keep the emissions price low. As a consequence, other emitting sectors will not face strong incentives to reduce their emissions. Options for more forestry will, in the medium term, run out, as suitable land is used up. This outcome will leave New Zealand with substantial gross emissions around the middle of this century (eg, David Evison, pers. comm., 14 February 2014; Parliamentary Commissioner for the Environment, sub. DR387). Participants with these views usually recommend that forestry is incentivised through subsidies outside the NZ ETS. The subsidies could be funded from the proceeds of auctions of NZUs.

The modelling of transition pathways in Chapter 3 shows that forestry does offer New Zealand a cost-effective way to reach low or zero net emissions by 2050. Relative to its population size and national emissions, New Zealand has a very large land area suitable for forestry. As a result, the emissions prices needed to achieve very low emissions are moderate compared to international emissions prices consistent

with meeting the Paris Agreement goals (Stiglitz & Stern, 2017). Yet, though net emissions are low or zero in all scenarios, substantial gross emissions remain in 2050, ranging from 47 to 59 megatonnes of CO₂e. This illustrates that forestry is an interim rather than a permanent solution to reducing net emissions.

Even so, sectors causing emissions should anticipate a future when mitigation options through forestry will no longer be available or, at least, will be more expensive as the most suitable land is used up. Unless other low-cost mitigation technology has emerged, emitting sectors will anticipate that the emissions price will rise and factor this into their investment decisions. Doing so will steer them towards lower emissions options. Given the long life of many investments (such as boilers for process heat; or refurbishing an industrial plant), the future emissions price is as relevant to these decisions as the current price.

Forestry now has a decade of experience with the NZ ETS with systems established to support participation and significant understanding of how the scheme works. While the scheme can be and should be improved, the Productivity Commission considers that it is best to build on this experience, rather than discard it.

F11.15

Forestry offers New Zealand a path to reducing net emissions to a very low level or to zero by 2050 at moderate cost. Yet a risk remains that a low or moderate emissions price will, at least for a period, weaken incentives for other sectors to reduce emissions. Even so, as forestry options to sequester carbon are used up over the next 30 to 50 years, they will become more expensive. Emitters who anticipate a rising emissions price will instead seek non-forest options to reduce emissions.

Proposed improvements to the treatment of forestry in the NZ ETS

During 2015 and 2016 the previous government reviewed the NZ ETS. That review included a specific focus on forestry (MfE, 2015b, 2016d, 2016e, 2017h). Three main issues emerged.

- The complexity of participation for small forest owners relative to the size of their operation. Hughes and Molloy (2017) calculate that the administrative costs for foresters who participate are around \$3 000 a year – and that foresters risk facing penalties around accounting rules (NZIF, sub. 73; Waikato Regional Council, sub. 48). The NZ ETS essentially provides a single, once only cash inflow for foresters; so, complexity can easily outweigh any advantages of participation for small forest owners.
- The possible use of “averaging” to reduce uncertainty about liabilities at harvest for forest owners; if replanting, averaging would allow owners to earn credits up to the long-term average carbon sequestered, without having to surrender them at harvest.
- The possible recognition of carbon sequestered in harvested wood products (HWPs) – a recognition that might reduce foresters surrender liabilities at harvest.

As a result of the review, the previous Government announced (MfE, 2017n) that it would:

- look at a range of possible improvements to forestry operational settings to reduce complexity (subs. 39; 50, 71, 88 and 115 seek reduced complexity and other operational improvements in the NZ ETS);
- seek better alignment between the NZ ETS and other carbon forestry schemes such as the Permanent Forest Sinks Initiative (PFSI); and
- look at averaging as a way to reduce barriers to participation in the NZ ETS.

Oji Fibre Solutions (sub. 71) supported averaging. On the other hand, NZCFG (subs. 95, DR293) opposed making “averaging” compulsory, as it would not fit with their permanent forest business model. Carver et al. (2017) favour averaging, but point out that averaging would blunt incentives to optimise carbon sequestration through adjustments to pruning regimes, planting density and rotation length. Rules would be needed to cover forest management for those choosing to use averaging. Catherine Leining submitted that an average approach should maintain incentives to plant permanent native forests (DR279). As NZCFG submitted, this would be achieved by making averaging a voluntary option.

Other approaches to reducing the administrative burden and risks of participation for small forests include using aggregators to manage the administrative arrangements (Karpas & Kerr, 2011) and using financial instruments to manage the risks associated with price uncertainty (Deidre Kent, sub. 87; Coleman, 2011; D. Hall, 2017a). The Afforestation Grants Scheme (AGS) currently provides a way for small forests to be rewarded for planting without taking on the full risks of participating in the NZ ETS (Box 11.5).

Box 11.5 Government grants for afforestation and the NZ ETS

The Afforestation Grants Scheme (AGS), established in 2008, is currently funded for five years up to 2020 to encourage new forest planting. Applications are prioritised, if necessary, for their contribution to environmental outcomes. The programme is on track to establish 15 000 hectares of new forests over this period, and a total of \$19.5 million has been allocated to support this. In the year to June 2017, grants totalling \$3.9 million were disbursed. Grants are limited to forests of between 5 hectares and 300 hectares at a rate of \$1 300 a hectare. Grantees are prohibited from receiving NZ ETS carbon credits for a period of 10 years (MPI, 2017a). David Evison and Euan Mason (sub. 27) note that up to 2012 the AGS had led to 12 000 hectares of new planting, the amount being limited by the allocation of government funding.

The Permanent Forest Sinks Initiative (PFSI) requires a commitment from participants to continuous forestry cover for 99 years, in return for which they receive credits for the carbon sequestered. The initiative, administered under the Forests Act 1949, was designed before the NZ ETS was set up, and, in effect, runs parallel to the NZ ETS. Yet, since 2015, NZUs have been the only credits available through the PFSI. Reviews in 2011, 2013 and 2016 all looked at the means to better align administration of the PFSI and the NZ ETS, but deferred substantive decisions. In the longer run, a high enough emissions price might induce more forest to be held permanently (Tunakino Forestry, 2016).

The Erosion Control Funding Programme had funding for four years to June 2017 of \$23 million. It has supported afforestation of 42 000 hectares since its inception, with almost 1 500 hectares approved for planting in the last financial year.¹⁴⁰ Its focus is increasingly on the most erosion-prone land on the East Coast (MPI, 2017a).

Submitters also supported giving greater recognition to carbon sequestered in HWP (subs. 19, 34, 39, 46, and 127) but without adding complexity (subs. 48 and 127). Carver et al. (2017) consider the treatment of HWP. They argue that it would be best to keep this simple by “[e]stablishing a national average for what products harvested trees are turned into and using this to adjust NZ ETS liabilities [or alternatively incorporating] emissions from HWP and on-site residuals into subsequent carbon look-up tables” (p. 33).¹⁴¹ The Morgan Foundation favours a similar approach (sub. 127). The New Zealand Institute of Forestry (NZIF) suggested, on the other hand, that the wood processing sector should be allocated credits for carbon sequestered in HWP (sub. 73). As the Morgan Foundation argues, this would add considerable complexity to the NZ ETS, and other policies could be used to support more wood processing and use of wood products downstream (see Chapter 16).

F11.16

Only a minority of eligible foresters participate in the NZ ETS. Many owners of small forests find participating in the NZ ETS costly and risky relative to any benefits afforded by earning New Zealand Units. Simplifying administration of the NZ ETS for small forests, allowing an averaging approach to surrender obligations over time (on a voluntary basis), and providing policy certainty are all ways to encourage more forest owners to participate.

¹⁴⁰ Funding for the Programme has been incorporated into a new appropriation that runs until June 2021 (MPI, 2017a).

¹⁴¹ Manley and Evison (2017) show that 53% of New Zealand’s national harvest is exported, of which 96% goes to three countries – China, South Korea and India. Carbon stocks in timber exported to India, China and South Korea are halved within one, two and 12 years respectively, and, in aggregate, in just over two years.

Many submitters supported simplifying participation on the NZ ETS for forestry and recognition of HWPs (eg, Taranaki District Council, sub. DR188; Waikato Regional Council, sub. DR227; Venture Taranaki, sub. DR255; Wellington City Council, sub. DR276; Genesis Energy, sub. DR301). In August 2019, the Government issued a discussion paper on options to improve provisions for forestry in the NZ ETS (Te Uru Rākau, 2018a). Broadly the main options are as follows.

- The Government could introduce an averaging approach to simplify accounting for carbon sequestered in new post-1989 forests. The Government estimates that changes to accounting in the NZ ETS would drive much higher rates of planting and “could increase forestry’s contribution to our 2030 climate change target from 18 million tonnes to 32 million tonnes” (p. 9).
- The Government could establish a permanent forestry category in the NZ ETS (this could replace the PFSI). The Government’s preferred option is to use the current carbon stock change accounting process for such forests. Participants in this category would be unable to clear fell their forests for a period of 50 years. There could be options for rotational forest participants to transfer to the permanent forestry category after the first rotation.
- The Government could introduce recognition of carbon stored in HWPs in a way that would match the approach it intends to follow in meeting its international climate-change mitigation commitments. The Government could separately assist the forestry sector to develop longer-lived wood products.
- The Government proposes a suite of operational improvements to make it easier for forest owners to participate in the NZ ETS and to do so with greater certainty.

R11.8

The Government should continue to refine the NZ ETS for forestry to make it easier and less risky for small foresters to participate; and to provide recognition for carbon sequestered in harvested wood products.

Complementing pastoral agriculture with forestry

Pastoral land, particularly sheep and beef farming, includes many areas that are not particularly productive for agriculture, but which could support forests for harvest or permanent forests (Karpas & Kerr, 2011). This could include planting trees in riparian areas fenced off to protect water quality. Many submitters and others supported options to make on-farm and riparian planting more attractive, for instance by making such planting eligible for emissions credits (subs. 18, 22, 37, 39, 48, 67, 68, 88, 98, 115 and 127, DR362, DR396). Beef and Lamb NZ is currently undertaking an assessment of existing woody vegetation on sheep and beef farms, “with preliminary indications that it is in the millions of hectares” (sub. 98, p. 4).

D. Hall (2018) points out that policy makers and popular perception currently see the landscape as divided into sharply different categories such as “forest” (native and exotic) and “farm.” In fact, a range of mixed land uses is likely both to reflect reality better and to provide for better environmental outcomes. Scion also advocated an “integrated land usage approach ...growing both niche and emerging new primary sectors, and cross-sectoral and multi-sectoral land use” (sub. DR366, p. 65). The Bioenergy Association advocated growing energy crops (for instance in woodlots) in conjunction with food crops (sub. DR352). Other submitters advocated planting of other crops such as hemp and mānuka (Northland Regional Council, sub. DR226) and miscanthus (section 11.5). The US Department of Agriculture has investigated the potential for carbon accounting in such land use types, including both “silvo-pasture” and “agro-forestry” (Schoenberger et al., 2017). Yet, as discussed below, finding internationally robust ways of accounting for such carbon sequestered in silvo-pasture or agro-forestry remains elusive.

Reisinger et al. (2017) investigated the economics of on-farm forestry options for the Biological Emissions Reference Group. Generally, the study concluded that forestry (on between 10% and 30% of land) reduced the profitability of the average sheep and beef farm, but by much less than for the average dairy farm. For some sheep and beef farms, forestry on marginal land would be profitable even without an emissions price. The implied cost of mitigation across all options ranged from less than \$10/tCO₂ to \$35–\$45/tCO₂ depending on the type of forest. Most costs were due to effects on the profitability of the pastoral activity

(particularly spreading fixed costs over a smaller base), rather than the direct costs of afforestation.¹⁴² Reisinger et al. (2017) note that the economics of planting trees on pastoral land are highly dependent on individual farm characteristics. More fine-grained regional analysis would be required to identify profitable and practical ways to combine afforestation with pastoral farming.

Some inquiry participants argued that the NZ ETS accounting rules should be amended to include smaller areas of planting (eg, Waikato Regional Council, sub. 48; Molly Mellhuish, sub. 79; Federated Farmers of New Zealand, pers. comm. 21 September 2017). Current accounting rules mean that technically relevant plantings (eg, riparian plantings of less than 30 metres wide) are not included in the NZ ETS. New technology could allow finer-scale definition of forest plantings for the purpose of the NZ ETS.

Yet MPI point out that the NZ ETS might not provide sufficient financial incentive to include small “standalone” areas of trees. For instance, riparian planting at 5 metres wide would generate between 3 and 8 NZUs a kilometre each year, providing between \$60 and \$160 in income. Against this, the fees associated with the NZ ETS are at least \$500 to register and \$102 for returns to claim units (MPI, pers. comm., 22 December 2017).

Other difficulties might also limit planting. Marginal farm land may be scattered in small parcels, creating management difficulties and increasing the cost of fencing. Marginal land may be inaccessible for harvesting or have high harvest costs and so limit planting to permanent forests. Pastoral farmers may see scrub and trees as undesirable and may not warm to the idea of on-farm planting (Karpas & Kerr, 2011; David Evison & Euan Mason, sub. 27). The FLG and Scion submitted that pastoral farmers are likely to have less knowledge about forestry; so, they may have heightened perceptions of risk (subs. 1 and 67).

Aggregation of small areas of on-farm planting, both on individual farms and across farms, could reduce the administrative costs of receiving recognition for the carbon sequestered and make it more economic to do so (Te Rūnanga o Ngāi Tahu, pers. comm., 22 March 2018). DairyNZ proposed a hybrid approach combining on-farm planting with purchasing carbon offsets elsewhere. It recommends

establishing an afforestation scheme for the agricultural industry, which captures the carbon sequestered from shelter belts and riparian planting and includes additional mechanisms to incentivise afforestation. It could include community based afforestation blocks where farmers collectively purchase land for the purposes of carbon sequestration. It could enable Dairy companies to plant trees to offset on-farm emissions which make up 85 percent of the dairy supply chains footprint on behalf of suppliers. This would be similar to Air New Zealand’s afforestation scheme where they plant trees on behalf of their customers who voluntarily opt into the scheme. (sub. 18, p. 13)

Small-scale and riparian plantings do not currently count towards meeting New Zealand’s emissions-reduction targets. Any accounting change would need to be able to credibly demonstrate additionality. While future technology may facilitate aggregation for accounting purposes, any changes in accounting for NZ ETS purposes would need to fit with international conventions, if this was to benefit New Zealand in meeting its international net emissions reduction commitments (MPI, pers. comm., 7 August 2018).

Potential for sequestering carbon on farms in ways not currently eligible in the NZ ETS

Burrows et al. (2018) investigated the potential for carbon sequestration on farm land in ways that were not currently eligible for participation in the NZ ETS. They carried out “desk-top” research to look at small woodlots, shelterbelts, riparian strips, pole planting and natural wetlands, noting that available information was deficient. They found that, in aggregate, the potential for carbon sequestration through these means was modest. Small woodlots might sequester 1 Mt CO₂e each year (up to 2050) if established on 0.4% of agricultural land. Riparian strips of 10m on half the length of New Zealand’s streams and rivers would sequester a further 0.7 Mt CO₂e each year. If existing peatland was retained, wetlands on farms would sequester less than 0.1 Mt CO₂e each year. The study found that these forms of sequestration would offset at most only a minor proportion of pastoral farming emissions.

This study did not look at forestry woodlots that would meet NZ ETS eligibility criteria or indigenous forest areas on farms. Beef + Lamb New Zealand submitted that a recent study (about to be released) showed that

¹⁴² The study did not include the costs of off-farm infrastructure and supply chains and risk premiums (raised by reducing flexibility in farm operations). Nor did it include changes in land value.

there are more than 1.3 million hectares of native forest on sheep and beef farms (sub. DR389; Norton & Pannell, (2018)). Whether and the extent to which this forest would be eligible for participation in the NZ ETS is not currently known. This would depend on its age, canopy coverage, tree height and extent.

The modest potential for yearly sequestration of carbon on currently “non-ETS” farm land identified by Burrows et al. (2018) (less than 2 Mt CO_{2e}) compares with the almost 24 Mt CO_{2e} currently being sequestered by forests across New Zealand each year (MfE, 2018d).

Many submitters on the draft report supported policies that would enable on-farm planting not currently covered by the NZ ETS to be rewarded (subs. DR188; DR 191; DR192; DR226; DR285; DR306; DR310; DR317; DR334; DR365; DR372; DR378; DR380; and DR389) Allowing this would help gain the support of farmers for participating in the NZ ETS in relation to their biological agricultural emissions (Chris Livesey, sub. DR247). Yet, while a few submitters pointed to modern satellite and other imaging technology that might facilitate this (Steve Cranston, sub. DR442; Sustainable Business Networks, sub. DR254; New Zealand Farm Forestry Association, sub. DR338; Environment Institute of Australia and New Zealand, sub. DR260), none was able to suggest proposals that would overcome difficulties of high administration costs relative to rewards, or align with international accounting rules.

Te Uru Rākau (2018a), in its discussion paper on proposed revisions for forestry in the NZ ETS, advised that the Government does not intend to alter the NZ ETS eligibility criteria to include riparian margins,

- because the financial benefit for farmers is likely to be small;
- to avoid incentives to plant trees that are less effective in promoting water quality, have higher maintenance costs and risk flood debris; and
- to avoid misalignment with international accounting rules.

F11.17

Any feasible on-farm planting outside the current NZ ETS eligibility criteria for forests would make only a minor contribution to off-setting New Zealand’s annual gross GHG emissions. Under current international GHG accounting rules, such off-sets could not be used to meet New Zealand’s international climate change commitments. Also, the financial benefit for farmers would likely be small.

The question of small on-farm planting being eligible for the NZ ETS could be revisited in the future. Feasibility would depend on international GHG accounting conventions changing to include smaller plantings, and technology emerging to cost-effectively and reliably monitor carbon sequestered in such plantings. Aggregation for accounting purposes would also be required, so that the rewards to participating landowners outweigh the administrative costs.¹⁴³ New Zealand, of course, has a voice in international fora that decide GHG accounting conventions. In the meantime farmers will continue to plant in ways not eligible for the NZ ETS, but for other benefits such as improving water quality and reducing erosion.

What emissions prices will result in increased forest planting and less deforestation?

The modelling of transition pathways reported in Chapter 3 shows that emissions prices (in the range from \$70 to \$250 per megatonne of CO_{2e}) will incentivise large areas of new forest planting (in the range from 1.3 million to 2.8 million hectares).

A range of previous studies have also estimated the potential effects of an emissions price on net afforestation in New Zealand (Adams & Turner, 2012; Kerr et al., 2012; Manley & Maclaren, 2009). The studies use a variety of models and assumptions about an emissions price, but come to similar conclusions that a price in the range of \$20 to \$25 would stimulate net afforestation of an additional 250 000 to 300 000 hectares in the period from 2008 to 2030. Most of the estimated effect on afforestation results from the conversion of marginal sheep and beef land (Kerr et al., 2012).

¹⁴³ New Zealand Carbon Farming recommended contestable government funding for more research on these issues (sub. DR293).

These conclusions are consistent with the results of yearly surveys of deforestation intentions which show that as the price of NZUs has risen in the last few years, deforestation intentions have fallen (Manley, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017). Even so, other policies that price or otherwise regulate the externalities from alternative land uses, such as nitrate leaching, are likely to be having a larger effect than an emissions price on net afforestation rates, in regions where they apply (Manley, 2017).

New Zealand Carbon Farming Group (NZCFG, 2016), in its submission on the review of the NZ ETS, argued from its own experience and business analysis, that at prices of more than \$19 for a NZU, the volume of planting could easily exceed 50 000 hectares each year. More recently, NZCFG told the Commission that it had planted 25% of all the new forests planted in 2011 and 2012, when the price of a NZU was \$20. When the price collapsed in 2013 NZCFG had no choice but to suspend planting. As noted in its submission: “If the price moved again to an appropriate level and there was certainty in terms of current and future policy settings, we would recommence our planting program at large scale” (sub. 95, p. 13). If the price were above \$18.50 and there was policy certainty, NZCFG could commit to planting 20 000 hectares of new forests.

Yet, as more land is planted in forests, planting on additional land is likely to become ever more expensive over time, as the modelling of transition pathways in Chapter 3 shows. This is because either suitable cheaper land options have been exhausted; or because it is more expensive to plant and manage forests on remaining available lower-price land.

F11.18

Emissions prices above \$20 and rising to \$70 and above for a NZU in the NZ ETS will likely lead to a substantial increase in afforestation rates, mostly on marginal land currently used for beef and sheep farming. A rising emissions price is likely required to incentivise sustained afforestation over future decades.

Accelerating afforestation

Rapidly planting forests is a key part of a transition to a low-emissions economy (section 11.1). A revamped NZ ETS will take time to put in place and to earn the confidence of investors. In the meantime, the new Government has announced a target of planting one billion trees over the next 10 years, partly as a regional development initiative and partly to accelerate carbon sequestration (Z. Wilson, 2017). It is using Crown Forestry to develop opportunities for the planting of forests. Crown Forestry looks to lease land suitable for harvest, or to enter into joint ventures with owners. Owners may be eligible to receive NZUs for the carbon sequestered on their land.

The Government has now established Te Uru Rākau as a unit within MPI to cover the role of Crown Forestry and other forestry-related functions of MPI. The Government is currently working on the exact scope, size and governance functions of Te Uru Rākau. The agency now has the lead role on the one billion trees programme (Jones, 2018a).

Crown Forestry is a commercial trading entity and a functional unit within MPI which manages the Crown Forest Estate. In 2017 this covered 16 forests with a total area of 14 300 hectares, mostly on Māori-owned land; six afforestation leases on Crown forest land; and three forestry loans to the Dunedin City Council (MPI, 2017c). Forest management companies undertake the day-to-day management of Crown Forests. The previous policy was for Crown Forestry to exit from commercial forestry by selling assets on commercial terms. This included selling forest assets to Māori owners of the land on which the forests are situated. In addition, Crown-owned land (and sometimes trees) can be transferred as part of Treaty settlements (MPI, 2017c).

MPI expects that around 500 000 hectares of existing plantation forest will be replanted over the next ten years, though this will have no effect on New Zealand’s emissions accounts (pers. comm, 22 December 2018). At a typical planting rate for *pinus radiata* of 1 000 stems a hectare (Farm Forestry New Zealand, 2007), this would fulfil half of the Government’s planting target. The remainder would require planting an extra 50 000 hectares each year (around the rates achieved during the 1990s).

The potential for the Government to lease substantial areas of land on commercial terms for afforestation (or to enter into joint ventures with landowners) is in the early stages of being demonstrated. Pending revision to the NZ ETS and its provisions for afforestation, the Government may also need to consider an expansion of its current afforestation subsidy programmes (section 11.4). This could be roughly fiscally neutral, by setting the subsidy level to match the emissions credits kept by Government for a defined period. The programmes have the advantage to smaller foresters of reducing the emissions price risk and administrative costs, and smoothing cashflows (though proposed revisions to the provisions for forestry in the NZ ETS will also address these issues).

By August 2018, over 59 million additional trees had been planted since the one billion trees programme was announced. Sixty-seven million seedlings had been sold for planting in 2018, of which more than 6 million were funded by the Government. Of trees planted, 13% were native and 87% exotic (Te Uru Rākau, 2018b). By this date, the Government had allocated over \$485 million from the Provincial Growth Fund to the programme. This included three years funding for two initiatives. The first provides \$118 million to help landowners, government agencies, iwi and non-government organisations (NGOs) plant or regenerate native forests. The second, \$120 million, seeks to work with regional councils, training organisations, Māori landowners, NGOs and community groups on a range of initiatives to establish planting. The Minister of Forestry, Hon. Shane Jones said:

This approach will allow us to leverage co-funding opportunities and existing know-how and experience. We'll be looking at promoting innovation, securing sufficient labour to get trees in the ground and providing support and advice to landowners on how they can improve land use. (L. Bennett, 2018)

In 2015, forests of more than 1 000 hectares accounted for over 60% of forests registered in the NZ ETS. Overseas investors are potential sources of capital to fund afforestation at scale (CCILG, 2016b). The Commission understands that a number of large investors in Australia and North America are willing and ready to undertake such investments. Purchase of land for forestry by overseas investors is subject to the Overseas Investment Act 2005. The Government has made the sale of forestry rights also subject to the Act, while at the same time streamlining and liberalising the application process to give overseas investors more certainty (The Treasury, 2018b). Forestry rights of less than 1 000 hectares a year are exempt (The Treasury, 2018a).

11.8 Māori and land in a low-emissions economy

Māori are substantial owners of productive land, including an estimated 30% of land under plantation forests, 10% of kiwifruit and dairy production and 25% of sheep and beef production (MPI, 2017b, p. 11). Almost 40% of Māori freehold land is covered with native forest (Harmsworth et al., 2010).¹⁴⁴ What Māori do with their land is crucial for their economic and social wellbeing (Federated Farmers of New Zealand, sub. 39). It will also have a significant impact on New Zealand's transition to a low-emissions economy.

Māori have multiple interests in, and likely a range of views on, land use. They are, for instance, landowners under different ownership arrangements, such as individually owned land (under general title) and collectively owned land (under Te Ture Whenua Maori Act 1993), as well as land held by iwi as an outcome of Treaty of Waitangi settlements. Māori have interests as farmers and foresters and as owners and employees of farm-supply or primary-produce-processing businesses. More generally, Māori have ancestral ties to the land. This will have a significant influence on how land is used over time (Emissions Trading Scheme Review Panel, 2011).

Māori have an ancestral and multigenerational relationship with the land

Māori have strong cultural and spiritual connections with their land, protected under New Zealand law. In particular the Resource Management Act 1991 recognises that Māori, as tangata whenua, have an ancestral relationship with the land (ADLS, sub. 7). This relationship gives rise to the ongoing rights and responsibilities of kaitiakitanga.

¹⁴⁴ The four different types of Māori land are customary land, Māori freehold land, general land owned by Māori, and Māori reserve land. Comprehensive and definitive data on how all types of Māori land are used are not available. Harmsworth et al. (2010) provide a detailed analysis of current land use based on the Māori Land Information Base held by Te Puni Kōkiri and the Land Cover Database held by the Ministry for the Environment.

Kaitiakitanga “denotes the obligations of stewardship and protection ... [and] is most often applied to the obligation of whānau, hapū and iwi to protect the spiritual wellbeing of natural resources within their mana” (New Zealand Law Commission, 2001, p. 40). Kaitiakitanga is closely linked to whanaungatanga – the organisation of relationships through whakapapa or familial connections. The Waitangi Tribunal explains:

Kaitiakitanga is really a product of whanaungatanga – that is, it is an intergenerational obligation that arises by virtue of the kin relationship. It is not possible to have Kaitiakitanga without whanaungatanga. In the same way, whanaungatanga always creates kaitiakitanga obligations. (Waitangi Tribunal, 2011, p. 105)

In a similar vein, Te Rūnanga o Ngāi Tahu (sub. 83) submitted:

Kaitiakitanga is about ensuring that future generations have a relationship with Te Ao Tūroa (the natural world) that sustains them in the way that generations before have been sustained. (p. 5)

Measures to reduce GHG emissions from land use are likely also to have benefits in protecting the health (mauri or life-supporting properties) of New Zealand’s lands, forests and waterways. Māori values about land and the natural environment, and the multigenerational perspective these entail, are a potential source of strength in New Zealand’s search for a path to a low-emissions economy.

Te Rūnanga ... recognises that as Treaty partner, Ngāi Tahu must play an active role in the change process. We are well equipped to partner with central and local government, as natural agents of change and intergenerational investors within the Ngāi Tahu takiwā and nationally. (sub. 83, p. 5)

Chapter 10 identifies the value of partnerships of industry and environmental organisations, iwi and central and local government in finding and promoting opportunities to move towards a low-emissions rural economy. Iwi-based organisations are leading a multigenerational approach to climate change mitigation and adaptation. They generally support full inclusion of agriculture in the NZ ETS (CCILG, 2016b; Te Rūnanga o Ngāi Tahu, sub. 83).

Opportunities and barriers to reducing net emissions from Māori land

Māori customary, freehold and reserve land is governed by Te Ture Whenua Māori Act 1993, with a strong presumption against alienation (that accords with Māori values about ancestral ties to the land). One result of this presumption is that:

Māori land-owning bodies constituted under Te Ture Whenua Māori [often trusts or incorporations] typically face considerable difficulty in raising external capital, and it is extremely difficult (ie, prohibitively costly or otherwise impossible) to rationalise the ownership of Māori land assets. (Insley & Meade, 2008)

Māori land is often held in small parcels and poorly located. Often the land has multiple beneficial owners, making decisions about land use difficult and reducing incentives to make changes. Together, these factors mean that a considerable proportion of Māori land is relatively undeveloped (Insley & Meade, 2008; PwC, 2013, 2014). These same issues create barriers to making changes in farm management practices and technology to reduce GHG emissions (Insley & Meade, 2008). Iwi, research agencies, and industry organisations have developed initiatives to address these issues (Chapter 10). Te Rau Aroha Trust submitted on the importance of improving governance of Māori land. They point, for instance, to training initiatives such as the one they have set up in a strategic partnership with Toi Ohomai (Bay of Plenty Polytechnic) (sub. DR207).

More than 150 000 hectares of Māori land “is hilly, erosion prone, or marginal, was not in trees at 1990, and has the opportunity to be used for carbon farming ... through planting forest or allowing regeneration of scrub and low forest” (Harmsworth et al., 2010, p. 23).¹⁴⁵ Yet Scion (sub. 67) again noted that “[m]ultiple ownership of Māori land and its consequences for accessing capital is limiting the development of forestry on underutilised Māori land” and noted the lack of finance to undertake long-term forestry investments (p. 2) (see also Sandra Cortés-Acosta, sub. DR294). Partnering with forestry investors or the Government is an important route for accessing finance to plant forestry on Māori land (section 11.7).

¹⁴⁵ Most of this land is in Northland, and in the central and eastern regions of the North Island.

Many Māori-led initiatives to plant trees on marginal land for carbon sequestration are in development. For example, in August 2018, the Māori Carbon Foundation was established, with the aim of working with Māori landowners to establish forests on 150 000 hectares of marginal land around the country. The initiative, led by Sir Mark Solomon, aims to balance Māori control over their own lands, and access to finance to plant trees, in return for landowners receiving income from emissions credits. The initiative also intends to establish a trust aimed at social benefits for communities where trees are planted (Fisher, 2018).

Some forests from Treaty settlements are on land suitable for dairying and could be at risk of deforestation (Manley, 2017). Even so, Māori are strong advocates for expanding forests, including native forests (CCILG, 2016b; Te Rūnanga o Ngāi Tahu, sub. 83). The Climate Change Iwi Leaders Group (CCILG) argued for strengthening of afforestation grants and investment into pest-control in native forests.

Land, and forest land in particular, features in settlements of historic Treaty claims. Policies to reduce agriculture emissions and sequester carbon in forest could potentially affect the value of land and forests. Consistent with this, iwi had a particular interest in the design of the NZ ETS and its bearing on past and future Treaty settlements (Indigenous Corporate Solutions, 2008; Insley & Meade, 2008). Allocations of credits for pre-1990 forests (to compensate for potential liabilities from deforestation) were set at a level that acknowledged that much of this forest was already protected. Any amendments to the NZ ETS will need to consider whether and how those amendments may interact with the provisions of particular Treaty settlement legislation. Te Rūnanga o Ngāi Tahu advised, “as the Crown considers pathways to a low-emissions economy, policymakers must be mindful of a fiduciary duty to protect the interests of iwi” (sub. 83, p. 5).

11.9 Conclusion

Biological emissions from land use make up almost half of all New Zealand’s GHG emissions; while growing forests currently offset about 30% of those emissions. Any plausible transition to a low-emissions economy over the next 30 years requires a large shift (in the order of 1.3 to 2.8 million hectares) in land use – primarily from marginal sheep and beef farming to forestry. While this is, overall, similar to the change in rural land use that has occurred over the last 30 years, the required rate of forest planting that needs to be sustained will be challenging.

Opportunities to reduce agricultural emissions, particularly from dairying, will also be important. Even with current practices and technologies, modest reductions can be achieved without reducing overall agricultural output. The potential reductions from a breakthrough technology, such as a methane vaccine, are large, though research success is highly uncertain.

An emissions price that covers all land use, including agriculture, should be the main driver of change. The NZ ETS should at least cover long-lived nitrous oxide emissions. Short-lived biogenic methane could be covered separately within the NZ ETS or in a separate methane quota scheme (Chapter 9). Emissions pricing will stimulate a search for and implementation of ways to reduce biogenic agricultural emissions. A well-designed and stable NZ ETS will also incentivise more afforestation. The Government can best support the rural transition through ensuring emissions pricing policy is stable, and a measured phase-out of free allowances for agricultural producers.

Policies that address barriers to change will also support the effects of an emissions price and reduce its stringency. These policies include a search for new emissions-reduction technologies, developing the knowledge and skills needed in new land uses, and reducing regulatory barriers to change. The Government has a role in working with farmers, industry organisations, iwi, local government and research institutes in developing a range of initiatives (Chapter 10).

12 Transport

Key points

- New Zealand's transport system is dominated by private road transport. Compared to other developed countries, vehicle ownership rates are high, public transport use is low, and the vehicle fleet is old with poor fuel economy. Rapid population growth and a decline in prices for fossil-fuel vehicles have caused the private vehicle fleet to greatly expand.
- As a result, New Zealand's transport emissions have risen more than any other emissions source since 1990. Road vehicles were the primary driver of emissions growth and contribute the vast majority of transport emissions.
- The New Zealand Emissions Trading Scheme currently plays a very limited role in reducing transport emissions, since the current emissions price is a small component of fuel prices. Even with a significant increase to the emissions price, additional measures are needed to achieve large emissions reductions.
- Adoption of electric vehicles (EVs) represents the most significant opportunity to reduce transport emissions in New Zealand. EV uptake is rising, though price remains a barrier, as well as the limited travel range of EVs. Fast uptake is likely to be essential to achieve a low-emissions economy. For the bulk of light vehicles to be electric by 2050, nearly all vehicles entering the fleet would need to be EVs by the early 2030s.
- To encourage EV uptake, the Government should introduce a price feebate scheme, lead on procurement, and continue to support the development of the charging network. Introducing vehicle emissions standards would also help to spur uptake and reduce the risk of New Zealand inheriting more high-emitting vehicles from overseas. New Zealand is one of the few developed countries without vehicle emissions standards.
- Decarbonising heavy transport (such as trucks, planes and ships) is more challenging than for light vehicles. Large reductions will rely on further advances in technology. Some of the key mitigation opportunities are electrification and switching to drop-in biofuels. Yet, the most effective solution is not yet clear, and may involve a mix of fuel sources. The Government should pursue a mix of policies that provides even-handed support for these technologies.
- While low-emissions vehicles will provide the bulk of transport emissions reductions, other mitigation options can provide immediate reductions and valuable co-benefits. Shifting to lower-emitting modes of travel (eg, public transport and cycling) and increasing the uptake of mobility sharing are examples. Another is shifting some of the freight load from road to rail and shipping, although possible reductions are limited since most freight is carried over small distances.
- Inadequate pricing of vehicle externalities (including emissions), and the land transport funding system skewing investments towards roading, stifles the potential for mode shifting and leads to excessively high vehicle travel and inefficient vehicle choices. Levelling the playing field for infrastructure investments and more cost-reflective pricing of vehicle externalities would help to better support low-emissions modes of transport.
- Without additional support, the mitigation policies recommended for transport may place a disproportionate burden on low-income households, at least in the short term. The Government should undertake further analysis to evaluate options for compensatory policies (eg, scrappage incentive schemes).

Transport is New Zealand's second largest source of greenhouse gas (GHG) emissions, contributing nearly 20% of gross emissions (and about one third of long-lived GHG emissions). Compared to other large emitting sources like agriculture and industrial heat, significant scope exists to mitigate transport emissions in the short term. For example, opportunities exist to reduce transport emissions through adopting low-emissions vehicles and shifting to cleaner modes of transport.

Transport therefore should play a large part in New Zealand's overall strategy to reduce emissions. Chapter 3 concluded that the electrification of the light vehicle fleet is one of New Zealand's most important levers for reaching a long-term emissions reduction target.

Given transport's vital role, this chapter recommends a range of measures to reduce transport emissions. An emissions price will have some impact on emissions, but other options will need to play a part too, such as policies to incentivise the uptake of low-emissions vehicles. The external costs associated with vehicle use mean that reducing transport emissions can also lead to wider improvements in the health and wellbeing of New Zealanders. However, some policies recommended in this chapter may place a disproportionate burden on lower-income households. Chapter 10 further discusses how to address the negative effects of mitigation policies on these households.

Box 12.1 Vehicle terms used in this chapter

This chapter frequently refers to the *light vehicle fleet* and the *heavy vehicle fleet*. Light vehicles fit into two categories – passenger and commercial. Light passenger vehicles include cars, vans, and people-movers, while light commercial vehicles include goods vans or utility vehicles (utes), and trucks under 3 500 kg. Heavy vehicles refer to trucks and buses over 3 500 kg (eg, freight trucks and commercial buses).

The Commission uses a working definition of *low-emissions vehicles* as vehicles that produce zero, or near zero, tailpipe GHG emissions. An electric vehicle (EV) is an example of a low-emissions vehicle that uses electricity from an external source to power its motor. The two main types of EVs are:

- battery EVs (also known as pure EVs) – vehicles fuelled solely by a battery that can be charged by plugging into an electric power point; and
- plug-in hybrid EVs – vehicles that have two engines: one engine is fuelled by a battery like the one used in a pure EV; the other engine is fuelled from a tank that generally uses petrol or diesel.

The Commission also defines *fossil-fuel vehicles* as both vehicles with internal combustion engines solely powered by fossil fuels and conventional hybrid vehicles. While conventional hybrids are more fuel-efficient than an average fossil-fuel vehicle, their batteries are only charged by re-capturing energy when braking or from electricity generated by the petrol engine. As such, they produce higher emissions than plug-in hybrids. Vehicles with internal combustion engines can also be fuelled using biofuels that can reduce emissions.

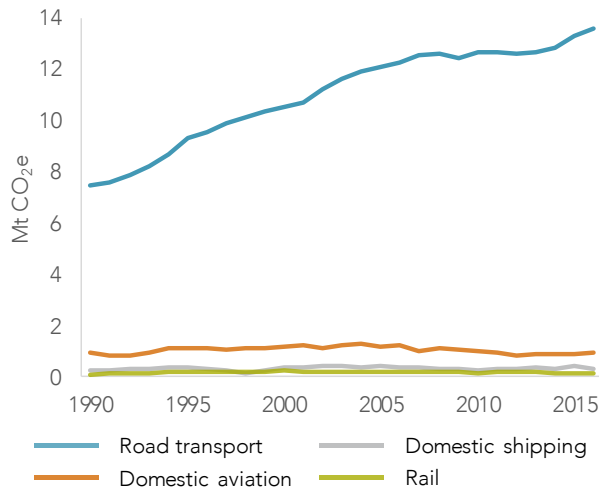
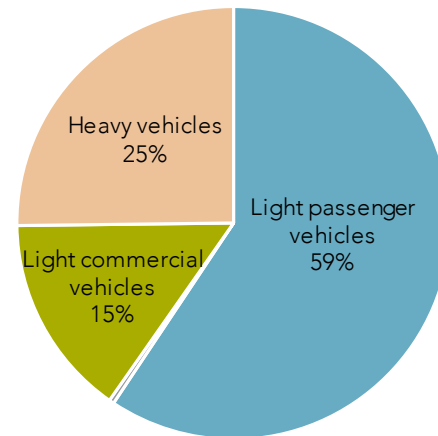
Source: EECA (2017b); MoT (2016a).

12.1 Transport emissions in New Zealand

Transport drove the increase in New Zealand's emissions

Transport emissions rose by more than 70% between 1990 and 2016. In absolute terms, transport was by far New Zealand's fastest-growing emissions source over this period. Much of the increase in transport emissions occurred before 2005, though emissions have trended upwards again in recent years (MfE, 2018d). Nearly all transport emissions are carbon dioxide (CO₂) that arise from the consumption of fossil fuels.¹⁴⁶

¹⁴⁶ About 1% of transport emissions are methane and nitrous oxide emissions resulting from the use of transport fuels.

Figure 12-1 Transport emissions by mode, 1990–2016**Figure 12-2 Composition of emissions from road transport, 2015**

Source: MfE (2017h); MoT (2016a).

Note: Motorcycles in 2015 produced about 0.4% of road transport emissions.

Road transport is the dominant source of transport emissions, and its emissions have increased substantially since 1990 (Figure 12-1). In 2015, light vehicles (passenger and commercial) accounted for about 75% of emissions from road transport (Figure 12-2). Heavy vehicles contributed 25% of these emissions, even though they accounted for only 6% of total vehicle kilometres driven.

Domestic aviation emissions make up about 6% of transport emissions. These stayed relatively unchanged between 1990 and 2016, as the shift to larger and more fuel-efficient aircraft offset the increase in travel. Rail and domestic shipping emissions rose slightly, but together they make up only 4% of transport emissions.

Figure 12-1 excludes emissions from off-road vehicles. These vehicles, such as boats, tractors and construction vehicles emitted just over 1 megatonne (Mt) of carbon dioxide equivalent (CO₂e) in 2016. This chapter does not focus on these vehicles.

In addition, Figure 12-1 excludes emissions that occur outside New Zealand – that is from international aviation and shipping. At present, international commitments exclude these emissions, as they are more difficult to attribute (Box 12.2). Yet, these emissions are material. Based on fuel supplied locally, New Zealand's international transport emissions in 2015 were 3.8 Mt of CO₂e – the equivalent of about 5% of New Zealand's total emissions (MBIE, 2017d).¹⁴⁷ Given New Zealand's remote location and the prominence of its tourism sector, failing to address these emissions presents a risk, if global policy action against these emissions is strengthened or New Zealand's export markets focus more on emissions embodied in goods (Bioenergy Association, sub. DR352).

Box 12.2 International transport emissions

International aviation and shipping emissions are not covered under the Paris Agreement. The main reason for this is that attributing these emissions to a specific country is more difficult than for other emissions sources. For instance, if a plane flies from Auckland to London with a stopover in Singapore for refuelling, it is not obvious how the emissions liability from these trips should be allocated. Countries are required to separately report their international transport emissions (based on fuel supplied), but emissions are not subject to any commitments to reduce emissions.

The United Nations Framework Convention on Climate Change appoints the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) as regulators of international

¹⁴⁷ New Zealand's international aviation and shipping emissions in 2015 were 2.8 Mt CO₂e and 1 Mt CO₂e respectively.

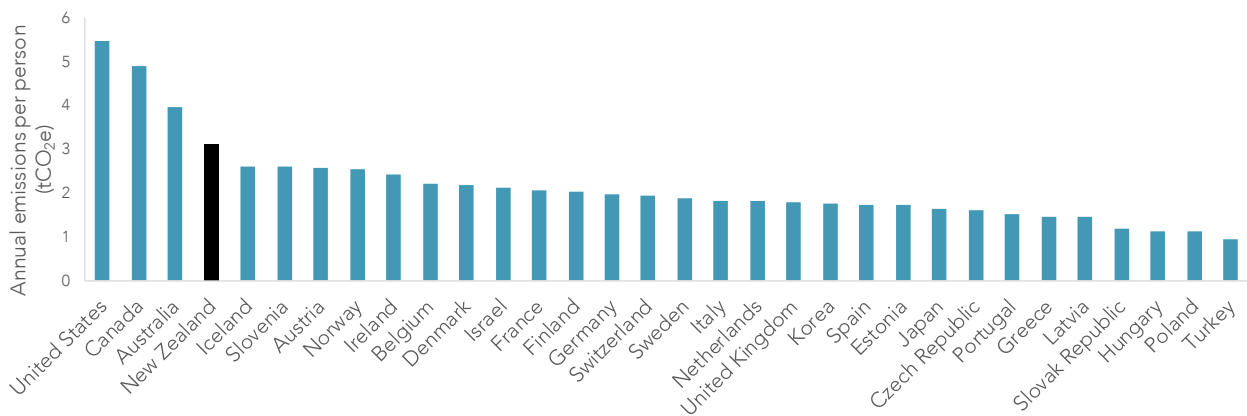
aviation and shipping emissions respectively. Yet, these emissions remain largely unregulated. Some progress has been made recently, particularly in aviation. In 2016, the ICAO announced that it will implement a Carbon Offsets and Reduction Scheme (CORSIA), which aims to avoid growth in international aviation emissions above 2020 levels. Any growth in emissions must be offset by certified emission reduction units. Since 2016, 66 parties including New Zealand have volunteered to participate in the initial phase between 2021 and 2026. Only routes where both affected parties participate in the scheme are covered. New Zealand is also working with the IMO on developing mechanisms to address marine emissions (Ministry of Foreign Affairs and Trade, sub. DR291).

Source: Romera (2016); European Parliamentary Research Service (2018); ICAO (n.d.).

New Zealand's per person transport emissions are high

New Zealand's per person transport emissions are the fifth highest among OECD countries (Figure 12-3).

Figure 12-3 Transport emissions per person, OECD countries, 2014



Source: OECD (2018a); UN DESA (2018).

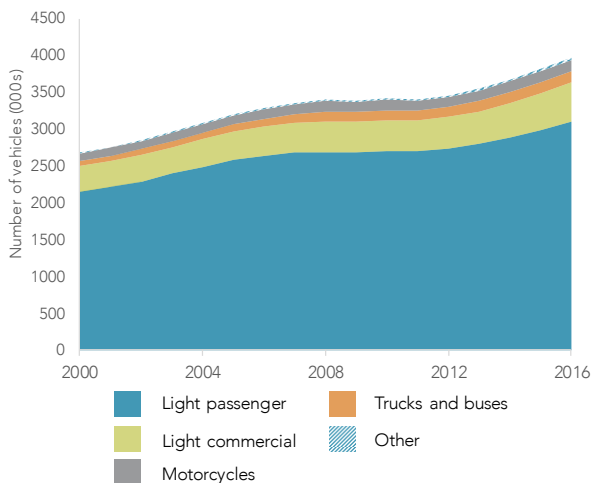
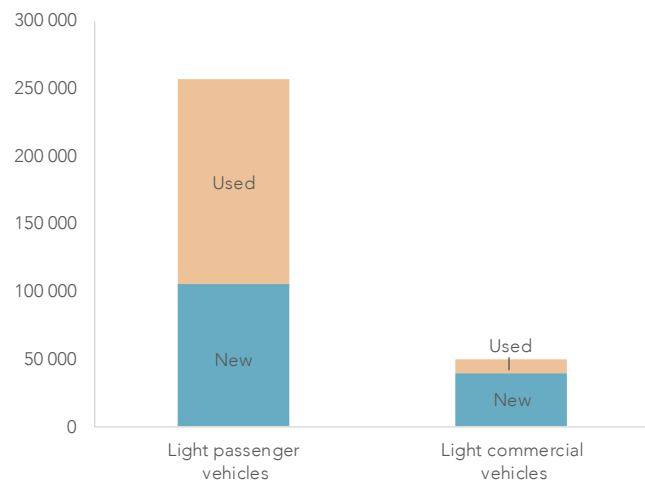
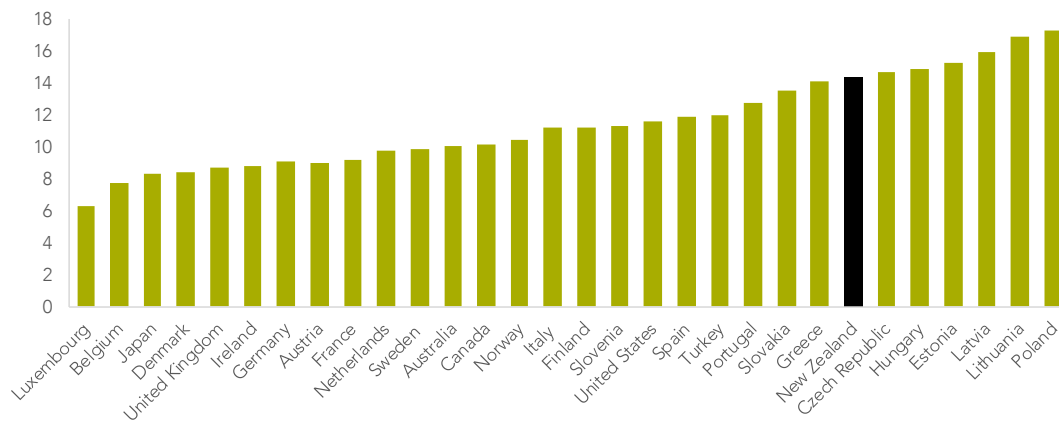
Note: Luxembourg is an extreme outlier and is therefore excluded.

Private road transport dominates New Zealand's transport system

The relative size of New Zealand's per person transport emissions is partly a result of the transport system's reliance on road transport and private ownership of vehicles. New Zealand has the second highest rate of vehicle ownership among OECD countries (RSNZ, 2016). New Zealand's low-density geography and widely distributed population are both important factors. Decisions in the 1950s to focus on completing the motorway network instead of upgrading and electrifying Auckland's rail system, and to remove the tram networks, were also influential in shaping New Zealand's road-dominated system (Transport and Industrial Relations Committee, 2017). Also, the removal of tariffs on vehicle imports in the 1990s played a role in increasing vehicle ownership rates (Chapter 4).

Demand for vehicle travel is rising with a growing population and greater economic activity

Roughly four million road vehicles are registered in New Zealand. The number of vehicles has grown by nearly 50% since 2000, with light vehicles dominating this growth (Figure 12-4). New Zealand's growing population has been a key driver of the rise in vehicle numbers and travel demand, though notably per person travel (in terms of kilometres travelled) has been relatively stable since 2000. Population growth has also driven greater economic activity, requiring more vehicle kilometres to transport goods and people across the country. Increased travel from trucks, buses and light commercial vehicles accounted for just over 60% of the growth in transport emissions since 2001 (MoT, 2016a).

Figure 12-4 Vehicle fleet size by type, 2000-2016**Figure 12-5 Vehicles entering New Zealand's light fleet in 2016****Figure 12-6 Average age of light passenger vehicles, OECD countries, 2015/16**

Source: AIA Canada (2017); Australian Automobile Association (2017); European Automobile Manufacturers' Association (2016); Mock (2016); MoT (2016a); Statistics Norway (2015).

Note: Figure 12-6 excludes Chile, Israel, South Korea, and Mexico due to unavailable data.

New Zealand's road vehicles are comparatively old and emissions-intensive

New Zealand's vehicle fleet is old relative to most other OECD countries, and getting older (Figure 12-6). The average age of light vehicles in New Zealand increased from 11.8 years to 14.2 years between 2000 and 2016. Also, vehicles entering New Zealand's fleet are more emissions-intensive (ie, have a poorer fuel economy) than in many other developed countries (ICCT, 2017; MoT, 2016a). Older vehicles tend to be more emissions intensive.

A key reason for the age and poor fuel economy of the fleet is that most vehicles entering New Zealand's fleet are used imports (Figure 12-5), while most vehicles in other OECD countries enter the fleet as new. The dominance of used imports, while damaging to the climate, has been hugely important for reducing the cost of vehicle ownership for low-income households (Chapter 4).

Another important factor is the slow turnover of the fleet – New Zealanders tend to hold on to vehicles longer than individuals in other developed countries. Vehicles are scrapped on average after 19 years (compared with about 14 years in the United Kingdom) (MoT, 2016a; SMMT, 2018). The fleet's fuel economy also reflects a preference in New Zealand for larger, heavier vehicles, which has increased in recent years.

Reliance on road transport has led to significant external costs

In addition to producing GHG emissions, the use of road vehicles has led to several other costs not fully borne by the user (section 12.7). External costs from road transport include traffic congestion, air pollution from harmful exhaust gases (eg, carbon monoxide), noise pollution, and road fatalities and injuries.

Advances in technology could fundamentally transform the transport system

Due to advances in technology, New Zealand's transport system could look markedly different in a few decades time.

The transport sector is going through an unprecedented period of innovation in vehicle, infrastructure, and services. Transport could be at the forefront of a 'fourth industrial revolution' – a fusion of the physical and digital worlds that is transforming how people live and work. This is being driven by breakthroughs in fields such as artificial intelligence, robotics, the Internet of Things..., and energy storage. (MoT, 2017b, p. 20)

Improvements in digital technology are enabling new business models to emerge that harness shared mobility (eg, ride sharing and vehicle sharing) (section 12.6). The development of autonomous vehicles (AVs) has the potential to disrupt New Zealand's traditional models of vehicle ownership (Box 12.3).

These changes in travel patterns could have a significant impact on future fuel demand, and transport emissions. Of course, the fundamental driver of emissions will be changes in the type of fuel consumed (eg, electric or fossil fuel); but new models of vehicle use (eg, vehicle sharing) could facilitate a faster shift towards low-emissions vehicle technology. The pace and scale of change is uncertain and will depend on many factors beyond New Zealand's control, such as the development of technology overseas and commodity prices. Consumer attitudes towards new transport technologies will also be influential.

Box 12.3 The potential for autonomous vehicles to transform New Zealand's transport system

Globally, vehicles capable of fully driving themselves are expected to be commercially available by the early 2020s (MoT, 2017b). The convergence of digital and AV technology advances could lead to a shift away from traditional individual vehicle ownership to an on-demand model of transport provided through driverless shared vehicle fleets. Z Energy (2017) suggests that this shift will happen because of the potential for substantial cost savings.

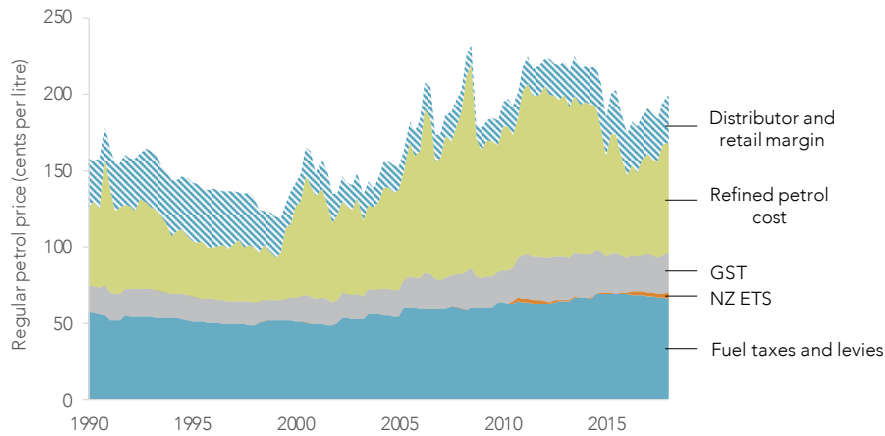
Given the large proportion of time (roughly 96%) that vehicles are not used, a shift to such a model may mean fewer vehicles are needed in total to meet overall mobility needs. The use of driverless shared fleets could reduce transport costs, provide opportunities for new land uses due to reduced demand for parking (The Morgan Foundation, sub. 127), and improve road safety.

Recently, a US think tank predicted that AVs will drive 90% of total vehicle kilometres in the United States by 2030 (Arbib & Seba, 2017). MRCagney's (2017) report on the potential impact of AVs in New Zealand provides more conservative predictions, suggesting that AV uptake will be small before 2040 and largely limited to commercial use (eg, taxis and delivery vehicles). After 2040 though, the report anticipates AVs will become more affordable, and be used for the bulk of private vehicle travel in cities after 2055.

12.2 Pricing transport emissions

At current prices, the New Zealand Emissions Trading Scheme (NZ ETS) is likely to have a limited impact on transport emissions. This is primarily because the emissions price is a relatively small component of fuel prices at current levels compared to the total costs of importing and distributing fuel and the total taxes on fuel (Figure 12-7). While the point of obligation for transport emissions sits with fuel importers and producers, the majority of the ETS cost is passed through to consumers. At the current New Zealand Unit (NZU) price of around \$20, the emissions component of fuel prices is just under 5 cents a litre for petrol and around 5.5 cents a litre for diesel (NZAA, 2018).¹⁴⁸ A rise in the emissions price to \$100 per tonne of CO₂e would roughly mean a 10% increase in the petrol price (about a 20 cent increase) compared to the current petrol price.

¹⁴⁸ This assumes full surrender obligations.

Figure 12-7 Breakdown of the retail price of petrol, as at March 2018

Source: MBIE (2018f).

Although price inelasticity and the small impact of the NZ ETS on fuel prices pose a challenge to the effectiveness of an emissions price in the transport sector, there are several reasons to believe that higher and sustained emissions prices could drive more meaningful changes.

- Evidence suggests that well-signalled taxes can elicit a significantly stronger demand response than other variations in fuel price (The Morgan Foundation, sub. 127, p. 8).
- A strong emissions price will make production of alternative fuels (ie, biofuels) more viable (section 12.5).
- The emissions price could have a larger impact in other areas of transport, particularly aviation. Concept Consulting (2017a) estimates that an emissions price of \$100 per tonne of CO₂e could reduce domestic air travel demand by up to 12%.
- Increased availability, and declining prices, of low-emissions vehicles (particularly EVs) would be expected to increase the responsiveness to an emissions price.
- Pricing emissions may have a sizeable indirect effect on transport demand. In recent modelling work, Infometrics (2017) estimates that a \$25 emissions price would reduce transport emissions by roughly 3% by 2030 (compared to no emissions price). Most of this response is an indirect effect of the emissions price raising the cost of emissions-intensive goods and services, which would reduce both household disposable income (and firm output) and fuel demand.

Even so, it seems clear that an emissions price, by itself, will not be sufficient to deliver a significant reduction in transport emissions, and complementary policies are required. While this demonstrates the relatively high value that New Zealanders place on private mobility, it does not necessarily imply that reducing transport emissions will come at a large cost. Rather, as discussed in Chapter 5, well-designed complementary measures can lower the emissions price that would otherwise be needed, and co-benefits (such as reduced air pollution) can increase the value to society of reducing emissions. Inadequate pricing of these co-benefits can work against an emissions price (section 12.7). The cost of low-emissions vehicle alternatives is also expected to fall (section 12.4), while investment in alternative transport options, such as public transport and cycling infrastructure, should increase the responsiveness to an emissions price by improving choices available to people – particularly those on lower incomes (section 12.8).

F12.1

At the current low-emissions price, the New Zealand Emissions Trading Scheme (NZ ETS) has a small effect on fuel prices, and therefore, a small effect on consumer behaviour and transport emissions. A higher emissions price would have a greater impact on behaviour, and make production of alternative fuels more viable. Yet, additional measures will be required to achieve large emissions reductions.

12.3 Electrifying the light vehicle fleet

Chapter 3 identified electrification of the vehicle fleet as a key component of achieving a low-emissions transition. This section looks at the opportunities for increasing the uptake of EVs, with a focus on the light fleet. Section 12.5 digs deeper into opportunities for decarbonising the heavy fleet. A hydrogen-fuelled vehicle is (effectively) a type of EV¹⁴⁹ that could reduce light vehicle emissions. Yet, since hydrogen presents a much bigger opportunity for the heavy fleet, hydrogen-fuelled vehicles are discussed in the later section.

EVs are one of New Zealand's most promising mitigation opportunities

Using electricity to power an EV produces zero tailpipe emissions (GHGs and other harmful gases). The only direct emissions that arise from using battery EVs comes from generating the electricity to charge the battery. The process of manufacturing and importing EVs can also produce emissions.

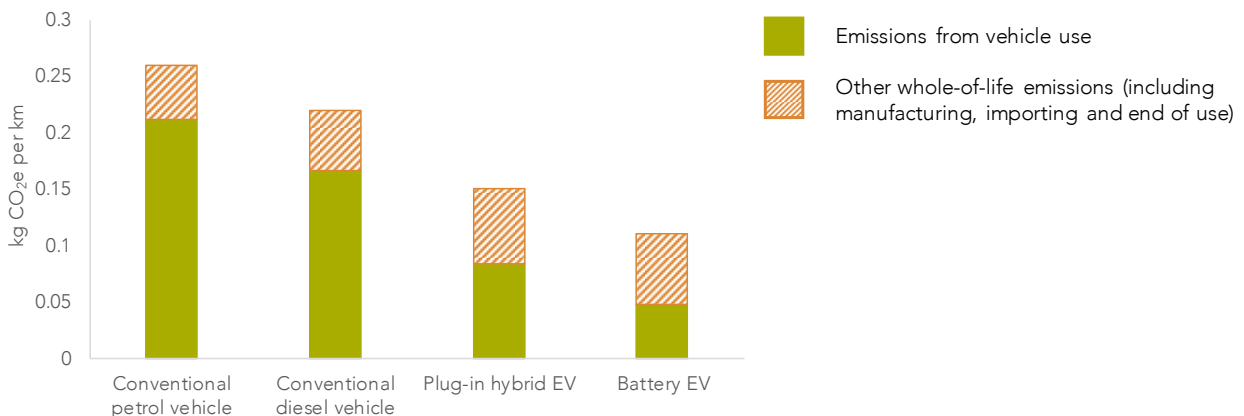
Several submitters consider EVs are one of New Zealand's most promising mitigation opportunities. Mercury summarises the range of benefits from EVs:

Electrification of transport is one of the largest areas of opportunity if significant reductions in New Zealand's emissions is to be considered. New Zealand is well suited to Electric Vehicles (EVs) due to our abundance of renewable electricity, off-street parking and low-average commuting distances. The cost of electricity is far lower than petrol at the equivalent of 30c/litre and the running costs of EVs are lower due to fewer moving parts. EVs also have no tailpipe emissions and therefore have the potential to significantly improve air quality and reduce healthcare costs. (sub. 49, p. 2)

New Zealand is especially well-placed to achieve substantial emissions reductions from adopting EVs because most of its electricity is generated using low-emissions sources. ARUP and Verdant Vision (2015) estimate that driving a battery EV produces 80% fewer emissions compared to a petrol vehicle, while a plug-in hybrid EV produces 60% fewer emissions (Figure 12-8). Reductions will improve as New Zealand continues to decarbonise its electricity system (Concept Consulting, 2016a).

While the process of manufacturing EVs tends to produce more emissions compared to fossil-fuel vehicles, as shown in Figure 12-8, EVs still produce fewer emissions compared to fossil-fuel vehicles when applying a whole-of-life perspective. Disposing of EV batteries at the end of their life can also have negative environmental effects which need to be managed (Motor Industry Association, sub. DR342; New Zealand Centre for Sustainable Cities, sub. DR311).

Figure 12-8 Estimates of emissions across light vehicle types in New Zealand



Source: ARUP and Verdant Vision (2015).

Notes:

1. Emissions from manufacturing and importing EVs occur outside New Zealand.
2. For the purposes of their analysis, ARUP & Verdant Vision assumed that each vehicle drove 210 000 km throughout its lifetime.

¹⁴⁹ As section 12.5 notes, hydrogen fuel-cell vehicles are powered by converting hydrogen into electricity.

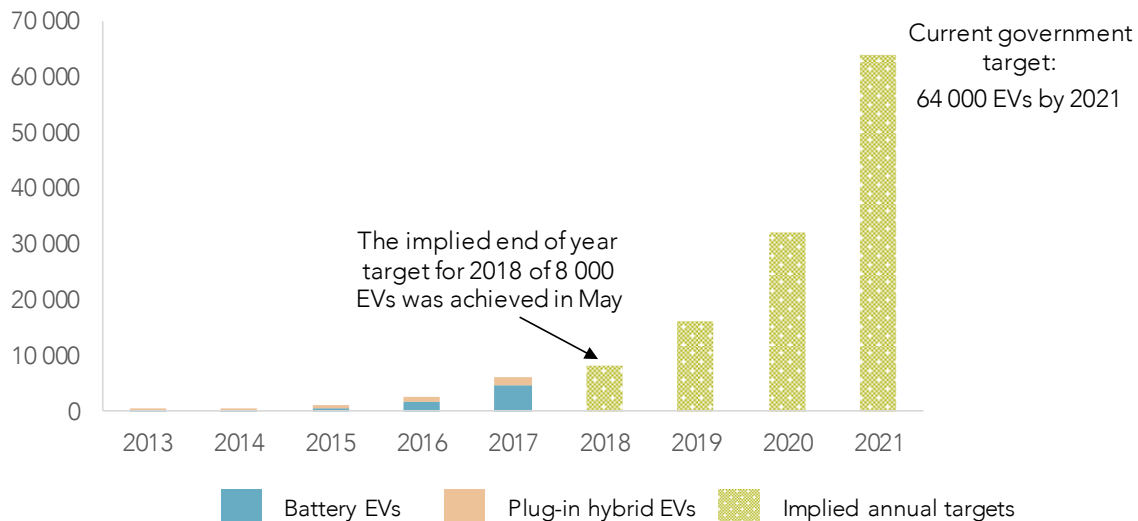
F12.2

The use of electric vehicles (EVs) leads to substantial emissions reductions compared to fossil-fuel vehicles, due to New Zealand's low-emissions sources of electricity generation. EVs also contribute to reduced air and noise pollution, and involve lower fuel and maintenance costs.

New Zealand's EV fleet is small, but is growing quickly

New Zealand's EV fleet is small, but it has been rising quickly in recent years. As at July 2018, New Zealand had about 9 200 registered EVs in its fleet. The previous Government set a target of doubling uptake each year, reaching 64 000 registered EVs by 2021 (Figure 12-9).

Figure 12-9 Size of New Zealand's EV fleet, 2013–2017, and current government targets



Source: MoT (2018a).

Note: The implied yearly targets are calculated from a baseline of 2 000 EVs in 2016, doubling each year to 64 000 in 2021.

Modelling indicates that rapid EV uptake is needed

The Commission's modelling indicates a rapid uptake of EVs will be critical for achieving a low-emissions economy. The three scenarios modelled (for a net-zero target) produced estimates for the amount of EVs as a share of the light fleet in 2050 that range from about 40% to 80% (Concept Consulting et al., 2018a). Differences in assumptions (eg, rate of EV cost reductions, and rate of efficiency gains for fossil-fuel vehicles) explain much of the variation in estimates. If technology development in other sectors or forest planting is slow, the speed of EV uptake becomes even more crucial.

To electrify the bulk of the light vehicle fleet by 2050, nearly all newly registered vehicles (including used imports) would need to be electric by the early 2030s (Concept Consulting, 2018a). The importance of early uptake reflects the long period that vehicles stay in the fleet. Because of the lock-in effect of high-emitting vehicles, the earlier that EV uptake accelerates, the lower New Zealand's total emissions will be over the next few decades.

If we could wave a wand and magically replace the light vehicle fleet (private and commercial) with electric vehicles, annual emissions would fall by about 11 million tonnes of carbon dioxide... But no such magic wand exists. Even though electric vehicle technology costs are projected to fall, the transition to electric vehicles will take several decades because New Zealand cars are typically not scrapped until they are 20 years old. (PCE, sub. 54, p. 7)

F12.3

Modelling indicates that a rapid uptake of light EVs will be a critical part of achieving a low-emissions economy. To electrify the bulk of the light vehicle fleet by 2050, nearly all newly registered vehicles would need to be electric by the early 2030s.

Barriers to the uptake of EVs

Several demand-side barriers currently inhibit the uptake of EVs. These include:

- *The upfront cost of purchasing EVs* (Box 12.4): In a recent quarterly consumer survey undertaken by the Energy Efficiency and Conservation Authority (EECA), the upfront purchase price was the most important reason consumers gave for not purchasing an EV (pers. com., EECA, February 2018).
- *Limited travel range, and range anxiety*: Current models of battery EVs typically can travel between 100 km and 300 km on a full charge (S. Magnusson, 2018). The fear that EVs will run out of power due to lack of charging infrastructure deters people from investing in EVs (NZAA, sub. 43).
- *The lack of public awareness and understanding of EVs*: In EECA's recent consumer survey, only 52% of respondents agreed that EVs are cheaper to run (in terms of fuel costs) than fossil-fuel vehicles, and only 35% agreed that they are cheaper to maintain. Only 10% of respondents said they were familiar with EVs.

Supply-side issues, including the lack of model options for EVs and constraints on global supply (discussed in section 12.4), also present a real risk to accelerated uptake.

EECA considers one of the most significant barriers to EV uptake is the lack of model supply and choice in New Zealand. New Zealand accounts for a very small proportion of global sales of new light vehicles. EV models available in other countries are not offered here, and some models are offered at a significant price premium over the same model in other countries (EECA, sub. DR326, pp. 7–8)

Box 12.4 The upfront cost premium for EVs

At present, the total cost of ownership (including purchase, fuel and maintenance costs) for a new EV is usually greater than for a 'comparable' fossil-fuel vehicle, due to the upfront price premium (Concept Consulting, 2017a). The recent *Running Costs* report from AA Motoring (2018) estimates the total purchase and running costs (for the first five years of ownership) for a range of vehicle types. The report finds the yearly cost of a battery EV is approximately 76 cents per kilometre (km) driven, compared to 65 cents per km driven for a comparable petrol vehicle, and 74 cents per km driven for a petrol hybrid vehicle. With travel distances above 25 000 km in a year, EVs become a slightly cheaper option.

The price of EVs is falling. Since 2010, the cost of EV batteries (per unit of energy capacity) has dropped by about 80% (IEA, 2016c). Bloomberg New Energy Finance (2017) predicts the upfront cost of light EVs will reach parity with fossil-fuel vehicles in the United States in 2025. After reaching this milestone in New Zealand, EVs would potentially deliver significant savings in transport costs for New Zealanders, especially given their cheaper fuel and maintenance costs.

F12.4

The most significant barriers inhibiting the uptake of EVs in New Zealand are:

- the upfront price premium compared to petrol and diesel vehicles;
- limited travel range, and associated range anxiety;
- the lack of public awareness and understanding of EVs; and
- constraints on supply and lack of model options.

A large uptake of EVs would add significant load to the electricity grid and, depending on the time at which vehicles are charged, could lead to much higher emissions from electricity generation. Without cost-reflective pricing for electricity, consumers will face little incentive to actively charge their vehicle at off-peak periods when the actual cost of supplying electricity is much lower (Concept Consulting, 2018a). As a result, demand for electricity at peak periods will be inefficiently high, leading to higher emissions.

ERANZ and the Electricity Networks Association (sub. 8) submitted that under current price structures for electricity, consumers pay roughly double what they should for charging an EV, due to the Low Fixed Charge regulations. Submitters also raised concerns about the pressure EV uptake could put on electricity networks, and the risk of an unmanaged demand for EV charging causing network instability (Vector, sub. DR287; Orion, sub. DR210). Chapter 13 looks at the current approaches to reforming electricity pricing, as well as the role of demand–response within the electricity network and challenges around distribution line capacity.

F12.5

A large uptake of EVs would add significant load to the electricity grid. Without cost-reflective pricing of electricity, electricity emissions could rise significantly due to increasing peak demand (with EVs being charged at peak periods). The additional electricity load could also put significant pressure on the existing network and require large investments to provide additional capacity.

Current measures for supporting EV uptake

Two main policies underpin the Government’s current programme for supporting uptake of EVs: road-user charge (RUC) exemptions for EVs¹⁵⁰; and the Low Emission Vehicles Contestable Fund. The RUC exemptions reduce the cost barrier to EV uptake - owners of light EVs save around \$600 a year (MoT, 2017c). The exemption is due to be removed at the end of 2021, or when light EVs reach 2% share of their fleet.

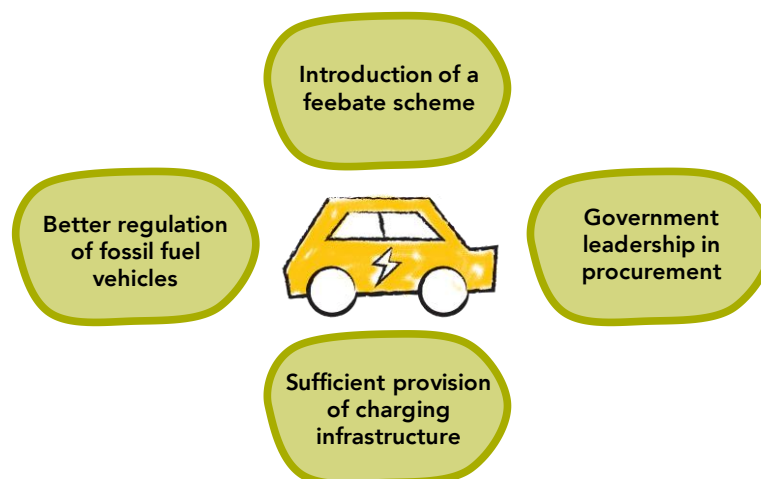
The Low Emission Vehicles Contestable Fund provides up to \$6 million each year to co-fund (up to 50%) projects that encourage “innovation and investment to accelerate uptake of electric and other low emission vehicles” (EECA, 2018c). The only projects considered for assistance are those not commercially viable without funding assistance. So far, three rounds of funding have been completed, with over \$10 million of funding provided. The fund has not been evaluated to determine whether it is achieving its objectives.

Other policies in place to encourage EV uptake include enabling local authorities and the New Zealand Transport Agency (NZTA) to create bylaws allowing EVs to travel in special vehicle lanes, and a nationwide EV information campaign. Local government also plays a role in promoting EV uptake. For instance, Wellington City Council is trialling the deployment of residential, public charging stations.

An EV policy package to support the low-emissions transition

The Commission has identified four key components of a policy package to support EV uptake (Figure 12-10). Improving the regulation of fossil-fuel vehicles (eg, through introducing vehicle emissions standards, see section 12.4) is an important element. But the biggest driver of EV uptake will very likely be a continued reduction in price. Indeed, achieving parity with fossil-fuel vehicles, in terms of lifetime costs, could be a tipping point in stimulating uptake.

Figure 12-10 Key components of an effective policy package to support EV uptake



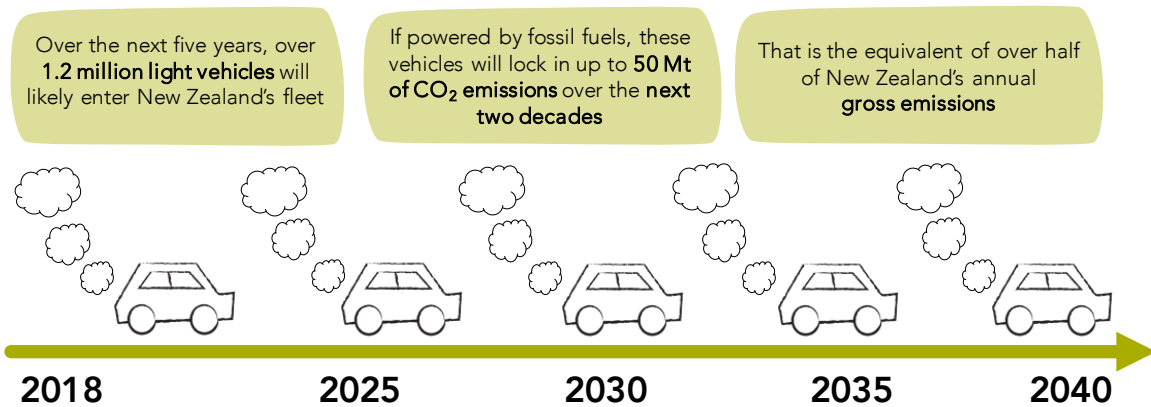
¹⁵⁰ Plug-in hybrid EVs are subject to RUCs for the portion of their travel that is fuelled by petrol.

The case for price incentives for EVs

Policies to address the upfront cost barrier are needed to achieve accelerated uptake of EVs, until the price premium disappears.

The emissions lock-in effect of fossil-fuel vehicles is a key rationale for providing incentives for low-emissions vehicles. Fossil-fuel vehicles emit a significant volume of cumulative emissions over their lifetime (Figure 12-11). The more fossil-fuel vehicles entering the fleet, the smaller New Zealand's remaining emissions budgets will be over the next ten to twenty years, and the higher the future emissions price across the economy (ie, the greater cost to meeting future commitments).

Figure 12-11 Lock-in effect of fossil-fuel vehicles on emissions



Source: Based on MoT (2016a) and MfE (2017h).

In principle, the existence of an emissions price would encourage consumers to consider the impact of their future emissions when choosing what vehicle to purchase. However, in practice, future emissions prices are highly uncertain and unclear to vehicle purchasers, while consumers also tend to heavily discount future vehicle-related costs when purchasing vehicles (section 12.4). This provides a case for encouraging EV uptake in the short term to insure against a high emissions price-path and lock-in.

Another rationale for providing support for EVs is that consumers currently do not fully benefit from reducing social costs when switching from a fossil-fuel vehicle to an EV. This is mainly due to the currently low emissions price and the lack of pricing for air pollution (section 12.7). Also, a lack of cost-reflective pricing for electricity (noted earlier as a barrier to uptake) means that EV users can pay more for charging overnight than the true cost of supplying the electricity during off-peak periods.

Instead of providing price support for EVs, an obvious option to incentivise EV uptake is to directly resolve the issues related to air pollution, GHG emissions and electricity pricing. However, policies to address these issues will likely take time to implement. In the meantime, a significant number of fossil-fuel vehicles would likely enter the fleet. Some form of support is therefore likely to be required as a transitional measure.

Finally, early price support could also help to facilitate 'technology learning' and achieve greater acceptance of EV technology among consumers. That is, early uptake of EVs delivers spillover benefits that justify transitional price incentives.

F12.6

In choosing a vehicle, consumers are likely to under-value the large emissions locked in over the vehicle's lifetime (eg, due to high discounting of future running costs and uncertainty about future emissions prices). Additionally, under-pricing of CO₂ emissions and air pollution from fossil-fuel vehicles and over-pricing of off-peak electricity mean that the running costs of EVs (relative to fossil-fuel vehicles) are higher than they should be. This provides a case for the Government to provide some form of transitional price support to incentivise the uptake of EVs.

Currently, the Government already provides some price support for EVs in the form of RUC exemptions. These exemptions are poorly targeted. As the Treasury (2016b) explains:

If a subsidy is to be given it is unlikely that a RUC exemption is the most effective approach. EVs use the roads in the same way as other cars so should be exposed to RUC. An expanded RUC exemption would also increase expectations about support of this form, which could drive inefficient long-term decisions on whether to purchase EVs. Explicit subsidies focused on purchase costs would be less likely to drive perverse outcomes and would target the apparent issue of up-front costs. (p. 15)

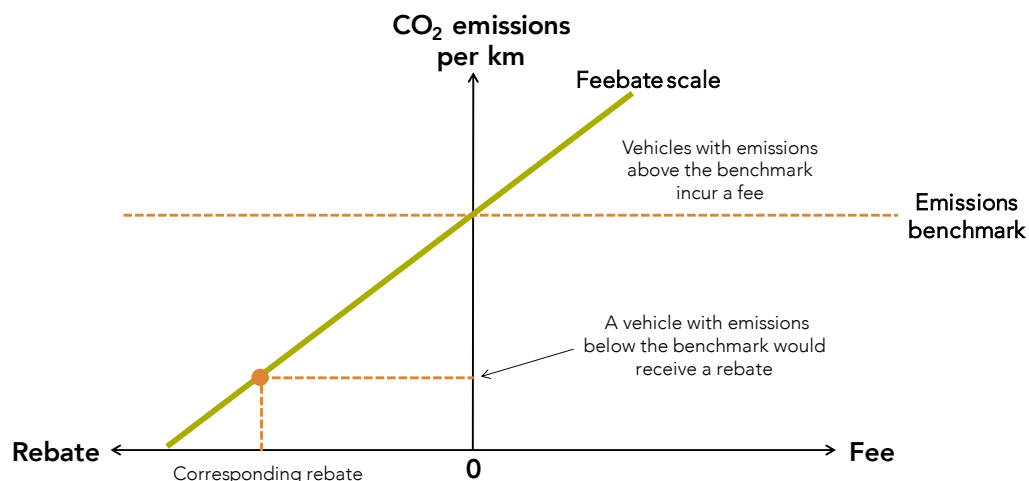
It is reasonable that EVs should be subject to RUCs, on the basis that funds are used to maintain roading infrastructure that all vehicles, including EVs, benefit from.

A price feebate scheme

A price 'feebate' scheme offers a tool to encourage households and businesses to purchase less emissions-intensive vehicles, including EVs. Under a feebate scheme, all vehicles (new and used) would be assessed for their GHG emissions potential. Essentially, higher-emission vehicles would incur a fee, while lower-emission vehicles would receive a rebate (so the name feebate). The feebate could be a one-off transaction at the point of importing a vehicle, a yearly transaction, or a combination of the two. As Figure 12-12 illustrates, the difference between a given vehicle's emissions and an emissions 'benchmark' would determine the size of the vehicle's feebate.

Among the large number of submitters who commented on a feebate scheme for the light vehicle fleet, a clear majority, including Meridian Energy (sub. DR253), Jonathan Boston (sub. DR368) and Robert McLachlan (sub. DR151), expressed their support.

Figure 12-12 Stylised structure of a feebate scheme



A big advantage of a feebate scheme is that it would not only encourage consumers to switch to EVs; it would also encourage the purchase of more fuel-efficient fossil-fuel vehicles (including hybrids) until such point that EVs become more cost-competitive. In the case that early EV uptake is slow, improving the efficiency of fossil-fuel vehicles would become especially important.

Another advantage is that the scheme could be designed to be revenue-neutral for the Government, so that total revenue from fees offsets the cost of providing rebates. To maintain revenue neutrality, the emissions benchmark would need to be monitored and adjusted over time as purchasing decisions change.

Because feebates incentivise the uptake of vehicles that consume fewer fossil fuels, they indirectly create a bias against straight substitutes for fossil fuels – ie, biofuels (Bioenergy Association, sub. DR352; Scion, sub. DR366; National Energy Research Institute, sub. DR337). Theoretically, a feebate system could be designed to address this bias by basing the feebate on the emissions intensity of *fuel sources* (eg, biofuel or electricity) rather than *vehicle type* (eg, internal combustion engine vehicle or EV). However, in practice, such a design

would be highly impractical.¹⁵¹ Also, this design would not help to overcome the greatest barrier to EV uptake – the higher upfront cost – because incentives would only affect the costs of using an EV over time.

In modelling pricing policies for vehicle ownership in the United Kingdom, Brand et al. (2013) suggested that feebates were the most cost-effective in reducing emissions and accelerating the market share of EVs. Barton and Schütte (2015) identify a feebate scheme as a policy that has “credibility”, “a proven record of success internationally”, and is “suitable to New Zealand conditions” (p. iii).

France, Sweden and Singapore have implemented feebate schemes. France introduced their *Bonus-Malus* system in 2008 for new vehicles entering the fleet to reduce CO₂ emissions. The system offers rebates of up to €7 000 to the purchase price of the lowest-emitting vehicles, and charges fees of up to €6 000 for the highest. The scheme has been largely successful. Average emissions from newly registered vehicles fell from 149 grammes of CO₂ a km to 114 grammes between 2007 and 2014. One adverse outcome was an increased demand for diesel vehicles (since diesel vehicles are often more fuel efficient), worsening air pollution (OECD, 2016b).

F12.7

A well-designed price feebate scheme based on the greenhouse gas emissions of light vehicles entering the fleet would provide a cost-effective approach to incentivising the uptake of low-emissions vehicles. The approach:

- provides an incentive for purchasing lower-emitting vehicles (including more fuel-efficient fossil-fuel powered vehicles; and
- can be designed to be revenue neutral.

Effective design of a feebate scheme is critical to achieving its desired objective, and to avoid unintended costs from the scheme. As an example, setting excessively high rebates could lead to greater overall demand for vehicles. On the other hand, insufficient rebates would risk achieving low behaviour change for a high transaction cost.

One important design consideration is the point at which the feebate is applied. The Commission favours applying a one-off feebate when the vehicle enters the fleet (ie, vehicles already in the fleet are unaffected). A one-off feebate would be more effective in addressing the upfront price barrier and affecting purchase decisions, given consumers’ high discounting of future vehicle costs. Also, if a feebate scheme is introduced as a transitional policy for a limited period, then an annual charge would provide weaker financial incentives.

Table 12.1 outlines some other design features of a feebate scheme, and specific issues to consider.

Table 12.1 Key design features of a feebate scheme, and issues to consider

Design feature	Issues to consider
The scale of the feebate incentives	The greater the feebate, the stronger the incentives for purchasing lower-emitting vehicles, but the larger the financial burden for purchasers of higher-emitting vehicles.
The level of the emission benchmark	The emission benchmark determines which vehicles receive rebates and which receive fees. A high emissions benchmark, with rebates for lower-emitting, fossil-fuel vehicles, could increase overall vehicle demand. A low emission benchmark could lead to excessive costs for consumers.
The coverage and treatment of different vehicle types	A scheme that treats all vehicles the same (eg, passenger vehicles and commercial vans) would be more efficient, in terms of emissions. However, such a scheme may be less equitable for those with few low-emissions alternatives (eg, rural businesses). Another option is to have separate schemes for different vehicle classes.

¹⁵¹ A feebate based on the emissions intensity of the fuel used to power a vehicle would not be suitable for EVs. Most EV charging occurs at home, where it would be impractical to distinguish between electricity used to charge an EV and for other purposes.

Design feature	Issues to consider
Revenue neutrality	A revenue neutral scheme may be more politically acceptable than the alternative. But, the Government may prefer for a feebate to come at a fiscal cost (ie, adopt larger rebates and/or smaller fees), for instance to limit impacts on low-income households or to further incentivise EV uptake.

F12.8

The effective design of a feebate scheme is critical for its success, and for avoiding perverse outcomes. An important design element is the point at which the feebate is applied. Applying a feebate when a vehicle enters the fleet is the most suitable option, as it specifically addresses the upfront price premium for low-emissions vehicles.

Designing a feebate scheme to support low-income households

The introduction of a feebate scheme would effectively raise prices for high-emitting vehicles newly imported into New Zealand. Given current prices for EVs and the limited range of models available, feebates would very likely be regressive (New Zealand Centre for Sustainable Cities, sub. DR311). In other words, lower-income households would likely disproportionately bear the costs of a feebate scheme.

To make low-emissions vehicles a more viable option for lower-income households, a feebate system could provide these households with a greater rebate when purchasing EVs. The Californian EV rebate system uses this approach. A household with income below a set threshold receives a rebate of \$USD4 500 when purchasing a battery EV compared to \$USD2 500 for a standard household (California Climate Investments & California Air Resources Board, 2018). Section 12.4 also discusses the option of providing incentives to lower-income households to scrap a high-emitting vehicle in replacement for a lower-emitting vehicle.

R12.1

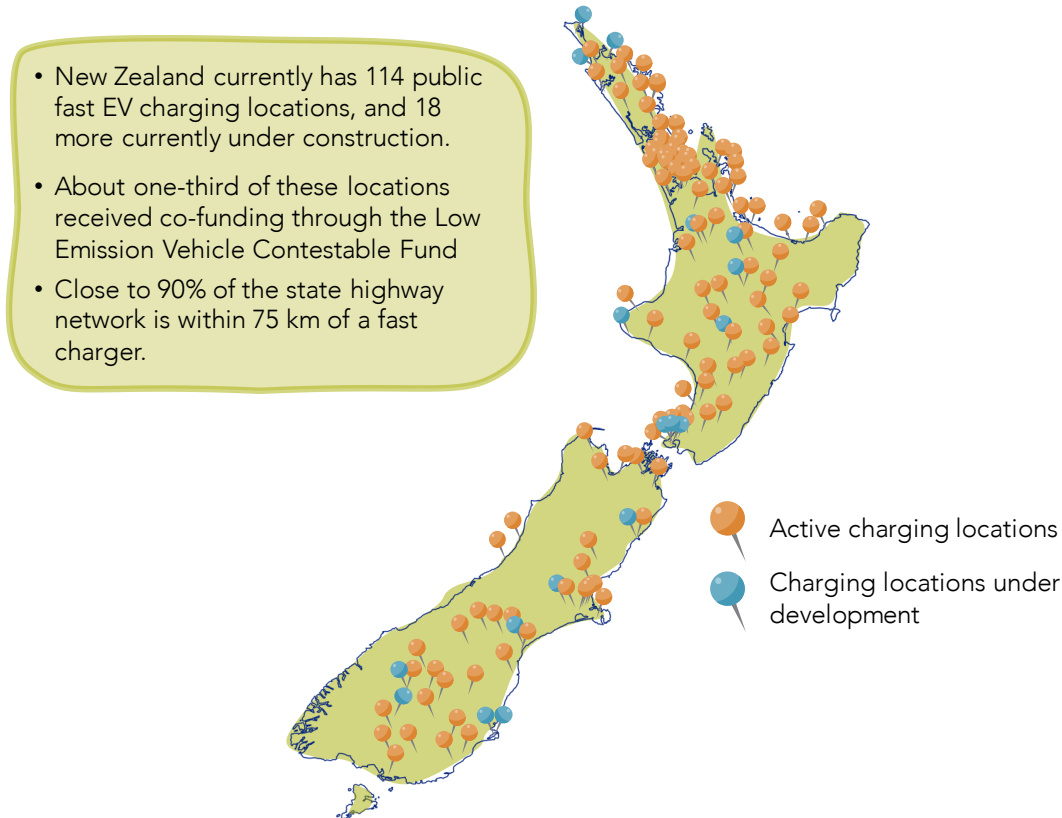
The Government should introduce a price feebate scheme for new and used vehicles entering the fleet, subject to identifying the most suitable design features for the New Zealand context (including features to limit the burden on low-income households). The feebate scheme should replace the existing road-user charge exemptions for light EVs.

Ensuring sufficient provision of charging infrastructure

Providing sufficient charging infrastructure is important for encouraging households to invest in EVs, especially because of their limited range. About 85% of New Zealanders have access to off-street parking (The Morgan Foundation, sub. 127). Yet, public charging infrastructure¹⁵² is still needed to enhance accessibility throughout the country, and to provide charging for households without access to off-street charging.

New Zealand's fast-charging network is fairly developed, compared to the size of its EV fleet. Most fast chargers in the network take roughly 25 minutes to provide 100 km of charge (S. Magnusson, 2018). Currently, there is roughly one fast-charging location for every 80 EVs, and the majority of state highway network is within 75km of a fast-charger (Figure 12-13). For most residents without access to off-street charging, EVs are still likely to be less of an attractive option given limited charging options. Also, some specific gaps in the fast-charging network do exist – particularly in sparsely populated regions, such as the West Coast. Supported by EECA, ChargeNet, the dominant investor in charging infrastructure in New Zealand, is planning to develop several charging stations over the next two years, including in the gap between Christchurch and Nelson and in Southland (ChargeNet, 2018; EECA, 2018d).

¹⁵² Public charging infrastructure refers to charging stations where all people can freely charge their EV. This infrastructure is not necessarily funded by the government or free to use.

Figure 12-13 The state of New Zealand's fast-charging network for EVs

Source: NZTA (2018); NZTA, pers. com. August 2018.

Notes:

1. The map only includes active charging stations that are integrated with NZTA's EVRoam database. These stations must meet NZTA guidelines. Some other stations exist that are active but do not meet these guidelines (eg, three of Tesla's proprietary charging stations in the North Island do not count – partly because they are incompatible with non-Tesla vehicles).
2. Many locations have more than one charging point.

The Government has played an important role in facilitating the development of charging infrastructure. Through the Low Emission Vehicles Contestable Fund, the Government has so far spent around \$3.5 million on charging-related projects (EECA, 2018d).¹⁵³ These funds contributed to developing 90 charging stations¹⁵⁴, including over a third of fast-charging stations currently active (or being developed) (pers comm, NZTA and EECA, August 2018).

Given the current small size of the fleet, continuing to expand the charging network and resolving the remaining gaps may be difficult without further government support. Vector noted that "while it is necessary to continue expanding and developing... infrastructure to enable further EV uptake, there is currently limited incentive for the private sector to do so" (sub. 63, p. 7). This highlights the potential for coordination issues. For example, firms may put off investing in more charging infrastructure until greater uptake is noticeable, but consumers may defer purchasing an EV until greater infrastructure is in place (the Treasury, 2016b).

Chapter 7 concludes that where a lack of coordination creates a barrier to investing in low-emissions infrastructure, there may be a good case for Government to provide financial assistance. In the context of EVs, the Commission considers that Government should continue to provide financial support for charging-infrastructure projects to support the development of the network. The Government should focus on specific gaps in the charging network that are commercially unattractive to the private sector (eg, charging stations in lowly-populated regions), yet are important for completing the network. Conversely, it should avoid providing funding for charging projects that would likely be viable without government support.

¹⁵³ Not including the recent announcement of the fourth round of approved projects for the Contestable Fund.

¹⁵⁴ The Contestable Fund contributes to developing slow- and medium-speed charging stations as well as fast-charging stations. These chargers complement the fast-charging network and are suited to end-of-destination locations (eg, motels, hotels, and tourist spots).

F12.9

New Zealand's fast-charging network for EVs is fairly developed, compared to the size of its EV fleet. Funding support from the Government has played an important role. Some gaps exist in specific regions.

R12.2

The Government should continue to provide financial support for charging infrastructure projects to support the uptake of EVs. Support should be limited to specific gaps in the charging network that are not commercially attractive to the private sector (eg, charging stations in lowly populated regions).

Government leadership in procuring low-emissions vehicles

Many submitters called for the Government to play a greater leadership role in promoting EV uptake. Z Energy (sub. 110) commented that the Government should be far more "bullish" in supporting uptake, specifically through procuring EVs. Federated Farmers of New Zealand (sub. 39, p. 8) suggested that "the Government can best encourage uptake in this country through influencing its agencies' purchasing decisions and through information and promotion". Vector (sub. 63, p. 9) stressed in the context of transport, "if the government does not take an active and visible role in promoting carbon reduction..., the urgency and desire to move to a low-emissions economy will be less likely recognised by the public".

Encouraging the procurement of EVs by government agencies could help signal future policy direction to the public and address the lack of public awareness of EVs. It would also increase the second-hand stock of EVs available for purchasing over the next decade. Government organisations own about 25 000 light vehicles, and purchase about 4 000 vehicles each year. The current Government's coalition agreement sets out a goal of achieving an "emissions-free" government fleet, where practical, by 2025/26.

However, as EECA submitted, the limited range of models available, along with the cost associated with EVs, can deter agencies from investing in low-emissions vehicles.

[T]here are significant barriers to EV uptake by government organisations – primarily, the high capital cost of new EVs and infrastructure installations, and secondly the range of models currently available through the New Zealand Government Procurement's (NZGP) All-of-Government vehicles catalogue. (EECA, sub DR326, p. 10)

Of the 18 models of low-emissions vehicles on the government vehicle catalogue, only three are non-luxury brands.¹⁵⁵ The Commission understands that the Ministry of Transport is investigating expanding the catalogue to include another lower-cost EV model. The Motor Industry Association anticipates that by 2020, 75 models of EVs will be available in New Zealand, including 36 battery EVs and 39 plug-in hybrid EVs (Drive Electric, sub. DR257 attachment one). The Government should regularly review the catalogue as more models of low-emissions vehicles become available in New Zealand.

R12.3

The Government should encourage government agencies where practical to procure low-emissions vehicles. It should regularly review its procurement catalogue with a view to increasing the model range of lower-cost low-emissions vehicles.

12.4 Other approaches to reduce emissions of the light fleet

Even with rapid development and adoption of low-emissions fuels, a full transition away from fossil-fuel powered vehicles will take decades to achieve. In the meantime, a large proportion of vehicles coming into New Zealand use internal combustion engines. This section builds on section 12.3, examining a range of measures to reduce emissions from vehicles entering the fleet – again with a focus on the light vehicle fleet.

¹⁵⁵ These are the Hyundai Ioniq and Toyota Prius plug-in hybrids, and the recently added Volkswagen e-Golf (MoT, pers. com, August 2018).

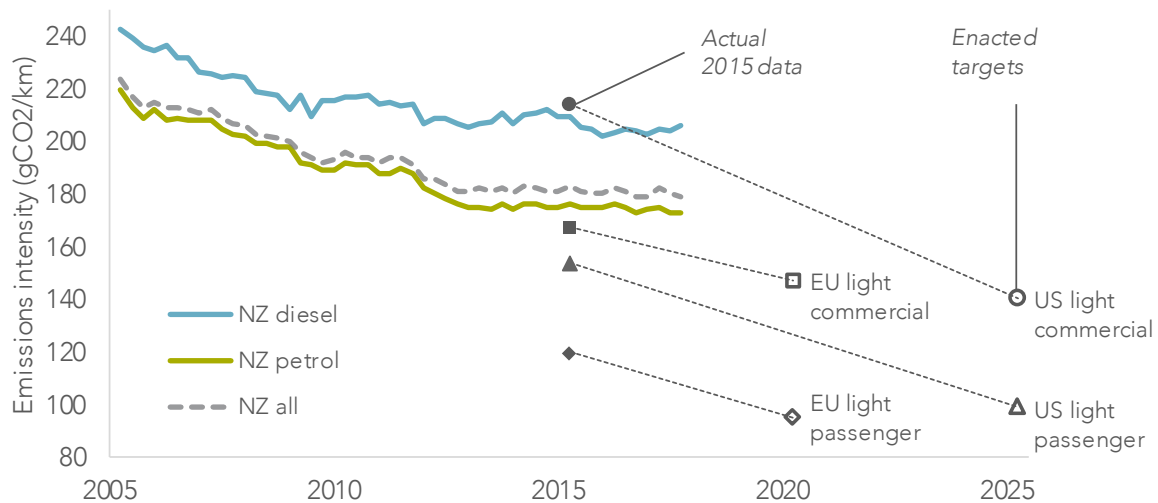
Vehicle CO₂ emissions standards

Regulated standards to improve fuel economy and reduce CO₂ emissions from light vehicles are now commonplace internationally. Coverage has increased significantly over the last decade to around 80% of the global light vehicle market today, including the United States, Canada, Japan, China and India (Yang & Bandivadekar, 2017). Differing in design detail, these regulations all require manufacturers to meet an overall average fuel economy or CO₂ emissions level, weighted across new vehicle sales within the country or region where the standard applies. New Zealand, Australia and Russia are currently the only developed countries without such standards.¹⁵⁶ Australia is in the process of developing one (Commonwealth of Australia, 2016).

New Zealand's light vehicle fleet is more emissions-intensive compared to most developed countries (section 12.1), and evidence indicates that relative performance is worsening. The average fuel economy of vehicles entering the New Zealand fleet steadily improved from 2005 to 2013 but has plateaued since (Figure 12.14). Other countries have continued to improve fuel economy since 2013, though at a slower rate than in preceding years (European Environment Agency, 2017; IEA, 2017c; US EPA, 2018b). New Zealand's worsening performance reflects two key factors.

- Although efficiency is generally improving within vehicle weight classes as manufacturers introduce fuel-saving technologies, New Zealanders are increasingly choosing to purchase larger, heavier vehicles (MoT, 2017b).
- Manufacturers choose to provide less efficient model variants into the New Zealand vehicle market than to markets where standards apply. Research indicates that the most efficient variants¹⁵⁷ of top-selling passenger vehicle models sold in New Zealand were 21% worse on average than the most efficient variants offered in the United Kingdom (MoT, pers. com., July 2018)¹⁵⁸.

Figure 12-14 Average emissions intensity of vehicles entering the New Zealand fleet, compared with EU and US emissions standards



Source: ICCT (2017); MoT (2018b); US EPA (2018b).

Notes:

1. Values are calculated from laboratory test measurements normalised to the New European Driving Cycle.
2. In the United States, sport utility vehicles (SUVs) are included in the light commercial category rather than the light passenger category.
3. New Zealand vehicle emissions data is only available by fuel type, but most light commercial vehicles are diesel-powered and most light passenger vehicles are petrol-powered.

¹⁵⁶ The *Land Transport Rule: Vehicle Exhaust Emissions 2007* sets minimum standards for emissions of substances directly harmful to human health: carbon monoxide, particulates, nitrogen oxides and hydrocarbons. It does not regulate CO₂ emissions (Barton & Schütte, 2015).

¹⁵⁷ Variants are vehicles of the same model (eg, Toyota Corolla). In some cases, the most efficient variants available in different markets differ in specification (eg, transmission type and engine size).

¹⁵⁸ The comparison is derived from data sourced from the UK Vehicle Certification Agency and from data that distributors routinely provide to the Ministry of Transport through the New Zealand Motor Industry Association's Model Information system.

F12.10

Light vehicles entering New Zealand's fleet emit significantly more CO₂ than in most developed countries, and efficiency improvements have stalled since 2013. Vehicle manufacturers tend to provide less efficient variants of vehicle models to the New Zealand market compared to markets where CO₂ emissions standards apply.

Standards address barriers to uptake of lower-emissions vehicles

Other governments have implemented CO₂ emissions standards to unlock cost-effective gains in fuel efficiency faster than market forces would be expected to deliver on their own. Even with much higher emissions prices, development and uptake of lower-emissions vehicles will very likely occur more slowly than optimal from a societal perspective, due to a misalignment between private and social valuation methods in vehicle purchases.

Evidence suggests that buyers behave as if they heavily discount future fuel savings, and that uncertainty around future fuel (and emissions) prices may play a role in this (Commonwealth of Australia, 2016). While this may reflect rational decision-making from the individual perspective, such heavy discounting will lead to poor outcomes for society. Commercial fleet managers may be better informed and better equipped to evaluate options – the majority of new vehicle purchases in New Zealand are by companies (R. A. Scott et al., 2012). That said, high discounting of fuel savings is still likely to occur. For example, many businesses may only retain a vehicle for around three years before reselling it and will likely require a corresponding short payback period on a more efficient vehicle.

Given New Zealand primarily imports vehicles from countries with standards in place, one could question whether it is necessary to adopt a similar standard here. However, as these standards operate as a sales-weighted average in the domestic market, they do not cover vehicles exported into other markets. The gap between the fuel efficiency of vehicle models in the United Kingdom and New Zealand (described above) shows that New Zealand is not fully benefiting from standards in other countries. Manufacturers will choose to offer a selection of vehicles to the New Zealand market that will maximise their profit, and that will likely mean selecting less efficient vehicles from their global portfolio.

The case for standards is strengthened by the fact that vehicles imported today will continue to influence New Zealand's emissions for decades. Assuming little change in vehicle ownership and patterns of use, the average new petrol or diesel light vehicle will stay in the fleet for around 20 years and lock in significant emissions over its lifetime (section 12.3).

Several submitters described the risk of New Zealand becoming a "dumping ground" for high-emitting vehicles (Guardians of NZ Superannuation, sub. 32; Vector, sub. 63; the Morgan Foundation, sub. 127; Sigurd Magnusson, sub. DR363). Evidence of more emissions-intensive variants of vehicles in New Zealand suggests that "dumping", to some extent, is already taking place, as other countries move to implement bans or other policies to phase out fossil-fuel vehicles.

F12.11

Vehicle CO₂ emissions standards are warranted because buyers tend to discount future fuel savings at a much higher rate than is socially optimal. Domestic standards could also mitigate risks around "dumping" of high-emissions vehicles in New Zealand due to stringent standards and regulations adopted in other regions.

Standards could deliver significant emissions reductions with net economic benefits

The Australian Government has modelled the impact of a light-vehicle CO₂ emissions standard at different target levels (Commonwealth of Australia, 2016). The modelling found net economic benefits under all targets considered, primarily because fuel savings outweigh expected increases in vehicle costs. The strongest target delivered the largest net benefit, with a similar benefit–cost ratio to the weaker targets. As an emissions reduction policy, this translated to a negative "abatement cost" with a net saving of A\$48.7 for each tonne of CO₂ avoided.

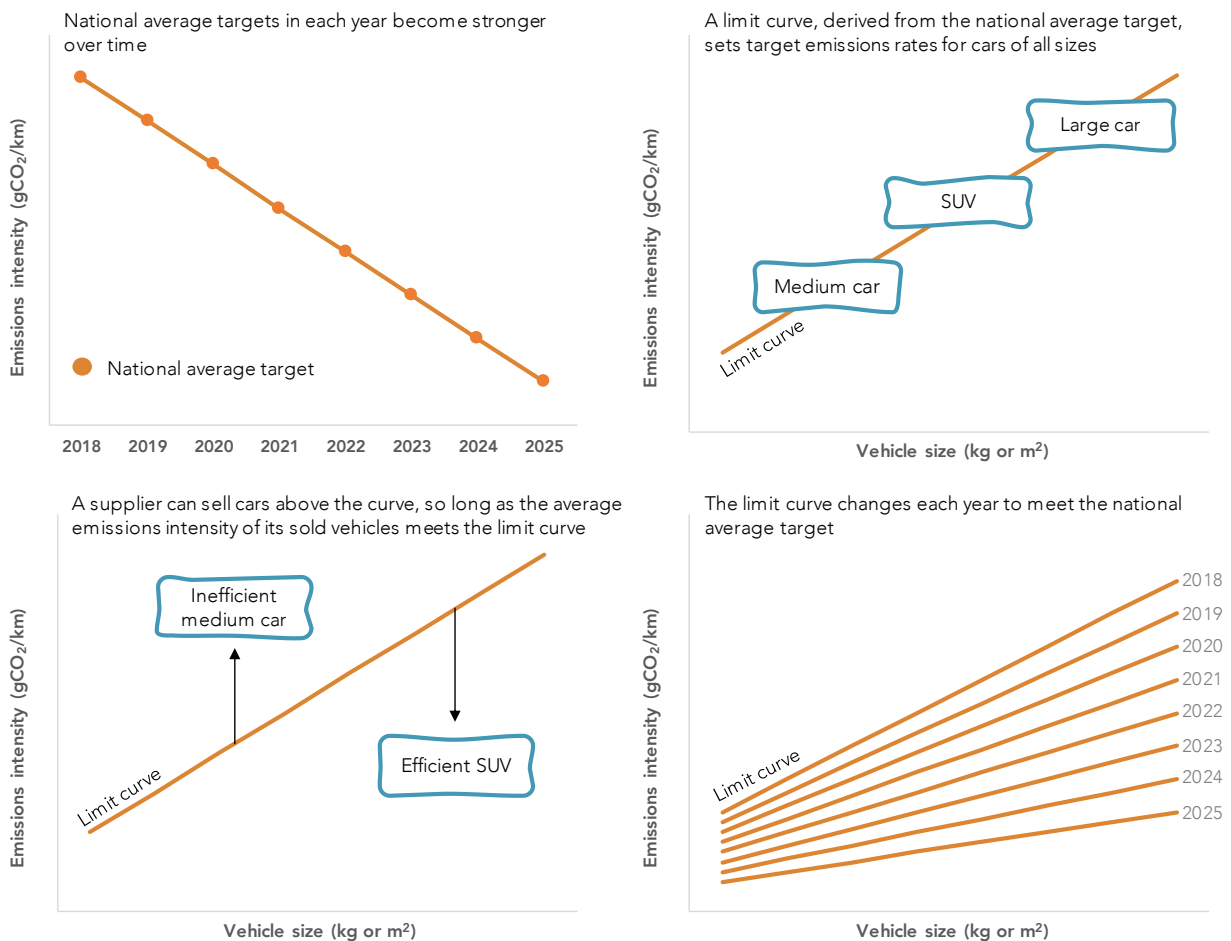
The current emissions intensity of New Zealand’s light vehicle fleet is very similar to Australia’s, so it is likely that similar results could be expected. However, a slower vehicle turnover rate would suggest a slower rate of emissions reductions. Further, as discussed below, characteristics of New Zealand’s vehicle market imply more complexity and higher administrative costs.

Fleet average standards provide flexibility and preserve choice

Countries that have introduced emissions standards have used *fleet average standards* (explained in Figure 12-15) Importantly, fleet average standards operate very differently to minimum performance standards, such as those used to regulate energy efficiency in appliances. A country sets a national target for average vehicle emissions (eg, an average vehicle entering the fleet in 2022 to emit less than 120 grammes of CO₂ per kilometre). Yet underneath this average, different targets are set for different vehicle types.

This design aims to drive efficiency improvements across the full range of vehicles on offer, rather than to influence the mix of vehicles (classified by size) being purchased. Suppliers have a high degree of flexibility around how they meet the standard – for example, they could choose to improve the efficiency across their whole vehicle range, or to increase their sales of vehicles that have very low emissions, such as EVs. In theory, it would be more efficient to allow for some form of permit trading between suppliers rather than requiring them to all meet a target individually. However, this would increase complexity and administrative costs.

Figure 12-15 How a fleet average emissions standard works



Source: Adapted from Climate Change Authority (2014).

Recommended earlier, a feebate scheme could achieve a similar objective to emissions standards (Toyota New Zealand, sub. DR177). Both feebates and standards have their own advantages. A benefit of feebates is they can be used to create a clear and strong incentive to purchase low-emissions vehicles (ie, EVs). On the other hand, as explained above, emissions standards can more directly target gains in efficiency across different types of vehicles, without influencing the mix of vehicle types. The two policies can complement each other (EECA, sub. DR326). As Barton and Schütte (2015, p. 31) explain:

A feebate provides a continuous long-term incentive to improve the performance of cars bought or manufactured. It is therefore different from a performance-based standard, which provides no incentive after minimum compliance, but it can readily co-exist with standards and complement them.

Designing a standard for light vehicles in New Zealand

Based on the arguments and research above, a strong case exists for introducing emissions standards for light vehicles in New Zealand. Many submitters, including the Ministry of Transport (sub. 4) and EECA (sub. DR326), supported the introduction of a vehicle CO₂ emissions standard for light vehicles. Both the Motor Industry Association and the New Zealand Automobile Association supported standards in principle, depending on their design. Motor Trade Association (sub. DR333) supported “the appropriate review of options and consultation that should accompany any such legislative move”.

Yet further work is required to determine precise design details that suit the New Zealand context. New Zealand’s vehicle market has very different characteristics to other developed countries – in particular, the reliance on used imports. CO₂ emissions standards in other countries are not applied to used imports, so for New Zealand to do this would be novel.

New Zealand also has many small importers dealing mainly in used imports. Provisional work by the Ministry of Transport indicates that over 400 traders imported between four and 20 used vehicles in 2017 (pers. com., MoT, 20 March 2018). For these small traders, compliance with a standard could be more challenging and costly. Toyota New Zealand (sub. DR177) submitted:

We believe administering such a scheme with used imports would ... have significant compliance and enforcement difficulties (and costs). A scheme of this type would be hard to apply to low volume importers, or ‘one-off’ imports. It’s conceivable that such difficulties could see commercial practices or arrangements emerge to avoid capture of used imports by an emissions standard (p. 4).

This would likely result in some market consolidation. The net benefits of a comprehensive, well-functioning standard may outweigh the costs of including small traders. If not, this problem could be addressed through a liability threshold, as is common for standards in other countries.¹⁵⁹

However, Toyota New Zealand considered that a maximum age for used vehicle imports would be a “simpler and more easily applied intervention” compared to standards for New Zealand. A maximum age would capture some of the benefits of a fleet average standard and involve much lower transaction costs. But, it would also limit flexibility and not achieve the gains in fuel efficiency across the wider fleet.

In designing vehicle-emissions standards, EECA (sub. DR326) recommends coordinating with Australia to signal to manufacturers the greater demand for low-emissions vehicles in Australasia. The Commission agrees that seeking to align New Zealand’s standards with an Australian system is a sensible approach, given many vehicle manufacturers would view Australia and New Zealand as a single market.

Introducing vehicle emissions standards is likely to raise average vehicle prices over time. Yet, the increase would be gradual, given that the standards only directly affect vehicles entering the fleet and most vehicles stay in the fleet for nearly two decades. Even so, the effect of any price increase would be felt particularly strongly among low-income households (Chapter 10). The Government should monitor the impact of emissions standards on vehicle prices over time.

R12.4

The Government should introduce CO₂ emissions standards for light vehicles entering the New Zealand fleet, subject to detailed consideration of design issues (for example, the treatment of small traders).

Accelerating the removal of dirty vehicles currently in the fleet

Drive Electric (sub. DR257), Toyota New Zealand (sub. DR177) and the Christchurch City Council (sub. DR284) recommended considering schemes to incentivise the scrapping of high-emitting vehicles. A scrappage

¹⁵⁹ The Australian Government suggested a potential threshold of 100 sales a year based on Australia’s market size relative to the European Union (Commonwealth of Australia, 2016).

scheme could be linked to incentives for low-emissions vehicles, providing the double benefit of removing older less fuel-efficient vehicles from the fleet, and increasing the stock of low-emissions vehicles. This would, in turn, reduce the emissions and improve the safety of New Zealand's fleet. The historic slow turnover of the fleet is a key contributor towards the poor fuel-efficiency of New Zealand vehicles compared to the fuel efficiency of vehicles in other developed countries (section 12.1).

A useful example of a scrappage scheme applied overseas is the Car Allowance Rebate System (also known as 'Cash for Clunkers') implemented in the United States in late 2009. The system allowed participants to trade an older, less fuel-efficient vehicle for a voucher of either \$3 500 or \$4 500 that goes towards buying a newer, more fuel-efficient vehicle. The scheme was hugely successful in encouraging the switch to lower-emitting vehicles, with an uptake of about 700 000 vehicles. However, the scheme cost about \$2.8 billion. Gayer and Parker (2013) estimate that the cost of the policy for every tonne of CO₂e reduced – between \$91 and \$301 a tonne – was relatively high compared to more cost-effective policies.

Previously, the Ministry of Transport ran trials of vehicle scrappage schemes in 2007 in Auckland, and in 2009 in Christchurch and Wellington. Both trials offered participants public transport vouchers worth between \$250 and \$400 to scrap their vehicle.¹⁶⁰ Separate reviews of the two trials found that the costs outweighed their benefits, mainly due to the low participation. About 16% of participants in the 2009 trial were planning on scrapping their vehicle before participating in the scheme.

Two key lessons follow from the New Zealand and US experiences that highlight the challenges of designing a cost-efficient scrappage scheme. First, sufficient incentives are required to encourage people to scrap a vehicle before its end-of-life, yet overly generous incentives can make a scrapping policy fiscally expensive. Second, scrapping incentives can result in providing incentives to those who were already planning to scrap their vehicle; therefore achieving no *additional* emissions reductions.

Even if a scrappage scheme may not be efficient in terms of emission reduction benefits relative to fiscal costs, the potential social benefits of the scheme may justify further consideration of such a scheme. Offering incentives to scrap older vehicles can provide a way of making lower-emitting vehicles more accessible to lower-income households. The incentives could limit any negative impacts from other transport mitigation policies, such as feebates or emissions standards, on these households. Targeting the incentives towards the most disadvantaged households (eg, using means testing) could be a useful approach.

R12.5

The Ministry of Transport should further evaluate the benefits and costs of incentivising the early scrapping of fossil-fuel vehicles to be replaced by low-emissions vehicles, taking into consideration any impacts of other mitigation policies (eg, feebates and the emissions price) on low-income households.

Signalling a transition to a low-emissions transport system

A rapid and widespread transition to a very low emissions light vehicle fleet is essential for New Zealand to achieve a long-term emissions reduction target. An option for New Zealand in signalling this transition is to commit to phasing out importing of fossil-fuel vehicles by some specified future date. Several other countries, including Norway, Ireland, United Kingdom and France, have made commitments of this sort, with target years ranging from 2040 to as soon as 2025 (IEA, 2018b).

The inquiry draft report asked participants to comment on how New Zealand could signal this transition, and specifically whether New Zealand should commit to phasing out imports of fossil-fuel vehicles. Submitters expressed mixed views (Box 12.5).

¹⁶⁰ The trials only accepted vehicles with current or recently expired Warrant of Fitness.

Box 12.5 A phase-out of fossil-fuel vehicles for the light fleet? Some views from submitters

New Zealand is typically a technology taker, primarily due to our smaller market and lack of vehicle manufacturing, and because of this it may not be necessary for New Zealand to commit to a firm date for the phase out of fossil-fuel vehicles. Our key source markets [...] are likely to commit to phasing out 100% ICE vehicles based on international and domestic regulatory pressure. (NZAA, sub. DR307, p. 19)

EECA agrees New Zealand should phase-out the importation of light fossil-fuelled vehicles by a sensible specified date, noting the size and age of the current light fleet. A stated end-date by the Government would provide certainty and a strong signal to both the industry (supply) and the public (demand). (EECA, sub. DR326, pp. 5–6)

The difficulty in mandating a specified date at this time will be knowing whether the date is both feasible and realistic, especially as New Zealand is heavily dependent on technology developments in other countries. The current level of uncertainty about what is achievable may result in a specified date being controversial. So, some care is needed in designing an appropriate national challenge based on a sound understanding of what is feasible. (Toyota New Zealand, sub. DR177, pp. 6–7)

While some of our Members would not be opposed to an explicit goal to phase out the importation of fossil-fuel vehicles, we as an organisation consider getting the price incentives right, to be far more important, and that with the right incentives, businesses and the public will transition along the most efficient path and avoid the potential shock that reaching a hard deadline might create. (Drive Electric, sub. 257, p. 2)

We consider the Government should signal the transition by providing a specific target date by which New Zealand will have phased out the importing of [fossil fuel vehicles].... [I]f New Zealand wants a domestic light vehicle fleet that is predominately EVs by 2050, we should work to phase out the importing of FVs[fossil-fuel vehicles] no later than 2030. (Genesis Energy, sub. DR301, p. 8)

Meridian considers the transport sector policies proposed by the Commission to be an adequate signal of New Zealand's commitment to a widespread transition away from fossil-fuel vehicles. (Meridian Energy, DR253, p. 17)

A targeted phase-out could send a strong signal of the need to transform the fleet...

A commitment to phase out importing of fossil fuel vehicles by a certain date could give a strong early signal to households and businesses about future mitigation policy, and the need to transform the vehicle fleet. This, in turn, could help to discourage future investment in fossil-fuel vehicles, improve awareness around low-emissions vehicles, and give confidence to vehicle suppliers and consumers to invest in low-emissions vehicles earlier, and businesses to invest earlier in the infrastructure for charging vehicles. The signal could also help to attract manufacturers of low-emissions vehicles to import to New Zealand, increasing supply.

... but it would also weaken incentives for investing in biofuels for the light vehicle fleet

However, such a commitment could also dampen incentives to invest in the development of biofuels. A phase-out would broadly aim to stop vehicles that are capable of producing CO₂ emissions (ie, vehicles with internal combustion engines) from entering the fleet. Yet, technically, such vehicles could produce much fewer emissions if powered using advanced "drop-in" biofuels – fuels functionally equivalent to fossil fuels made from plant material or waste (see section 12.5). Some submitters argue that pursuing a phase-out would rule out options for biofuels in the light fleet.

One of the big plusses for biofuels, particularly drop-in biofuels, is that they can reduce emissions but be used in engines designed for fossil fuels and distributed via existing fossil fuel distribution infrastructure. As identified in the report, banning fossil fuel-powered vehicles could rule out future options for using low-emission fuels like biofuels – which might be the best decarbonisation option for light vehicles in certain situations (e.g. remote locations). (Scion, DR366, p. 81)

A long-term signal should cover the full range of potentially feasible mitigation options

It seems increasingly likely that EVs will comprise a significant proportion of a future low-emissions fleet, given the relative development of EVs compared to other vehicle technologies and their potential scale. Yet,

other vehicle types such as high-efficiency hybrids, and biofuel- or hydrogen-powered vehicles could also feature, particularly in areas where electrification may be less suitable (eg, larger vehicles for farming, forestry, and other commercial and recreational uses in more remote country).

Given this, the Government should be cautious in setting a strong commitment to reduced transport emissions that rules out or discourages the development of potentially feasible mitigation options, such as drop-in biofuels (eg, through banning imports of internal combustion engine vehicles). Taking this approach could have the unintended result of transitioning the vehicle fleet at a higher cost, for instance if drop-in biofuels develop rapidly. In any case, complementary policies (eg, feebates), the relative cost of EVs and fossil-fuel vehicles, and the NZ ETS price, are what will fundamentally influence the vehicle and fuel choices of households and businesses.

There is, however, value in the Government clearly communicating the need to shift to a low or zero emissions fleet, for example through publishing a long-term policy target (eg, X% of vehicles entering the fleet very low or zero-emitting). Such a target could include EVs, as well as biofuel-powered vehicles. Setting a well-specified target could help give clarity about the objectives of other policies such as a feebate and emissions standards.

F12.12

There could be value in the Government specifying a long-term policy target that signals a transition to a very low (or zero) emissions fleet and covers the full range of potentially feasible mitigation options. Committing to phase out the importing of fossil-fuel vehicles for the light fleet could give a signal to households and businesses of the need to transform the vehicle fleet that could accelerate uptake of EVs. But, such a commitment could also impede the use of biofuels and other internal combustion engine technologies that may be important for uses where EVs may be less suitable.

Supply constraints could affect the feasibility of a long-term target

The risk that the supply of low-emission vehicles becomes constrained is important to consider in setting a long-term target. As New Zealand is primarily a technology taker in the vehicle market, the feasibility of any target depends on the development and adoption of right-hand-drive vehicles globally.

For the foreseeable future, there are likely to be some real challenges in sourcing sufficient volumes of new [low-emission] vehicles for the New Zealand market because of the pressure to supply other markets with limited global production of these vehicles (Toyota New Zealand, sub. DR177, p. 6)

There is an assumption here that suitable EV's will be available (new or used) - this is problematic. They are not, Tesla has consistently failed to deliver and the % of total manufactured volumes that are EVs is low. In 2016, Japanese people bought about 20,000 EVs, and by 2030 that number will increase to 210,000 out of a projected total of 5 million cars sold, according to the Economist. Only two Japanese companies sell EVs: Nissan and Mitsubishi. (Peter Hall, sub. DR205, p. 1)

Currently, Japan is by far New Zealand's main source of light vehicles.¹⁶¹ Compared to the pace of uptake likely needed in New Zealand, Japan's current national goal for EVs to make up 20-30% of vehicle sales by 2030 is relatively weak (IEA, 2018b).

12.5 Tackling heavy transport emissions

Emissions from trucks, buses, planes, trains and ships make up 6% of New Zealand's total emissions, and an even greater share when emissions from international transport are included. Decarbonising these fleets is tougher than the light vehicle fleet. Yet making headway in this area is important. Emissions from heavy road vehicles have been growing fast. Compared to light vehicles, heavy vehicles lock in an even larger amount of emissions over their lifetime (because they are used more intensively and have longer lives) and produce more air pollution.

¹⁶¹ In 2016, close to 80% of New Zealand's light vehicle imports were from Japan (MoT, 2016a).

The main opportunities for decarbonising heavy transport emissions are electrification, substituting fossil fuels with liquid biofuels and biogas, and adopting hydrogen-fuelled vehicles. Better utilisation of heavy vehicle fleets, using vehicles more efficiently (in terms of fuel), and shifting to cleaner modes of heavy transport (see section 12.6) can also achieve emissions reductions.

Electrifying heavy transport

The same battery technology used for powering light EVs can also be applied to heavy vehicles. While a small number (about 80) of electric trucks and buses are already on the road in New Zealand, high-duty cycle trucks and long-haul trucks are largely unsuitable for electrification under current technologies. Box 12.6 elaborates on the opportunities for adopting heavy EVs.

Box 12.6 Opportunities for adopting heavy on-road EVs

EVs currently have little penetration in the heavy vehicle fleet in New Zealand. This is primarily a result of the high cost and weight of battery packs for most types of heavy vehicles, their limited travel range, and the earlier stage of heavy EV development compared to light vehicles.

As with light vehicles, heavy EV technology is developing rapidly, and EVs are already commercially available that could replace buses and smaller heavy trucks powered by fossil fuels. The easy return to base and the predictable nature of bus travel make electric buses (e-buses) particularly suitable for some routes, since vehicles can be recharged while they are being unloaded (Heid et al., 2017) and using regenerative braking. In addition, air pollution co-benefits are particularly strong for buses operating within congested cities. While predicting at least ten years before the upfront price of e-buses matches diesel buses, Bloomberg New Energy Finance (2018a) estimates that the total cost of ownership for some electric buses is already lower than conventional buses. Reflecting this, Transit Group is investing in 10 pure-electric buses for public transport use in Wellington, while Shenzhen City's entire fleet of over 16 000 buses are now electric (Hanley, 2018).

However, larger heavy vehicles and those used for long-haul freight face greater hurdles to electrification. The limited travel range and the weight of batteries makes electrifying these vehicle tasks much less practical and economic (Concept Consulting, 2017a). The cost of deploying suitable charging infrastructure is also a significant barrier (Moultak et al., 2017). As such, commercial models of larger heavy EVs are, for the most part, not yet available (UK Department for Transport, 2017). That said, recent developments including the pre-release of the *Tesla Semi*, an all-electric, semi-trailer truck that Tesla is currently developing, suggest that technological solutions may emerge that will overcome existing barriers to electrification.

Electrifying rail lines is technically feasible, but the upfront cost is significant (especially compared to the size of rail emissions). KiwiRail (2016b) estimates a cost of \$2.5 million to electrify one kilometre of track. The section of the North Island Main Trunk Line (NIMT) between Hamilton and Palmerston North is one of the few track sections currently electrified. In December 2016, KiwiRail announced its plans to replace the electric fleet operating on the line with new diesel locomotives. The internal business case that underpinned this decision noted that replacing the fleet with diesel trains would increase CO₂ emissions on the NIMT by about 12 000 tonnes (equivalent to 0.08% of yearly transport emissions) (KiwiRail, 2016a). KiwiRail (2016b) considers that electrifying the rest of the NIMT could require capital expenditure of over \$1 billion.

Technologies for electrifying aircrafts and ships are less mature, although some positive developments have recently emerged. For example, in late 2017, EasyJet, a UK-based airline, announced it is working with Wright Electric (a start-up technology company based in the United States) to build an electric-powered commercial aircraft capable of flying up to two hours by 2028 (Monaghan, 2017). Researchers from the Robinson Research Institute at Victoria University of Wellington are working to develop an electric hybrid aircraft motor that is half the weight of a conventional jet engine (Robinson Institute, 2018) Norway also successfully trialled an 80-metre electric ferry that reduced emissions by 95% and operating costs by 80% (Lambert, 2018).

Removing tariffs to avoid discouraging the adoption of EVs

Tariffs of 5% or 10% are levied on a small range of vehicles, including e-buses, as well as some vehicle parts. Table 12.2 sets out tariffs that apply to EVs.

Table 12.2 Tariffs on EVs and parts

Tariff	Rate	Applicability
Motor vehicles for the transport of 10 or more people	5%	Applicable to vehicles with electric motors, hybrid motors and internal combustion engines
Motor homes	10%	Applicable to vehicles with electric motors, hybrid motors and internal combustion engines
Ambulances	10%	Applicable to vehicles with electric motors, hybrid motors and internal combustion engines
Parts – chassis	5%	Applicable to electrically propelled vehicles

Source: Customs, 2017.

In most cases, tariffs are applied equally across vehicle types. However, EVs generally have higher upfront costs when compared with fossil fuel-powered equivalent vehicles. As such, a tariff will further amplify the upfront cost premium for EVs; this may discourage uptake. In some scenarios, tariffs could also, at the margin, contribute to delaying the adoption of EV technology. For example, if a city council was considering replacing their diesel bus fleet with e-buses, the higher price of all buses might result in the council deferring investment for a further period of time. Also, because some countries are exempt from tariffs through free trade agreements, distortions could arise that disadvantage trade with countries that specialise in manufacturing and exporting EVs. For example, an e-bus from a country not exempt from tariffs through a free trade agreement (eg, India) would be at a disadvantage relative to internal combustion engine buses from a country that is part of a free trade agreement (eg, Malaysia).

The Commission understands that most of New Zealand's tariffs were set in the past to provide some protection for domestic industry. Despite changes in the mix of products produced domestically, tariffs have tended to remain in place, unless a deliberate decision has been made to remove them. Remaining tariffs are seen by some to have value, in that they can be used for bargaining purposes during the negotiation of free trade agreements. The Australian Productivity Commission (2010) assessed this argument and noted that while "some might argue that further domestic reform should be stayed to retain 'bargaining coin' in international trade negotiations, this would delay and potentially forego the relatively much larger and more readily achieved gains available from domestic reform in favour of smaller and uncertain benefits" (p. 26).

The Productivity Commission has previously recommended the removal of remaining tariffs:

Tariffs in both Australia and New Zealand continue to generate costs. These include administrative costs borne by the customs services, compliance costs borne by businesses, and distortions to production and consumption incentives... if governments seek to assist any activities or industries in the future, assistance should generally take the form of direct and transparent taxpayer funded subsidies. Against this background, the goal of free trade in goods with all trading partners should be the longer term objective for both countries. (APC & NZPC, 2012a, p. 108)

Although the presence of tariffs on some EVs is unlikely to be presenting a significant barrier to their adoption, retaining those tariffs is barely justified. Accordingly, the Ministry of Transport should work with the Ministry of Business, Innovation and Employment (MBIE) to remove any remaining tariffs on low-emissions vehicles, or parts for low-emissions vehicles.

R12.6

The Ministry of Transport should work with the Ministry of Business, Innovation and Employment to remove any remaining tariffs on low-emissions vehicles, or parts for low-emissions vehicles.

Biofuels

Biofuels made from plant material or organic waste can be used as a substitute for fossil fuels. The combined process of producing and consuming biofuels is often referred to as being “carbon-neutral”, since the CO₂ emitted when combusting the fuel is equal to the CO₂ that plants absorb as they grow. Growing a biofuel feedstock and converting the feedstock into biofuel typically involves some emissions, for example through the production and application of fertiliser used to grow feedstock (PCE, 2010).

Biofuels have the potential to reduce emissions across a range of transport modes

Even given the emissions involved with producing biofuels, many biofuels provide a real reduction in a vehicle’s emissions. Biofuels can play an important role in reducing emissions from the on-road heavy vehicle fleet, especially for long-haul and heavier tasks, due to the challenges with electrification. For the light fleet, EVs are likely to dominate emissions reductions, since their technology is further developed, and the scale of potential emissions reductions is much greater. Future biofuel technologies may produce a mix of fuel types, so biofuels can help reduce the emissions of fossil-fuel vehicles remaining in the light fleet (Scion, sub. DR366; Bioenergy Association, sub. DR352).

Biofuels also offer among the most promising options for reducing marine and aviation emissions, including from international transport. Ships are particularly well-suited to biofuels, since marine fuel specifications are much more flexible and biofuels produce much less sulphur pollution. In addition, the revised MARPOL Annex VI regulations for pollution from shipping will increase the attractiveness of marine biofuels (as well as electric ships) (National Energy Research Institute, sub. DR337). The regulations will lower the global cap on the sulphur content of fuels from 3.5% to 0.5% in 2020,¹⁶² restricting the use of dirty fossil fuels (IMO, 2016). For aviation, the International Air Transport Association has also set a target of reducing net emissions by 50% by 2050, with biofuels expected to feature prominently (Z Energy, sub. 110).

The total emissions reductions depend on the portion of biofuel contained in a fuel source. Due to technical limitations, biofuels currently available in New Zealand for road vehicles are typically blended with petrol and diesel in relatively small proportions (5% to 10% of a fuel) (EECA, 2017a). As such, emissions reductions from these fuels are relatively small. For instance, it is estimated that a typical blend of 10% bioethanol and 90% petroleum results in approximately a 5%–6.5% reduction in emissions (MBIE, 2016a). Larger-proportion blends are available, although only vehicles with specially modified engines accept these fuels.

More advanced “drop-in” biofuels are rapidly developing. Drop-in biofuels are functionally equivalent to fossil fuels, so can be used in much higher proportions than current biofuels without the need to modify vehicle engines (Scion, 2018). Neste Singapore (sub. 128) and Vladimir Koutsenko (sub. DR228) highlighted the recent development of renewable diesel, a type of drop-in replacement for diesel fuel. Z Energy (sub. 110) considers that an advanced biofuel technology could be ready to deploy in New Zealand in five years, while the Bioenergy Association (sub. DR352) expects that drop-in biofuels will be available in a few years.

Venture Southland (sub. DR336), Pavlovich Coachlines Limited (sub. DR357), First Gas Limited (sub. DR316) and Bioenergy Association (sub. DR352) also highlighted the potential for gaseous biofuels to replace fossil fuels in road vehicles and ships. Bioenergy Association noted that “liquid in solid waste treated in waste water treatment facilities or anaerobic digesters produces biogas which can be easily and cheaply upgraded to biomethane suitable for use as a vehicle fuel” (p. 15).

Opportunities for scaling up production of biofuels

Use of biofuels in New Zealand is small – only about 0.1% of total transport fuels consumed are biofuels compared to 4% globally (Scion, 2018). The most commonly used biofuel in New Zealand is bioethanol (an alternative to petrol), followed by biodiesel (an alternative to diesel). Most biofuels consumed locally are produced in New Zealand.¹⁶³

¹⁶² The New Zealand Shipping Federation (n.d.) notes that fuel refined in New Zealand has a sulphur content of between approximately 1.9% and 2.8%. It also suggests that the two possible approaches to complying with the revised MARPOL Annex VI (using fuel with less than 0.5% sulphur content, or using “scrubbers” alongside high sulphur fuels) are potentially significantly costly and impractical for vessel operators.

¹⁶³ In 2014, about 80% of biofuels consumed here were produced locally, the rest were bioethanol imports (Suckling, 2018).

For biofuels to have a more significant impact on emissions, New Zealand's domestic biofuel production needs to substantially rise (Box 12.7). While most fossil fuels consumed in New Zealand are supplied from international markets, the global supply of biofuel is much less abundant.¹⁶⁴ However, importing a larger volume of biofuels could be a useful opportunity to increase supply and reduce emissions, so long as the environmental integrity of these fuels is strong. The PCE (2010) emphasised the importance of avoiding the use of "dirty" biofuels that do not represent emissions reductions from a full life-cycle perspective.

Box 12.7 Feasibility of scaling up biofuel production in New Zealand

Historically, New Zealand has produced biofuels on a small scale, mostly using agricultural by-products such as whey and tallow. These are considered "traditional" feedstocks that are not grown purposely for producing biofuels, and are limited in volume.

Recently, Scion (2018) undertook a *Biofuels Roadmap Study* modelling the expansion of biofuel production in New Zealand up until 2050. The report focuses on a 30% substitution of liquid fuels with domestically produced biofuels under two broad scenarios: one where all land can be used to grow feedstocks; and the other where only non-arable land (ie, land unsuitable for producing food) is considered acceptable. The types of fuels, feedstocks and technologies used are modelled for each scenario. The following were useful insights from the study.

- Drop-in biofuels from non-food feedstocks (eg, from wood-based sources) appear the most suited to New Zealand. Most technologies for producing drop-in fuels are not yet commercially proven and come with technical risk.
- A rapid increase in biofuel production has significant implications for land use. For instance, in the scenario where arable land is unavailable, over 500 000 hectares of forests (including nearly 250 000 hectares of new forests) are used for growing feedstocks between 2046 and 2050. Where arable land is available, most fuels are produced from a mix of fibre logs, canola, and miscanthus.
- Only using *mature* technologies, scaling up biofuel production is already *technically* feasible. However, this would require engine modifications to new vehicles, a dramatic increase in cropping land to grow canola and sugar beet, and higher costs for biofuels.
- Compared to the range of fossil-fuel prices over the last ten years, the model suggests biofuels would be profitable in many cases. Although biofuels would not be profitable if current fuel prices persisted, an increase in the emissions price would hugely improve the competitiveness of biofuels.

The significant amount of afforestation identified in Chapter 11 as being necessary for achieving low-emissions could offer a useful source of feedstock for producing biofuels, subject to the economics of collecting, distributing and processing these feedstocks. Other emitting sectors (eg, users of process heat) are also likely to compete for the limited supply of feedstocks.

Box 12.7 identifies the technical risk associated with producing drop-in biofuels as a barrier to the scaling up of production.

Other barriers inhibit biofuel production. Most prominent is the low emissions price in the NZ ETS, which provides little commercial advantage in producing lower emissions fuels. Z Energy (sub. 110) estimates that emissions prices of over \$100 per tonne of CO₂e would be needed at present to make production viable with current fuel prices. The Bioenergy Association (sub. DR352) notes that some drop-in biofuels would be economic now "if there were economics of scale" (p. 14). Because of the maturing of bioethanol technology, costs of producing sugarcane feedstock and converting it into bioethanol in Brazil fell by 66% and 72% respectively between 1975 and 2004 (van den Wall Bake et al., 2009).

¹⁶⁴ For instance, Brazil, the largest exporter of biofuels globally, exported less than 1 billion litres of fuel ethanol in 2016, mostly to the United States (USDA Foreign Agricultural Service, 2017). New Zealand consumed over 3 billion litres of petrol in the same year (MoT, 2016a).

Scion (2018) also notes that the expansion of biofuel production would require coordination across the value chain. For instance, learning how to plant new feedstocks and the process of growing crops takes time (eg, forests planted today as a feedstock supply will take about 20 years before being harvested). The timing of growing feedstock must match the timing of future biofuel demand. The time needed to prove the feasibility of new biofuel conversion technologies provides an added uncertainty.

Finally, emissions from international aviation and shipping lie outside national GHG emission obligations and emissions pricing schemes. As such, use of biofuels in aviation and shipping is currently only incentivised for domestic application.

F12.13

Biofuels can potentially deliver considerable emissions reductions across a range of transport modes, including aviation and shipping. New Zealand's current production of biofuels is small. Drop-in technologies using non-food feedstocks (eg, wood-based sources) appear to be most promising opportunity for developing biofuels in New Zealand over the long term, but these are not yet commercially proven. Although biofuels tend not to be cost-competitive at current fossil-fuel prices, a higher emissions price in the NZ ETS would create a stronger incentive to develop and switch to biofuels.

Hydrogen fuel-cell vehicles

Several submitters suggested that hydrogen fuel-cell vehicles (HFVs) could play a useful role in decarbonising the heavy fleet (Contact Energy, sub. 29; Hera, sub. 96; Sustainable Business Council, sub. 131). HFVs are effectively a type of EV: the vehicle uses hydrogen gas to power its motor by converting the hydrogen to electricity. HFVs produce zero tailpipe emissions, however fuelling an HFV produces more emissions than charging a battery EV, because HFVs are much less energy efficient¹⁶⁵ (ie, driving a kilometre in an HFV requires much more energy compared to driving a battery EV the same distance) (Transport & Environment, 2017).

HFVs are technically more suited to long-haul heavy freight compared to EVs. Because of their longer travel range and faster rate of fuelling (due to their greater energy density), HFV fleets can be utilised more. In addition, the lower weight of hydrogen fuel-cells compared to EV batteries means that HFVs can carry heavier loads.

The biggest challenge with HFVs is the substantial infrastructure investment needed to produce, transport and distribute the hydrogen. Producing hydrogen (in a low-emissions way) in New Zealand could involve using electrolysis of water in power plants (Vivid Economics, 2017a). Once produced, the hydrogen needs to be distributed to support a hydrogen refuelling network. Unlike EVs that can be charged anywhere that is connected to the electricity grid, HFVs require some form of a refuelling station. The IEA (2017b) considers the cost of developing these stations to be the greatest barrier to the development of the HFV market.

HFVs are already currently sold and operated globally; for instance, California has nearly 5 000 hydrogen fuel-cell cars and 21 buses. Concept Consulting (2017a) also estimates that emissions prices of about \$100 to \$250 a tonne of CO₂ would be required now to make the technology viable. A government co-funded report on the opportunities for hydrogen in New Zealand will be released later this year.

EECA, the Ministry of Business, Innovation and Employment (MBIE), and other private sector partners have jointly commissioned a detailed study on the likely economics of hydrogen, and the implications for New Zealand specifically. The study will include a focus on hydrogen use in public transport and the freight sector. This work is expected to be completed in September 2018. (EECA, sub. DR326, p. 10)

Through its Provisional Growth Fund, the Government recently announced a grant of \$950 000 to Hiringa Energy (and its partners) towards scoping the development of infrastructure for hydrogen fuel in the Taranaki Region (H. W. Peters, 2018b). The Government should continue to monitor the developments of hydrogen fuel-cell technology.

¹⁶⁵ The lower energy efficiency of HFV vehicles compared to battery EVs is largely a result of energy losses that occur when converting the electricity to hydrogen using electrolysis and converting the hydrogen back to electricity.

F12.14

Some technical advantages of hydrogen fuel-cell vehicles (HFVs), including the lower weight and greater travel range, make them suited to long-haul heavy freight. However, the significant investment needed in new infrastructure to produce, transport and distribute hydrogen as a fuel, along with the higher cost of HFVs, provide large barriers to the development of an HFV market in New Zealand.

Supportive policies for adopting and developing decarbonisation technologies

In contrast to the light vehicle fleet where EVs have emerged as the dominant mitigation option, the most effective solution for decarbonising heavy transport is much less clear, and may involve a mix of technologies. Mitigation solutions for heavy vehicles, such as drop-in biofuels, EVs and hydrogen fuel-cell vehicles are immature, and most options already technically feasible are not yet commercially viable.

Complementary policies can help to accelerate the adoption of proven technologies. However, achieving significant reductions in heavy transport emissions in the long term will primarily rely on further advances in these technologies.

Complementary policies should be technologically neutral to provide greater optionality

Given the technological uncertainty, complementary policies for heavy transport should, as much as possible, provide even-handed support for different mitigation technologies. The NZ ETS is a good example of such a policy. Adopting a technology-neutral approach is critical to allow technologies to compete on a level playing field. This would avoid cancelling out options and favouring any particular technology in a way that unnecessarily raises the cost of mitigation efforts.

At present, biofuel alternatives to diesel fuel receive weaker support compared to low-emissions vehicles. While bioethanol (a substitute for petrol) is exempt from the fuel excise duty, other biofuels are not incentivised beyond the NZ ETS. In contrast, heavy EVs are currently exempt from RUCs. EECA also co-funds projects for low-emissions vehicles¹⁶⁶ through the Low Emission Vehicles Contestable Fund. For instance, Palmerston North City Council received \$350 000 to replace two diesel trucks with electric trucks for managing waste and recycling (EECA, 2018d).

F12.15

The most effective solution for decarbonising heavy transport is not yet clear, and may involve a mix of technologies. Given this, heavy transport policy should provide even-handed support for different technologies to deliver greater optionality and avoid unnecessarily raising the cost of mitigation efforts. At present, government policy provides relatively weaker incentives for investing in biofuels than for adopting low-emissions vehicles.

Policy stability is also critical for enabling investment in mitigation solutions

Among the key underlying themes of this report is the need for stable policy to provide confidence for businesses and households to invest in mitigation solutions. This is certainly true for heavy transport. Investing in the scaling up of a biofuel plant or the replacement of a diesel fleet with an electric fleet involves significant capital expenditure for a business. Whether a fleet owner or biofuel producer can be confident that the policy environment will continue to support their low-emissions investment will therefore be a key determinant of whether the investment is viable.

Historically, policies to support the production of biofuels have been highly unstable, contributing to the low levels of biofuel production. In 2008, the Government introduced a Biofuel Sales Obligation that required fuel companies to supply biofuels as a fixed percentage of their total sales. Later in 2008, following a change of government, Parliament revoked the obligation by repealing the relevant legislation. As a replacement, in 2009 the new Government introduced a biodiesel grants scheme that was guaranteed until 2012. The

¹⁶⁶ The Low Emission Vehicles Contestable Fund has not yet co-funded a project related to hydrogen fuel-cell vehicles.

scheme provided a grant of 42.5 cents a litre of biodiesel to producers who sold more than 10 000 litres a month. Initially, the grant was limited to biodiesels of no more than a 20% blend, but this was expanded in 2010 to allow for higher blends. The scheme was largely unsuccessful – less than \$2 million of funding was taken up compared to the planned \$36 million. The PCE (2010) considered that the three-year guarantee for the scheme was not long enough to encourage investment in large biofuel processing plants.

F12.16

Stable policy is critical to encourage significant upfront investments in heavy transport solutions. Biofuel policy, in particular, has been highly unstable, creating uncertainty for prospective investors in production plants.

Policy to support uptake of lower-emission vehicles

Earlier, the Commission concluded that the locking in of emissions from fossil-fuel vehicles entering the fleet justifies the use of policies over and above the NZ ETS for supporting the uptake of low-emissions vehicles (section 12.3). For the heavy fleet, the social benefits of shifting to low-emissions vehicles are even greater because of the large reductions in exhaust emissions that cause air pollution (these benefits are currently unpriced – see section 12.8).

Yet, under current technology, the range of options for fleet operators to invest in low-emissions vehicles is limited. Purchasing more fuel-efficient (less emissions-intensive) vehicles is the main mitigation option available for many heavy fleet operators, especially in the freight industry. While current policy does not incentivise operators to purchase more fuel-efficient vehicles, commercial fleets tend to place a much higher weight on fuel efficiency when making purchase decisions compared to consumers. This is because fuel costs often make up a high proportion of operational costs.

Including heavy vehicles in a feebate scheme or vehicle emissions standards (both recommended for the light fleet) could further encourage businesses to purchase less emissions-intensive vehicles. Several submitters supported a feebate for heavy vehicles, by which purchasing a lower-emitting vehicle earns a rebate while purchasing a higher-emitting vehicle incurs a fee (Robert McLachlan, sub. DR151; Genesis Energy, sub. DR301; Sigurd Magnusson, sub DR363; Greater Wellington Regional Council, sub. DR195; Wellington City Council, sub. DR276).

However, implementing these sorts of regulations is much more challenging for the heavy fleet than for the light fleet because the heavy vehicle market is more complex, with a wider range of vehicle types, sizes and applications (German & Meszler, 2010).

For a feebate scheme to cover vehicles within the heavy vehicle fleet, there needs to be reliable and comparable emissions data. As heavy vehicles (e.g. trucks) can vary significantly in terms of their performance, capability to carry loads, and componentry to suit individual business operations (as compared to light vehicles where a degree of standardisation can be observed), reliably comparing these for a feebates scheme will be difficult. (EECA, sub. DR326, p. 6)

Regulating the efficiency of road freight vehicles has proven more difficult than regulating the efficiency of passenger vehicles, which explains, in part, the lag in designing and implementing vehicle efficiency standards for these vehicles... As the operational performance of a truck depends not only on engine performance, standards should refer to the overall performance... Regulating vehicle performance is more complex as it depends on the vehicle's duty cycle, which... can have a significantly higher variance than for passenger vehicles. For example, a vehicle's efficiency and performance will differ when hauling a payload and without payload. (IEA, 2017b, pp. 41-42)

A handful of countries, including the United States and China, implement emissions standards for heavy vehicles, while the Commission is not aware of any international examples of feebate schemes for heavy vehicles. The US standards have been particularly successful, achieving a 24% improvement in the fuel efficiency of heavy-duty vehicles over six years (Transport & Environment, 2018). Transport & Environment (2017) consider fuel-efficiency standards to be the "single most effective measure" towards decarbonising heavy vehicles (p. 3). However, standards active overseas directly regulate truck chassis manufacturers operating in those countries, so would be less appropriate for New Zealand (IEA, 2017b). A feebate based on the emissions potential of a vehicle could also work against the uptake of biofuels (section 12.3).

The impracticalities of using feebates and standards for the heavy fleet raises the question of what policies are appropriate to incentivise the purchase of lower-emitting trucks and buses in New Zealand. Currently, e-buses and other heavy EVs are incentivised through the RUC exemptions and the Low Emission Vehicles Contestable Fund. Yearly savings from the RUC exemptions can range from around \$3 000 (eg, for a medium-sized delivery truck) up to \$20 000 (eg, for a larger freight vehicle) depending on vehicle weight and distance travelled (MoT, 2016b; EECA, sub. DR326).

EECA (sub. DR326), Sigurd Magnusson (sub. DR363) and Waste Management NZ (sub. DR332) recommended extending the RUC exemptions for heavy EVs beyond 2021. In the context of light vehicles, the Commission did not favour these exemptions, as it is reasonable for EV owners to contribute towards the maintenance of the road network. Because fleet operators place a greater weight on the ongoing costs of owning a truck or bus compared to say a household owning a family vehicle, RUC exemptions may be relatively more suitable for the heavy fleet than the light fleet.

However, incentives for low-emissions heavy vehicles can be designed in a way that does not stop vehicle owners from contributing towards the National Land Transport Fund (NLTF). For example, the UK Government provides grants of up to £20 000 for electric trucks; while in Paris, bus operators receive a €9 000 rebate for purchasing an e-bus (electrive.com, 2017). As Christchurch City Council (sub. DR284) submitted, a feebate limited to buses could be a useful option, given buses are more homogenous than other heavy vehicle types and a greater range of low-emissions alternatives for buses are available.

F12.17

Significant health benefits (from reduced air pollution) provide an even greater rationale for supporting the uptake of lower-emission heavy vehicles than for light vehicles. Yet, designing policies such as feebates or vehicle emissions standards is much more difficult for the heavy fleet. This is because the heavy vehicle market is more complex, with a wider range of vehicle types, sizes and applications. Simpler forms of price support (eg, upfront grants for heavy EVs) are likely more appropriate, although these should not prevent vehicle owners from contributing to road-user charges.

Policy to support uptake of low-carbon fuels

The Commission recognises that providing incentives for heavy low-emissions vehicles without additional support for biofuels would maintain the bias in favour of EVs. As identified, no policies beyond the NZ ETS currently incentivise the use of biofuels for heavy transport.

Suckling (2018) posits that a substantial increase in New Zealand's biofuel production is highly unlikely without government support. Z Energy also notes that

Z is the only biofuels manufacturer in the world (as far as we are aware) that has committed to biofuels production and supply with no subsidy... With support, Z could double the size of our biofuels plant in 18 months from 20 ML [megalitres] a year to 40 ML at a one-off cost of \$6-\$8m, further reducing transport emissions by 37 KT [kilotonnes]. While the marginal investment to increase capacity is relatively small, Z would be faced with greater price and quantity risk than we are currently facing for the total 40ML per year. With the right incentives, Z would be willing to forego the distinctive proposition of marketing NZ's only indigenously produced biofuel and make this product available to other industry participants. (sub. DR377, pp. 2-3).

While a rise in the NZ ETS price would make domestic and imported biofuels more cost-competitive, additional temporary support for biofuels may be warranted to accelerate the scaling up of biofuel processing plants. This support may achieve greater reductions in marginal production costs over time and drive greater innovation in the development of more advanced biofuel technologies. In its submission, Z Energy recommended introducing biofuel mandates for fuel sales or subsidies to support production.

Box 12.8 presents two policy options worth exploring that would better support investment in biofuels, as well as other low-carbon fuels.

Box 12.8 Options for incentivising low-carbon fuels

Low-carbon fuel standards

Several overseas jurisdictions have adopted low-carbon fuel standards (LCFS) to reduce their transport emissions. LCFS take different forms. California sets a limit on the carbon intensity – the amount of GHGs emitted per megajoule of energy produced – of fuels across the vehicle market. The limit falls gradually each year. This forces fuel companies to source lower-emission alternatives to fossil fuels to meet their target (or purchase credits from suppliers who overachieved their target). Alternatively, the UK scheme requires fuel companies to supply renewable fuels as a set proportion of their sales. This scheme is similar to New Zealand’s previous Biofuel Sales Obligation.

Vladimir Koutsenko (sub. DR228) and the Bioenergy Association (sub. DR352) proposed the introduction of LCFS in New Zealand. An advantage of LCFS is the ability to include a range of fuel types (eg, biogas and hydrogen). This provides fuel suppliers with flexibility about how they meet the standard. A stable LCFS system can also provide greater confidence to current and prospective biofuel producers about future demand for low-carbon fuels. Conceivably, the system could cover aviation and marine fuels.

However, without sufficient access to alternative fuels at a reasonable cost, standards could lead to damaging rises in fuel costs. A standards system therefore places the responsibility on government to set standards at a realistic level, taking into consideration the available supply of low-carbon fuel. The system could allow for fuel imports to increase the supply of low-carbon fuels available. Recognising recommendations made earlier in the chapter, another issue to consider is the risk of over-regulating the emissions from light vehicles if LCFS cover petrol as well as diesel fuel.

A grant scheme for low-carbon fuels

An alternative tool to LCFS is a grant scheme for low-carbon fuels. Such a scheme could be similar to the design of New Zealand’s previous biodiesel grants scheme – producers could receive a grant based on the amount of fuel they produce. The scale of incentive provided through the fuel grant (ie, \$ per litre) could be based on the carbon intensity of the fuel, so that fuels that deliver greater reductions receive larger incentives (and alternatively, fuels that do not deliver real reductions are not incentivised). Basing incentives on the carbon intensity of fuels would require comprehensive data on the full life-cycle emissions from the production of fuels.

An advantage of this approach over LCFS is the removed risk of damaging rises in fuel prices through the supply of low-carbon fuels. If fuels funded through the scheme are not cost-competitive even with the added incentive, then fuel companies will choose not to source them. In other words, fuel producers and suppliers face the financial risk rather than consumers. However, a grant scheme would be fiscally more expensive than using standards.

Source: IEA (2015b).

R12.7

The Ministry of Transport, with other relevant agencies, should explore the suitability of low-carbon fuel standards, and a grant scheme for low-carbon fuels, for decarbonising New Zealand’s heavy transport fleet.

Supporting innovation for decarbonisation technologies

Chapter 6 examines the role that innovation should play in supporting New Zealand’s transition to a low-emissions economy and recommends that Government should prioritise innovation support in areas unique to New Zealand, areas of existing research strength in climate mitigation, and areas where New Zealand needs to adapt imported innovations to support their uptake in New Zealand.

The challenge of developing mitigation solutions for heavy transport emissions is of particular interest to New Zealand because of its reliance on aviation fuels for the tourism sector and diesel fuel for long-haul freight. Even given its novel research into hybrid aircrafts and wireless charging for EVs (The University of Auckland, n.d.), New Zealand is broadly more likely to have a greater comparative advantage in producing biofuels than for other low-emissions fuel technologies, given its scope to grow feedstocks at scale. If researchers and firms with an interest in biofuels can demonstrate a comparative advantage in developing a fuel that can generate significant emissions reductions, then these entities should be well positioned to take advantage of any increase in R&D funding available for emissions-reduction research. Yet areas of biofuel research are also likely to exist where New Zealand has no comparative advantage. In these instances, New Zealand would be better placed to monitor international developments and seek to absorb and adopt technologies developed offshore.

F12.18

Achieving significant reductions in heavy transport emissions will largely rely on further advances in mitigation technologies. New Zealand's reliance on fossil fuels for tourism and long-haul freight provides a strong impetus for government support of innovation in promising emissions-reducing technologies where it has a comparative advantage, such as producing drop-in biofuels.

Emissions reductions are likely to be achievable through practical approaches

Practical approaches to reducing the fuel consumption of heavy transport, and better optimising the utilisation of fleets, can have a material impact on emissions. Reviewing mitigation options for freight transport in the United Kingdom, the UK Department for Transport (2017) estimates that both the use of more efficient driving techniques and industry collaboration to improve freight efficiency could reduce heavy vehicle emissions by about 15% by 2035 compared to business-as-usual levels, while retrofitting vehicles (eg, to minimise air resistance) could reduce emissions by about 5%. Deloitte (2018) notes that adopting intelligent transport systems to better plan, optimise, and adjust freight movements can improve freight efficiency by up to 10% and reduce emissions.

In 2014, the Government approved a ten-year plan, *New Southern Sky*, to modernise New Zealand's aviation system (Civil Aviation Authority, 2014). The plan signals the adoption of new and emerging technologies that will improve the efficiency of air traffic movements, achieve fuel savings, and reduce aviation emissions. More recently, the Government announced it is working towards setting regulations to support these changes (Neal, 2018).

In the freight sector, strong incentives already exist for fleets to be efficient – especially given that fuel is a large and growing cost, even for small operators. Yet lack of information about fuel-saving practices, and the short payback periods of freight operators are barriers to the adoption of emissions-reducing practices. EECA implemented a programme between 2012 and 2015 that worked directly with freight operators to improve the fuel efficiency of their fleet (eg, through driver training). A review of the programme suggested the costs far outweighed the small number of benefits from reducing emissions, largely due to small participation (MBIE, 2016c). Over 55% of freight trucks in New Zealand are in fleets with five or fewer vehicles, yet only 0.02% of these fleets participated.

The use of direct regulation may be more effective in achieving a high adoption of some specific practices. California, for instance, requires owners of new and existing large heavy-duty vehicles to adopt specific emissions-reducing devices, such as fuel-efficient tyres and aerodynamic technologies. The California Air Resources Board (2013) estimated that the regulations would reduce emissions by 0.7 Mt of CO₂e – about 3% of California's emissions from heavy-duty vehicles – and save trucking companies about \$5.1 billion between 2011 and 2020. In 2003, the Tokyo Metropolitan Government introduced regulations requiring owners to retrofit trucks and buses with devices to control particulate matter emissions.

An investigation into suitable vehicle technologies for regulating in New Zealand would be worthwhile. Regulations could help to overcome informational barriers around opportunities to improve vehicle efficiency, and the barriers related to short payback periods. Fuel savings from adopting emissions-reducing

practices may mean such a policy reduces emissions at a negative cost, depending on the cost of the technologies.

R12.8

The Ministry of Transport and the Energy Efficiency Conservation Authority should investigate the suitability of specific emissions-reducing technologies for regulating heavy vehicles in New Zealand.

12.6 Shifting modes, and other changes in travel patterns

The chapter so far has primarily focused on opportunities for reducing emissions through adopting new vehicle or fuel technologies. While these technologies will provide the bulk of transport emissions reductions in the medium term, changes in household travel patterns, and shifts towards cleaner modes of freight transport can deliver more immediate emissions reductions and provide valuable co-benefits.

Given that the co-benefits from these opportunities largely come from avoiding the negative externalities of private vehicle use, efficiently pricing these externalities is crucial. Section 12.7 looks at the arrangements for pricing transport services and negative externalities. Section 12.8 then assesses whether New Zealand's funding system for land transport adequately supports investment in infrastructure for low-emissions transport modes, so as to enable mode shifting.

Opportunities for changing household travel patterns

Mode shifting can deliver modest emissions reductions and significant wider benefits

Public transport, cycling and walking respectively make up about 3%, 1% and 17% of trips in New Zealand. Over the last decade, use of public transport has significantly grown while cycling and walking trips have been falling (MoT, 2014b, 2017b). The number of public transport trips in Auckland rose by 63% between 2003 and 2017, while the population only grew by 28% over this period (Auckland Transport, 2017). However, given its relative high density, the use of public transport in Auckland is low compared to the use of public transport in other Australasian cities (Nunns, 2014).

For a given trip, shifting from a private vehicle (powered using fossil fuels) to using public transport, cycling or walking effectively eliminates emissions. However, substantial mode shift would be needed to achieve a modest overall reduction in vehicle emissions. Modelling from Concept Consulting (2017b) estimates that an increase in public transport trips by 30%, cycling trips by 30% and walking trips by 100% over the next 20 years would achieve approximately a 1% reduction in light passenger emissions. Investigating the impact of more ambitious mode shift, Shaw et al. (2018) estimate that the combined effect of a 90% increase in Auckland's public transport's share of trips, 160% increase in cycling, and a 70% increase in walking, would be a 20% reduction in Auckland's light passenger emissions. To put this into perspective, such an increase would see Auckland's transport mode share equal to Wellington's current share.

Other benefits from shifting modes can be significant. Greater use of low-emissions transport modes can improve road safety and accessibility, relieve congestion, and provide gains in productivity (NZTA, 2013). The *2017 National Land Transport Fund Annual Report* shows that investments in public transport had the highest benefit–cost ratio of all activity classes in 2015/16 and 2016/17 (NZTA, 2017). CRL (2018) considers that the City Rail Link currently being developed will lead to over \$1.4 billion of travel time savings for public transport and road users. Increased cycling and walking can also lead to improved health outcomes.

A five percent increase in cycling and walking for trips of 2km or less in Auckland would bring health benefits of \$225 million per year, as well as reduce traffic... About half of regular public transport users walk for more than 10 minutes per day, compared with just 13 percent of people who do not use public transport. (MoT, 2017b, p. 25)

A large number of submitters emphasised the role of public and active transport in providing wider benefits from New Zealand's low-emissions transition. For instance, Guardians of NZ Superannuation (sub. 32) argued "the first priority of a credible climate change strategy in any country is improved public transport and a modern rail network for passengers and freight" (p. 10).

Addressing congestion through managing demand

Vehicles that frequently stop and start in traffic consume more fuel and therefore produce more emissions than when in free flow. Fast population growth, particularly in Auckland, has led to growing congestion pressures, and therefore higher vehicle emissions. An average weekday trip in Auckland took about 10% longer in 2017 than in 2013 (Ministry of Transport, 2017).

A core part of reducing congestion is influencing demand for travel, for instance through the adoption of intelligent transport systems that optimise the use of the transport network (NZAA, sub. DR307). An example of an intelligent transport system is the use of variable pricing across the road network to manage demand. Opportunities for congestion pricing are discussed in section 12.7. Initiatives that encourage car-pooling, such as transit lanes for high-occupancy vehicles, can also limit congestion in certain areas, as well as directly reduce emissions through avoided vehicle trips.

Travel preferences may change because of emerging transport and digital technologies

Discussed earlier in section 12.1, the dominance of private vehicle use may reduce over time, as services that provide on-demand mobility develop and consumer preferences towards mobility change. Several submitters, including Toyota New Zealand (sub. DR241) and the National Energy Research Institute (sub. DR337), noted that the emergence of ride- and car-sharing services¹⁶⁷, and other technologies that enable “mobility-as-a-service” (MaaS), has the potential to reduce vehicle ownership, travel demand and emissions. Toyota New Zealand suggested that incentives for MaaS are warranted.

Through the Low Emission Vehicles Contestable Fund, the Government has given funding to two car-sharing projects: \$500 000 to Yoogo – a fleet in Christchurch with 100 battery EVs; and \$500 000 to Mevo – a fleet in Wellington with 50 battery EVs. In 2017, NZTA, jointly with public and private partners, launched two pilot mobile applications for Queenstown and Auckland to connect individuals with different modes of mobility. The Government should continue to monitor developments of MaaS technologies that deliver more efficient transport solutions.

Technologies that minimise the need for face-to-face communication (eg, enhanced video conferencing) could also influence emissions. Attitudes towards vehicle use and air travel may change over time, especially with a higher emissions price.

F12.19

Greater use of public transport, cycling and walking will reduce light vehicle emissions, but a substantial mode shift is needed to deliver meaningful reductions. Reducing congestion (eg, using road pricing) and increasing uptake of technologies that enable mobility-as-a-service and minimise the need to travel can also reduce emissions. Shifting to lower-emitting patterns of travel can achieve significant other benefits, including improved accessibility, better health outcomes and overall productivity gains.

Opportunities for shifting from road freight to rail and coastal shipping

Roughly 90% of the more than 200 million tonnes of freight transported throughout New Zealand each year is carried on roads. In terms of freight kilometres, road transport satisfies about 70% of demand, while rail and coastal shipping each satisfy about 15%. Over recent decades, a gradual shift has occurred towards road transport and away from rail and coastal shipping (Deloitte, 2014; MoT, 2017b).

Some submitters viewed mode shift towards rail and shipping as a large opportunity to reduce emissions (Rangitikei District Council, sub. 35; Waikato Regional Council, sub. 48; Oji Fibre Solutions, sub. 71).

Rail and shipping offer low-emissions modes of freight transport...

In general, rail and coastal shipping are less emissions-intensive modes of freight transport compared to road. One study estimates that road freight is about twice as emissions intensive as rail and shipping (Cenek

¹⁶⁷ Ride sharing typically refers to services that provide one-off vehicle trips at short notice, but can also refer to car-pooling. Examples of ride-sharing services are Uber, Zoomy, and Lyft. Vehicle sharing is where people pay to use a vehicle usually for short periods of time (compared to normal vehicle renting services). Examples of vehicle-sharing services are Mevo and Yoogo.

et al., 2012). KiwiRail (sub. 124) estimates that moving a tonne of freight using rail produces 66% fewer emissions compared to road, though in some cases rail and shipping rely on heavy vehicles to transport goods at each end.

... but the volume of freight contestable across modes is limited

Often, certain types of freight are inherently suited to particular modes. Road freight has the advantage of providing faster, responsive, point-to-point service, so businesses often prefer using road, especially for time-sensitive loads (Deloitte, 2016). Where speed of delivery is less important, rail and shipping can be more cost-effective (Cenek et al., 2012). For instance, these modes are suited to bulk products such as meat (Asuncion et al., 2012). Even so, lack of access to effective rail and shipping networks can rule out using low-emissions modes (NZ Steel, sub. 64).

The distance of travel is an especially important factor in choosing a freight mode. Over short distances, rail and coastal shipping tend to be uneconomic (MoT, sub. 4). As such, road transport satisfies over 97% of freight demand within regions, while rail or coastal shipping is more competitive for inter-regional freight. Rail and shipping move about 30% of this freight load. However, the majority (nearly 80%) of New Zealand's total freight load, in terms of weight, is transported within regions (Figure 12-16).

Figure 12-16 Volume of freight transported across modes, 2012

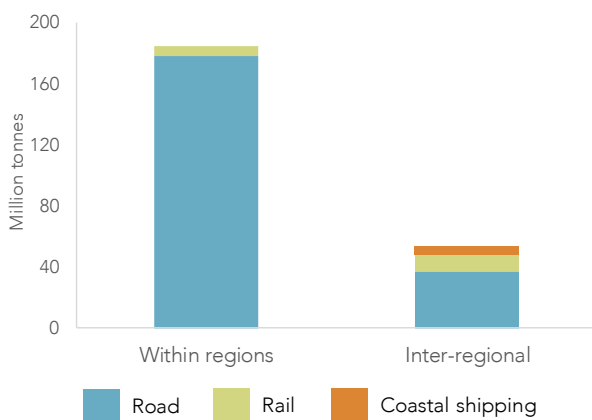
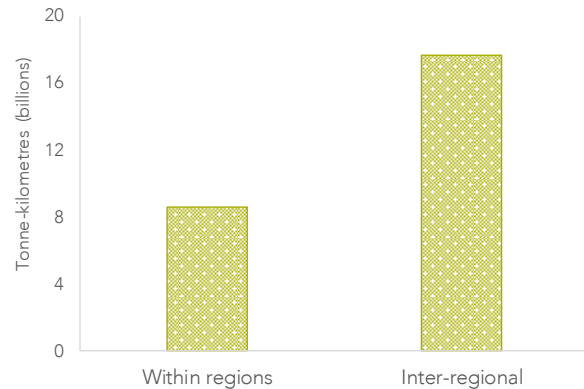


Figure 12-17 Total freight movements in tonne kilometres, 2012



Source: MoT Freight Information Gathering System, Deloitte (2014).

As a result, the volume of freight that is contestable across modes is limited (MoT, sub. 4; Federated Farmers of New Zealand, sub. 39). However, while the majority of freight demand involves travel within regions, about two thirds of freight tonne-kilometres involve inter-regional travel (Figure 12-17). In other words, well over half the emissions from heavy freight come from inter-regional travel (KiwiRail, sub. DR386). This suggests some potential for modest emissions reductions, since inter-regional freight is more suited to mode shift.

F12.20

Using rail and coastal shipping to move freight is less emissions intensive than using road transport. Because a large proportion of freight carried by road is not economically contestable, the potential for large mode shift in the freight sector is limited. Yet, freight trips over longer distances tend to be more suited to mode shift. This suggests some potential for modest reductions in emissions.

12.7 Pricing transport services and externalities

While providing large economic and social benefits, vehicle use also entails significant costs in terms of the development and maintenance of transport infrastructure and the negative externalities that affect the wider public. The way these costs are priced directly influences the transport choices that households and business make, and therefore affects overall transport emissions. Indeed, under-pricing of these externalities works against mode shift and other emissions-reducing changes in travel patterns.

Pricing of transport services

Current pricing and funding arrangements for transport involve a combination of cost-recovery approaches. Most costs are recovered through price mechanisms on road users, reflecting a “user pays” principle. Yet a significant share of the costs is borne by the general population, reflecting a view that some benefits from the transport system are shared even by those who do not use a vehicle.

The government imposes the following charges on those who own and operate motor vehicles.

- *Fuel excise duty on petrol:* This is a charge on petrol that is passed on to consumers at the pump. The current excise rate is 59.52 cents a litre.
- *Road-user charges on heavy vehicles and light diesel vehicles:* RUCs are distance-based charges, with the rate varying by vehicle weight and type. This reflects the fact that heavier vehicles contribute disproportionately to road wear. EVs are currently exempt from paying RUCs (section 12.3). New Zealand is unique in its use of a distance-based charging system for diesel vehicles instead of an excise tax. The reason for this different system is to avoid diesel that is used off-road (eg, on farms and in machinery) being charged to fund the transport system.
- *Licensing and registration:* These are fixed fees paid when registering a vehicle and obtaining a licence.

All revenue raised from these charges is hypothecated for investment in the land transport system through the NLTF. This covers road maintenance, building of new roads, public transport operations, road policing, and some other related expenditure. In addition to the charges listed above, rates revenue, fees for public transport, and general taxation revenue also contribute to transport funding.

Pricing externalities

A feature of current transport pricing arrangements is that they are designed to recover the costs of providing transport infrastructure and services. They are not designed to reflect negative externalities (such as air and noise pollution) associated with the use of private vehicles.

Concept Consulting (2017a) estimated the total annual costs arising from land transport in New Zealand. External costs added up to around \$9 billion a year, 40% of the total. For comparison, charges imposed on road users (through fuel excise, RUCs and licensing and registration fees) amount to around \$3.5 billion a year (NZTA, n.d).

Increasing the costs to better reflect the external costs of vehicle use would likely have significant impacts on the behaviour and vehicle choices of road users. Box 12.9 examines two examples of how road pricing could be adjusted to better account for externalities.

Box 12.9 Pricing transport externalities: congestion and air pollution

Congestion

Traffic congestion is detrimental to productivity and quality of life and causes higher vehicle emissions due to more stop–start travel. While those driving in congested conditions experience some costs directly, particularly from slower travel times, this does not account for the costs their trip is imposing on other road users. Cost estimates vary significantly depending on how congestion is defined and measured. For example, Wallis and Lupton (2013) estimate that congestion in Auckland costs between \$250 million and \$1.25 billion each year, depending on the measure used.¹⁶⁸

Congestion pricing, or road pricing, seeks to direct these costs onto the road user so that they are accounted for in private choices of if, when and how to travel. Many submitters (eg, Contact Energy,

¹⁶⁸ The amount of \$250 million a year measured the difference between the observed cost of travel and the cost of travel when the network is at capacity. The amount of \$1.25 billion a year measured the difference between the observed cost and travel and zero traffic (“free flow”). Both measures included the costs of travel time delay, schedule costs (ie, those who stagger or delay their trip times), crash costs, vehicle operating costs and environmental costs.

sub. 29; LGNZ, sub. 36; NZAA, sub. 43; and Z Energy, sub. 110) suggested introducing congestion or road pricing.

Well-designed road pricing could deliver multiple benefits such as more efficient use of road infrastructure and a reduction in investment in new road capacity. It could incentivise people who currently travel at peak times to pursue alternative options such as carpooling, shifting to public or active transport, or travelling at less busy times. Such actions would reduce emissions and other externalities.

The Government is currently working with Auckland Council on the joint project *The Congestion Question* to investigate whether to introduce congestion pricing in Auckland. Phase two of the project is due in August 2018, followed by a final report that will include recommendations along with a comprehensive evaluation of pricing options (MoT et al., 2017). Legislative changes are required to enable the use of road pricing tools.

Air pollution

In addition to CO₂, vehicle emissions include particulates, carbon monoxide, nitrogen dioxide, sulphur dioxide and benzene. The most harmful to human health are particulates and carbon monoxide.

- Particulates are very fine particles associated mainly with diesel vehicles. They can settle in the bronchial pathways and lungs causing respiratory problems such as asthma and bronchitis.
- Carbon monoxide is mainly associated with petrol vehicles. It makes heart disease worse, causes drowsiness and has been linked with learning difficulties. The effects of carbon monoxide are greater in cities due to high traffic and congestion rates (MoT, 2017a).

The Government's primary tool for reducing harmful vehicle emissions is the Land Transport Rule: Vehicle Exhaust Emissions 2007. The Rule sets emissions standards that new and used vehicles must meet when entering the New Zealand fleet. However, no pricing mechanisms are in place to internalise the costs associated with air pollution.

A good case exists to adjust the pricing arrangements for transport so that they more fully reflect the range of negative externalities associated with different modes of transport. In addition to improving wellbeing by creating a financial incentive to avoid travel that creates the externality, pricing externalities incentivises behavioural change consistent with lower transport emissions. Such changes include more efficient travel choices (for example, avoiding travel when roads are likely to be congested), and the adoption of more efficient vehicles. In addition, alternative modes of travel (such as public transport) are likely to become relatively more appealing if consumers face the full costs of private vehicle travel.

In the long term, shifting the road-user payment system towards a comprehensive electronic RUC system (and away from the system of fuel excise duty for petrol) could provide a useful means of pricing vehicle externalities (Toyota New Zealand, sub. DR177; Motor Industry Association, sub. DR342). An electronic system could gather vehicle data and base pricing on location and timing of vehicle use, and other factors linked to vehicle externalities. Some diesel-fuelled vehicles already use similar technology for their RUCs (EROAD, sub. DR182). Some reform of the road pricing system will likely be necessary in any case, given that no mechanism currently exists for EVs to contribute towards the NLTF. As the Ministry of Transport notes:

In the longer term, fuel taxes such as [fuel excise duty (FED)] are likely to become less sustainable and more inequitable as vehicles both become more fuel-efficient and move away from being powered by fossil fuels. While FED and RUC work reasonably well at present, a range of emerging issues and the opportunities provided by developing technology suggest they will not be the best way to fund transport in the longer term. (MoT, 2018d, p. 20)

The Ministry of Transport also warns that the cost of the technology needs to reduce before implementing a nationwide electronic RUC system becomes practical.

R12.9

The Government should take steps to amend the pricing system for transport so that a greater share of the external costs associated with private vehicle use are internalised. For example, the Government should continue to work with councils to enable and encourage the use of road pricing tools to reduce congestion and emissions in main urban centres. It should also investigate the potential for a comprehensive network pricing of road use through an expanded Road User Charges system.

12.8 Efficient investment in infrastructure for low-emissions transport

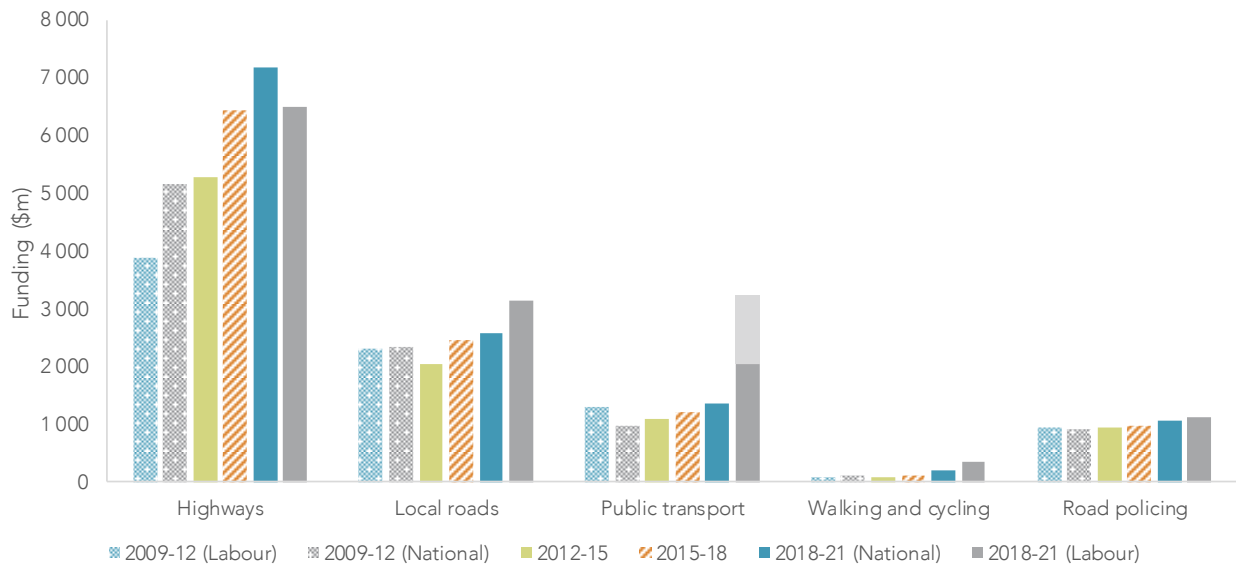
Section 12.6 discussed the potential to reduce emissions through shifting passenger and freight movements to lower emissions modes. Transport infrastructure dictates the travel options available and their relative attractiveness to individuals and businesses. Investment in low-emissions transport infrastructure is therefore a key determinant of the potential for mode shift to occur. The Ministry of Transport notes that, “travel habits can change when alternatives become more attractive” (MoT, 2017b, p. 24). Yet, over the last decade, investment in public transport and rail infrastructure has grown much slower than investment in roading.

Past transport investment in New Zealand has focused on roading

As mentioned in section 12.1, choices to focus investment on the motorway network rather than public transport networks date back to the 1950s. The road-building boom after the Second World War saw roading expenditure, as a percentage of gross domestic product (GDP), increase to around 2.5% before declining to around 1% through the 1980s and 1990s (MoT, 2014b). Investment in public transport and dedicated cycling facilities was very limited throughout this period.

A pronounced increase in investment across most transport activities began around 2004. Total transport expenditure each year has roughly doubled as a percentage of GDP since the early 2000s (MoT, 2011). Significant developments for low-emissions transport during this period include electrification of the Auckland rail network (2011–2015), upgrades to the Wellington metro rail network (2011–), the Urban Cycleways Programme (2014–), and construction of the Auckland City Rail Link (2017–).

However, investment in roading has increased significantly more than investment in alternative transport modes (Figure 12-18). The previous Government’s Roads of National Significance (RoNS) programme committed an estimated \$12 billion to seven large motorway projects (Bridges, 2017). NZTA states that the RoNS projects represent a “lead infrastructure” approach to encourage economic growth rather than wait until the network is under strain (NZTA, n.d.). This approach has not been applied consistently to investment in public transport and rail infrastructure. Under the assessment framework developed by NZTA for prioritising and allocating funding under the National Land Transport Programme (NLTP), any project that the government labelled a RoNS would receive a “high” rating for strategic fit – effectively guaranteeing funding – despite several of the RoNS projects being assessed with low benefit–cost ratios (Pickford, 2013).

Figure 12-18 Recent National Land Transport Programme funding by activity

Source: Government Policy Statements on Land Transport.

Notes:

1. The upper figure for public transport in 2018–21 Labour (shaded light grey) shows funding for transitional rail and rapid transit. These categories were not included in previous Policy Statements, although some funding was available for such activities.
2. The graph shows the upper limit of funding ranges.
3. Two sets of figures are shown for the 2009–12 and 2018–21 periods, as new funding ranges were introduced following changes of government.
4. Additional investment outside the NLTP is not shown. This includes around \$200 million a year in capital injections for KiwiRail and, prior to the current GPS, other Crown funding for rail projects.

Many submitters called for adjustment of funding settings to provide greater emphasis on public and active transport and rail freight. The Government released a new Government Policy Statement (GPS) in June 2018, which sees a marked shift in funding priorities away from state highway improvements and towards public and active transport (New Zealand Government, 2018b).¹⁶⁹ The GPS took effect from 1 July 2018.

The current system can inhibit efficient investment in low-emissions transport options

New Zealand's land transport investment system is set out in the Land Transport Management Act 2003. Every three years, central government issues a GPS on Land Transport. The GPS sets the overall objectives and long-term results sought for land transport over a 10-year period, as well as the national funding ranges for each class of transport activity (eg, new state highways, local road maintenance, public transport, and road policing). Regional authorities develop Regional Land Transport Plans which set out the regions' own objectives and intended activities. NZTA then develops a three-year NLTP, which gives effect to the GPS and outlines the activities and projects that will receive funding from the NLTF.

Several submitters referred to the current transport planning, funding and investment system – beyond simply the current settings – as a barrier to reducing transport emissions.

[E]xisting transport planning and policy settings, investment models, and forecasting methods, inhibit the development of innovative multi-modal transport solutions that could deliver emissions reductions in the transport sector. [...] The existing transport funding model incentivises councils to focus exclusively on road transport solutions, and regions are unable to adopt the best solution to transport issues, whether it be road, rail, air or sea. (South Island Regional Transport Committee Chairs Group, sub. 14, p. 1 & p. 3)

¹⁶⁹ Direct comparison between funding ranges in the current and prior draft GPS is problematic due to the introduction of new activity classes and the inclusion of funding previously excluded in the document (eg, funding for the Auckland City Rail Link).

The Commission has identified the following five issues within the current system.

Restrictions on which transport activities can receive funding from the NLTF introduce a bias towards road transport solutions and create inefficiencies

Despite its name, the NLTP does not encompass all investment in the land transport system – only those activities approved or managed by NZTA. Most notably, this excludes investment in rail track facilities.¹⁷⁰ Investment in rail infrastructure, managed by KiwiRail, is not covered in the current GPS. Instead, KiwiRail has relied on Crown appropriations through the annual Budget process. For example, investments in Auckland and Wellington’s metropolitan rail networks over the last decade received supplementary Crown funding. Coastal shipping facilities and inter-regional public transport services are also excluded from NLTF funding. A council or the NZTA may identify a preferred or more cost-effective investment involving these activities, but be forced to pursue a roading project instead unless they can successfully lobby for funding through other political processes. Box 12.10 presents two case studies that illustrate this issue.

Different assessment methods are used for investments in the road and rail networks

This is a further consequence of the current segregation in funding processes. Investments in the rail freight network are typically assessed as a business case for KiwiRail, limiting consideration of wider social benefits such as reductions in emissions,¹⁷¹ congestion, accidents and road maintenance requirements. Roothing projects, on the other hand, are assessed using a full social cost–benefit analysis along with other non-financial criteria set out in the GPS.

Funding levels can restrict the ability for projects to compete based on their merits

The government sets out NLTF funding ranges for different transport activity classes in the GPS. The funding settings reflect the Government’s view on how to best deliver on its stated priorities and objectives, but it is not clear how evidence is used to inform these decisions. While flexibility is provided by having funding ranges (which NZTA is tasked with optimising across), this is limited in practice, especially when dealing with large, one-off infrastructure projects. For example, even if the Auckland City Rail Link construction could be funded from the NLTF in principle, the scale of investment required would dwarf the typical yearly funding range for public transport activities. The activity class structure would prevent the project from competing with large roading projects in the Auckland region (or elsewhere) for funding.

In an analysis undertaken as part of the development of the draft GPS 2018 under the previous National Government, the Ministry of Transport received feedback from local government stakeholders that

[a]most all regions sought greater opportunity to use multi-modal approaches and/or flexibility in the GPS. Some regions felt that activity classes interfered with the overall story and objectives of the GPS. The regions felt that multi-modal solutions were less achievable under the current GPS structure. (MoT (2017d, p. 86)

Similar calls for greater multi-modal flexibility were made in submissions on this inquiry from the South Island Regional Transport Chairs Forum (sub. 32), Environment Canterbury (sub. 26) and Auckland Council (sub. 97).

Differences in the funding assistance rates for different activities incentivise councils to favour state highway projects

Funding assistance rates (the percentage of total project funding contributed by central government) for local roads, public transport and walking and cycling activities vary by region – with a nationwide average of 53% at present (NZTA, 2014). State highway projects are fully funded by central government. In urban areas where choices exist between expanding the state highway network or improving public transport networks, councils and ratepayers will be biased towards expanding the state highway network since it will not involve any direct financial contribution.

¹⁷⁰ Only passenger rail services and associated above-track infrastructure (such as train stations) can be funded through the NLTF.

¹⁷¹ KiwiRail’s business case would presumably include the projected cost it will face through the NZ ETS, but exclude the social benefit of reductions in emissions from road freight due to its operations.

Restrictions on revenue-raising tools limit councils' autonomy in a system that is already highly centralised

Current legislation inhibits councils from using alternative revenue-raising tools such as congestion pricing and value capture. This increases a council's dependence on central government funding sources and restricts its ability to determine their own transport priorities. These tools could help to overcome political and financial barriers to public transport investment by giving councils alternative options to raising rates. The Commission's 2017 report *Better Urban Planning* discussed the use of these funding tools and recommended that councils be enabled to implement road pricing and value capture mechanisms (NZPC, 2017a). In July 2018, the Government amended the Land Transport Management Act to enable councils to levy regional fuel taxes to fund transport infrastructure (MoT, 2018c).

The issues listed above work individually and in concert to create a bias towards investment in roading projects. This creates potential for poor outcomes that will lead to higher emissions, though it is unclear to what extent such bias has affected recent investment decisions in practice. However, evidence from submissions indicates that councils generally want to be able to invest more in public and active transport and alternatives to road freight, and favour a shift in central government funding priorities and processes.

Box 12.10 Examples of how restrictions on NLTF funding can inhibit low-emissions investments

Third Main Line from Wiri to Westfield

The Wiri to Westfield section of the North Island Main Truck railway in South Auckland is a key link for both freight and passenger services. The current twin track configuration is operating at maximum capacity. NZTA, KiwiRail and Auckland Transport collaborated to produce a case for investment which recommended building a Third Main Line (WSP and Parsons Brinckerhoff, 2016). This served as the basis for a 2017 Budget bid by KiwiRail, which was unsuccessful. The economic assessment gave an expected cost of \$60 million and benefit–cost ratio of between 1.5 and 2.3. While relatively low, this ratio is in a similar range to many roading projects funded under the current NLTP. Given NZTA's support for the investment case, it seems likely that if the Third Main Line could compete for funding through the NLTP process it would be successful.

Log cartage options in Marlborough

The South Island Regional Transport Committee Chairs Group's submission provided the following example where an investment in coastal shipping facilities would be considerably cheaper than a road upgrade, but is ineligible for funding.

The Marlborough RTC has been dealing with the issue of log cartage from the Pelorus and Kenepuru Sound areas. Significant commercial forestry was established in these areas in the 1980s and 1990s, supported by government subsidy. These forests are now ready for harvest but the required infrastructure is not in place. The cost of upgrading the Kenepuru Road to an appropriate standard is around \$6.1 million. In contrast, the cost of establishing a barging facility and upgrading roads to that facility is estimated at \$930 000. Barging the logs would also lead to less wear and tear on roads. Barging is also the cheaper option for forestry companies; although it requires double handling, the cost can be weighed against the distance trucks need to travel. The current GPS does not permit the funding of a barging solution. (South Island Regional Transport Committee Chairs Group, sub. 14, p. 3)

Levelling the playing field for transport investment

In principle, an efficient transport investment system will be designed to minimise biases and siloes, and to guide investment to deliver the highest value to society when all costs and benefits are considered.

Transport planning and funding should consider the most cost-effective modes of transport for each location, taking into account the full costs, including social, economic, and environmental. (Transport and Industrial Relations Committee, 2017, p. 26)

In practice, the economic impacts of transport projects – particularly large, transformative ones – are difficult to predict and quantify. Any assessment method will involve important value judgements. Transport infrastructure can have a strong effect on location choice for people and businesses over time, which poses a challenge to conventional economic assessment methods that focus on short-run impacts and put heavy emphasis on savings in travel time (NZIER, 2013). Uncertainty around the rate of uptake and the effects of new transport technologies such as autonomous vehicles (section 12.1) adds further complexity.

Even so, the Government should strive for neutrality as a guiding principle in the investment system. The previous Government signalled possible moves in this direction in May 2017 when it announced a review of KiwiRail’s operating structure (Burr, 2017). The review was stated to be focused on ensuring that KiwiRail is “on an even footing when it comes to funding”. Options that were mentioned included allowing KiwiRail to bid for funding from the NLTF and removing the requirement for the company to return a profit.

In the new GPS 2018, the current Government has introduced a theme of “a mode-neutral approach to transport planning and investment decisions” (New Zealand Government, 2018b, p. 24). The GPS states that “over time, this will mean that the scope of the GPS is likely to expand to include aspects of rail freight and coastal shipping” (p. 54). As such, the Government is planning a second-stage GPS “in order to fully realise Government’s direction for transport investment” (p. 5), which will rely on other work such as the Kiwirail review. In the meantime, the GPS includes a transitional rail activity class to provide immediate scope for funding passenger rail projects. It also establishes a new approach that will see results linked to objectives rather than activity classes, so that a single project may receive funding from multiple activity classes.

F12.21

New Zealand’s current transport investment system is biased towards investment in roading. An efficient transition to a low-emissions transport future requires an investment system that is:

- better integrated across modes;
- more flexible, with greater competition for funding across different transport modes and activities, and greater autonomy for councils;
- more neutral, by removing distortions and biases that favour particular modes or activities, and fully accounting for the social, economic and environmental costs and benefits.

Addressing path dependence

Removing biases in the transport investment system and improving the efficiency of transport pricing have the potential to drive significant change to travel choices and investment decisions in the direction of low-emissions mobility. However, the transport system is subject to strong path dependence. Past investment decisions and policy settings have shaped New Zealand’s present land use, travel patterns and social norms. Future choices will continue to be shaped by the past focus on roading and private vehicle travel.

Path dependence also affects the political economy of making beneficial policy changes. For example, a lack of quality alternatives to car travel due to past under-investment poses a barrier to implementing congestion pricing in Auckland. Over time, congestion pricing should enable a reduction in subsidies for public transport trips, but increased investment in infrastructure and services may be needed to smooth the transition, limit distributional impacts and “lean against the past”. This provides a case for some explicit prioritisation of low-emissions modes in the transition to a neutral system.

Providing a stronger focus on emissions reductions

The previous Government amended the purpose of the Land Transport Management Act in 2013 to “contribute to an effective, efficient, and safe land transport system in the public interest”. While the current legislation does not limit the Government’s ability to focus on reducing emissions from transport, neither does it provide any explicit steer in this direction. The extent to which reducing emissions is a consideration in transport investment is left to be determined by the GPS.

The previous Government's draft GPS 2018 largely represented a continuation from GPS 2015, renewing the same three strategic priorities – economic growth and productivity, road safety, and value for money – and six objectives. One objective was for a “land transport system that increasingly mitigates the effects of land transport on the environment” (New Zealand Government, 2017a, p. 12).

Yet the previous Government explicitly intended this objective to receive less focus than others (p. 12), implying only weak emphasis on reducing emissions. Notably, the draft GPS 2018 did not refer to any national emissions targets, even though it would span most of the period of New Zealand's first Nationally Determined Contribution under the Paris Agreement.

The new GPS 2018 promotes “environment” as one of four new strategic priorities, with a corresponding objective for a “land transport system that reduces greenhouse gas emissions, as well as adverse effects on the local environment and public health” (New Zealand Government, 2018b, p. 9). The Commission believes stronger emphasis on emissions reductions in the GPS is necessary and appropriate.

R12.10

The Government should make emissions reductions an ongoing strategic focus in transport investment and broaden the scope of the Government Policy Statement on Land Transport to cover the whole land transport system.

12.9 Conclusion

Transport has been the biggest contributor to New Zealand's rising emissions over the last thirty years. Yet, the wide range of mitigation options already available for transport means it can play a greater role than other emitting sources in achieving a low-emissions economy. The small impact of the NZ ETS on the fuel price means that a range of other policy instruments are needed to achieve large emissions reductions.

With New Zealand's low-emissions electricity grid, EVs provide a huge mitigation opportunity for decarbonising the light vehicle fleet. Modelling suggests that EVs can contribute a significant portion of emissions reductions across the economy. As costs continue to fall, EVs can also provide cost savings for consumers, though price is still among the key barriers to faster EV uptake. Policies such as feebates, emissions standards, and support for charging infrastructure, will be critical for driving behaviour change towards lower-emitting vehicles.

Decarbonising heavy transport is much more challenging, and large reductions in emissions will rely on further advances in technologies such as drop-in biofuels and heavy on-road EVs. Further work on policies to tackle heavy transport emissions, and appropriate support for innovation, is needed.

Across both the light and heavy fleets, modest progress can be made through changing travel patterns. These opportunities, such as shifting to cleaner modes of transport (eg, public transport and rail freight), managing demand of the transport network, and increasing the uptake of new mobility sharing technologies can also provide valuable health, environmental, and productivity benefits. Yet, investment skewed towards roading and a failure to price negative externalities from private vehicle use has led to high private vehicle travel and inefficient vehicle choices. Better pricing of vehicle externalities, and greater investment in infrastructure for low-emissions modes would lead to more efficient outcomes and lower emissions.

13 Electricity

Key points

- New Zealand already has a low-emissions electricity system (emitting around 5 megatonnes of carbon dioxide equivalent a year), with up to 85% of electricity generated from renewable sources. Remaining fossil-fuelled generation mostly serves, when required, as a currently vital resource to meet demand at daily and seasonal peaks and during dry years.
- The demand for electricity will increase greatly as other parts of the economy, particularly transport and process heat, replace fossil fuels with cleaner electricity. Expanding the supply of electricity could increase the challenge of reducing electricity emissions.
- New Zealand has abundant unused sources of renewable energy, particularly wind power (the cost of which has been falling rapidly) and geothermal (which still produces some emissions). Yet obtaining resource consents under the Resource Management Act 1991 may slow further expansion. The Government should review relevant planning instruments to reduce these barriers.
- Rapid technological development is allowing more responsive management of electricity demand and integration of distributed energy resources (such as solar power and batteries) into the system. These developments will complement grid-scale renewable energy generation to contain the need for fossil-fuelled generation.
- Under current technology and prices, no options exist to completely eliminate greenhouse gas emissions from electricity generation, without greatly increasing wholesale electricity prices. Yet technology is changing rapidly and by 2050 economic options, such as tidal or biomass generation, or excess wind generation, or carbon capture and storage, may have emerged.
- Given technological uncertainty and the importance of electricity prices for the adoption of low-emissions technologies in other parts of the economy, the Government should not favour particular electricity-generation technologies. The Government should, instead, through the New Zealand Emissions Trading Scheme, rely mostly on effective emissions pricing to guide new investment and decommissioning of existing plant.
- Integration of flexible demand response and distributed energy resources into a future electricity system will require ongoing adjustment to the regulation of electricity distribution. The Electricity Authority (EA) has a programme of work to address these issues. Yet the capability of the electricity distribution sector may not match the scope and speed of the required regulatory change. The EA is reviewing the capabilities of the electricity distribution businesses to ensure they can fully support innovation that will benefit consumers and help reduce emissions.
- With rapidly developing technology, the mix of monopoly and contestable network-based services is changing rapidly. The Government should review and amend statutory provisions so as to maintain strong incentives for innovation.
- The electricity market is complex and has been evolving over time as participants and regulators learn from experience with regulatory adjustments, and respond to changing technology, weather patterns and economic conditions. The Government should pay close attention to the risk of unintended and expensive consequences of any new interventions in the electricity system. An efficient and well-functioning electricity system will play a central part in the transition to a low-emissions economy.

New Zealand already has an electricity system with a high proportion of renewable generation and relatively low greenhouse gas (GHG) emissions. Electrification of transport and process heat will play a big role in New Zealand's path to an economy with very low emissions (see Chapters 3, 12 and 14). This implies a large expansion in electricity generation in the years to 2050, by as much as 65%. This, in turn, puts a premium on reducing electricity emissions, without raising electricity prices to a point where they dissuade electrification in other parts of the economy.

This chapter looks at the challenges in reducing electricity emissions efficiently, while ensuring that electricity supply meets demand at all times. Particularly important is the need to provide for dry years when hydro energy supply is limited. Based on current technologies, almost all the scenarios considered in this chapter envisage some generation continuing to use fossil fuels and produce emissions up to at least 2050 to meet this need. The scenarios also all involve additional emissions from geothermal generation. Yet technology is changing at a rapid pace and it is likely that over the next 30 years further options to reduce electricity emissions will emerge.

13.1 Low-emissions electricity will help reduce transport and process heat emissions

By international standards, New Zealand already generates a high proportion (85%) of electricity from renewable energy. Hydro generates more than 50% of New Zealand's electricity (in some years up to 65%). Electricity generation from fossil fuels produces around 4 megatonnes (Mt) of carbon dioxide equivalent (CO₂e) or around 5% of all New Zealand's emissions, while geothermal generation produces almost an additional 0.9 Mt CO₂e. The electricity and waste sectors produce comparable levels of emissions.

The path to a very low-emissions electricity system requires decommissioning and not replacing existing fossil-fuelled plants. Two major gas plants closed in 2015. Yet fossil-fuelled plants currently play a crucial role in covering both daily peak demand and the risk of a dry year (section 13.2). As the proportion of electricity generated from intermittent renewable sources rises, ensuring that supply meets demand at all times may be more challenging (section 13.3).

Electricity is a significant input into other parts of the economy and will grow substantially in importance (Chapter 3). Electrification of light vehicles and of process heat will play a central role on a pathway to a low-emissions economy (see Chapters 3, 4, 12, and 14). Light vehicles currently emit over 12% of all emissions, while using fossil fuels to produce heat for industry produces over 11% of all emissions. If reducing emissions from electricity generation significantly increases the cost of electricity, this could delay the electrification of other sectors where the reductions are potentially larger. The cost of reducing electricity emissions is therefore material not only for the effects on electricity consumers, but also for effects on the overall efficiency of emissions reductions across the economy (Mercury, sub. 49; Meridian, sub. 55; Transpower, sub. 81; Genesis, sub. 118; New Zealand Wind Energy Association, sub. DR274; Orion, sub. DR210).

The New Zealand Emissions Trading Scheme (NZ ETS) covers electricity generation. The NZ ETS requires upstream suppliers of fossil fuels to surrender New Zealand Units (NZUs), with an option for major downstream fossil-fuel users to be points of obligation (Chapter 5). Section 13.4 investigates the emissions prices that are needed to incentivise generation of very low emissions and the flow-on effects on wholesale electricity prices.

13.2 Security of supply and resource adequacy

The biggest challenge for New Zealand in moving to an electricity system with very low emissions is providing for resource adequacy, particularly in dry years.

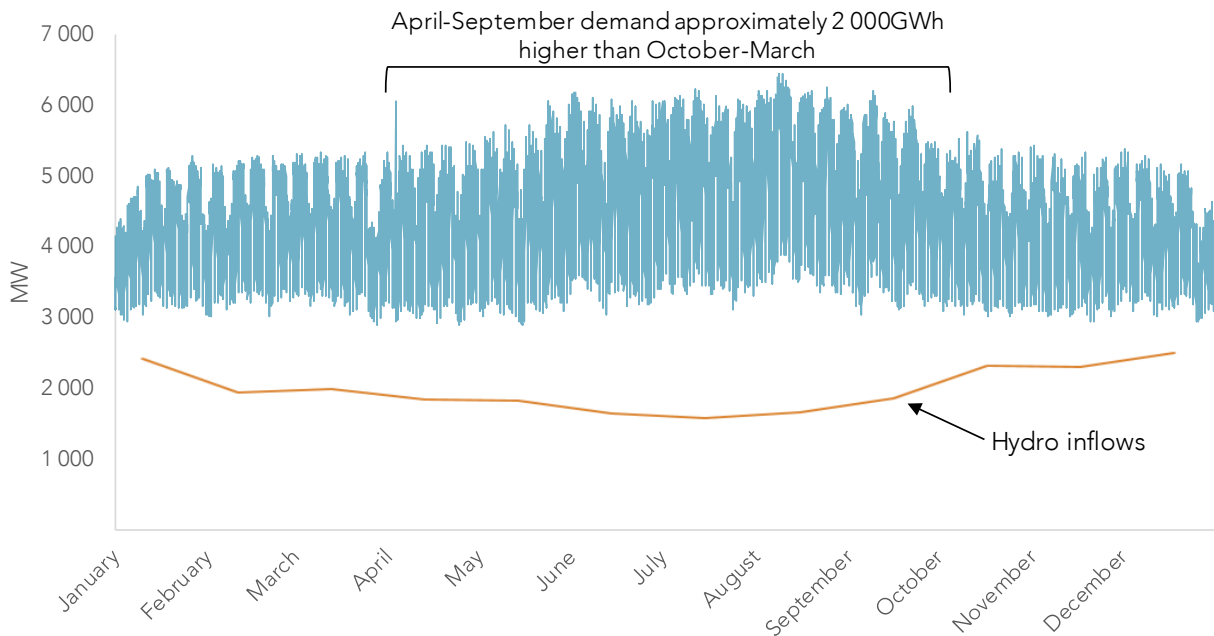
Resource adequacy

Resource adequacy has two broad dimensions:

- meeting the highest instantaneous demand from the system (capacity adequacy); and
- the ability to meet demand over a period of time (energy adequacy).

Demand varies by time of day, and by seasonal weather patterns (Figure 13-1). In 2016 demand peaked at over 6 000 megawatts (MW) and fell below 3 000 MW at its lowest. Some generation needs to be flexible to provide energy adequacy from one period to the next, as generation from intermittent fuels and demand varies over time. In the short term, wind and solar generation vary; in the medium term, hydro, wind and solar energy inflows are uncertain and, on average, negatively correlated with demand. Heavy reliance on hydro energy means that seasonal changes in the weather potentially have a strong impact on energy adequacy in New Zealand.

Figure 13-1 Electricity half-hourly demand and monthly hydro inflows, 2016



Source: Stevenson et al. (2018).

Flexible fuel contracts (eg, for coal and gas) and storage of fuel in gas and hydro reservoirs and coal stockpiles have historically been important for supporting flexible generation (Genesis Energy, sub. DR301). In the future, batteries and demand response (DR) will play significant roles in providing this flexibility; yet both are likely to provide only short-term flexibility (section 13.5). They are unlikely to provide the flexibility to deal with the confluence of seasonal changes in demand and seasonal changes in inflows, particularly during dry years.

Capacity and energy adequacy have a time dimension. The energy a plant can supply on average over a prolonged period is different to what it could supply in any given half hour. As a result, intermittent fuels, such as wind, contribute more to energy adequacy than to capacity adequacy. Wind is relatively dependable over extended periods, but cannot be relied on to supply energy in a particular half hour. On the other hand, gas plants, if required, can run at near capacity at any time, providing they have fuel on hand.

Solar, without accompanying battery storage, does not provide any capacity adequacy as peak demand in New Zealand occurs during winter nights. Without battery storage, a system with a large solar capacity will experience substantial hour-to-hour swings in output that need to be matched by some other flexible, responsive capacity.

Resource adequacy in “dry years”

Inflows to hydro lakes in particular years do not generally reflect the pattern of “average” inflows shown in Figure 13-1. Inflows can be quite volatile from month to month and season to season. Generators collectively manage this volatility currently by using a combination of:

- hydro reservoirs to “shift” some of the summer inflows to winter; and
- discretionary (fossil-fuelled) plant to supplement supply in winter (sometimes referred to as “hydro firming”).

Figure 13-1 shows that in an average year, a significant amount of storage will be required to shift enough energy from periods of low demand and high inflows to periods of high demand and low inflows. New Zealand currently has around 4 000 gigawatt hours (GWh) of national storage, which provides an ample buffer in an average year.¹⁷² Even so, other factors increase the need for discretionary generation:

- weather patterns are not predictable and hydro inflows do not reliably match the averages depicted in Figure 13-1; and
- reservoir managers consider the risk of a dry year when deciding how much water to store before each winter (for instance, if rainfall is low in November, generators may then use fossil-fuelled plant to meet current demand so as to preserve water in hydro reservoirs).

The electricity market coordinates generators' expectations and choices through the wholesale electricity price. In addition, Transpower currently conveys information to the market on seasonal resource adequacy through two measures – the Winter Capacity Margin (WCM) and Winter Energy Margin (WEM).¹⁷³

The energy margin... assess[es] whether it is likely there will be an adequate level of generation and HVDC [high-voltage direct current] south transmission capacity to meet expected electricity demand in extended dry periods. The capacity margin assesses whether it is likely there will be adequate generation and HVDC north transmission capacity to meet peak North Island demand. (Transpower, 2018a, p. 4)

A future increase in demand for electricity (due for instance to electrification of the vehicle fleet and industrial heat) may increase the amount of energy required to be shifted across seasons through hydro storage. Current storage capacity may need to be further supplemented from other flexible sources of generation (such as thermal) or demand management (section 13.4) or changes to hydro water resource consents.

Quality of supply and system stability

A well-functioning electricity system needs to reliably supply electricity of suitable quality to meet demand at all times. The system needs a stable, resilient grid that can adjust rapidly to sudden fluctuations in demand and supply, including unplanned breakdowns of major system components. The System Operator (a unit within Transpower) commissions ancillary services to maintain quality of supply. These services keep frequency and voltage within specified ranges and restore operation in the event of a major outage. A system with a high percentage of intermittent renewable generation poses challenges for maintaining system stability (section 13.6).

13.3 Decision making in the New Zealand electricity sector

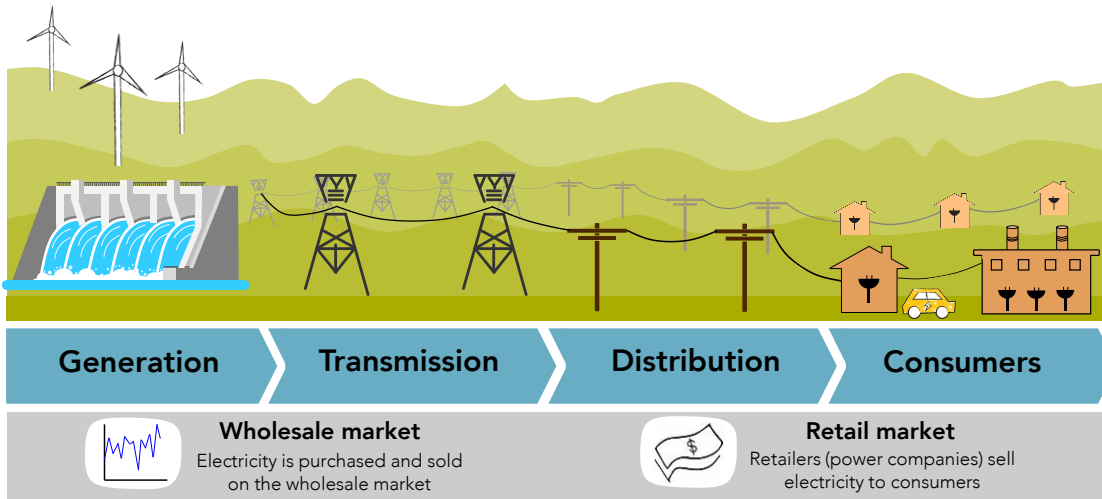
Five large generation companies operate 179 power stations to produce the majority of New Zealand's electricity. Transpower, a state-owned enterprise, owns and operates the national transmission grid, while 29 electricity distribution businesses (EDBs) transport electricity from the grid to homes and businesses.¹⁷⁴ Consumers buy their electricity from one of more than 30 retailers. Some generators also operate retail businesses (Figure 13-2).

Transpower, as the contracted system operator, coordinates electricity supply and demand to ensure a continuous balance both in real time and for future periods. The Electricity Authority (EA) oversees the operation of the wholesale electricity market.

¹⁷² Mercury (sub. 49) advised that a typical dry year shortfall in hydro-generation is equivalent to around 4 terawatt hours (TWh). Mercury points out that meeting this shortfall through battery storage, even at 5% of the current cost of batteries, would be prohibitively expensive.

¹⁷³ Transpower also publishes daily hydro lake levels relative to hydro risk curves.

¹⁷⁴ While New Zealand has more EDBs than Australia (which has 16) and the United Kingdom (which has 13) (see IEA, 2017a) other jurisdictions such as Sweden and Germany have large numbers of small, municipally-based EDBs (Yarrow, 2018).

Figure 13-2 Electricity supply in New Zealand

Institutions and regulation of the electricity sector

The EA, an independent Crown entity, is the primary electricity market regulator, and responsible for the efficient operation of the New Zealand electricity market. Section 15 of the Electricity Industry Act 2010 specifies the EA's objective as being "to promote competition in, reliable supply by, and the efficient operation of, the electricity industry for the long-term benefit of consumers". The EA sets the framework for the operation of the sector, including provisions for "security of supply" (or resource adequacy). In particular, it establishes rules for the sector through the Electricity Industry Participation Code 2010 (the Code). The EA also guides the methodologies for allocating transmission and distribution network costs between different network users.

Under Part 4 of the Commerce Act 1986, the Commerce Commission regulates Transpower and EDBs because they operate in environments with little or no competition.

The Commission applies price-quality regulation to Transpower and 17 of the 29 EDBs. The Commission sets:

- the maximum prices/revenues that are allowed at the start of the regulatory period;
- the yearly rate at which maximum allowed prices can increase; and
- the minimum service quality standards that must be met.

Twelve mostly small, trust-owned EDBs are subject only to information-disclosure requirements.

In addition, Transpower must obtain Commerce Commission approval for investment in transmission grid upgrades above a certain size and for base capital expenditure.

How the New Zealand electricity market operates

The International Energy Agency (IEA) notes:

New Zealand's electricity system is unique. New Zealand was among the first IEA members to introduce unbundling and competition in its electricity market. The country has an effective energy-only market based on financial transmission rights and locational nodal pricing – it is a leading example of a well-functioning electricity market design among IEA member countries, and continues to work effectively, thanks to appropriately targeted Government intervention. (IEA, 2017a, pp. 101-102)

Since the 1990s, the main features of New Zealand electricity market have been:

- an energy-only electricity market (meaning generators are paid only for electricity they supply and no payments are made simply for supplying capacity or energy adequacy);

- financial contracting for risk management (whether over the counter or through an organised exchange in financial instruments);
- separation between lines and retail businesses (although this was relaxed in 2010, the extent of retailing activity by lines companies remains minor);
- open or equal access arrangements to transmission and distribution networks; and
- full retail contestability.

Retail tariffs are not generally regulated, but are subject to the Low Fixed Charge (LFC) Tariff Option regulations (2004) (section 13.6).

The “energy only market” establishes the lowest-cost supply of electricity at the margin to meet demand in all conditions. Generators only receive payment if and when they run. No payment is made for available but unused capacity.

As electricity demand rises and falls, the System Operator calls additional generators onto the system or dispatches them off based on their offer prices and so supply meets demand. Wholesale prices are published every 30 minutes for a number of locations around the grid, while indicative spot prices are published every five minutes. All generation that runs generally receives the price of the highest-priced, dispatched generator’s offer, adjusted to each generator’s (and load’s) location. Discretionary plant (such as hydro and thermal) generally set the wholesale price as such plant can operate “at the margin”, while other less-flexible plant is a “price taker”.

The Code provides for scarcity pricing in the form of a price band between \$10 000 and \$20 000 a megawatt hour (MWh), which is introduced into the market when an electricity supply emergency forces power cuts (called emergency load shedding). This provides an incentive for retailers to hedge wholesale purchases and to take other steps to avoid exposure to high wholesale prices.

As noted, markets are also available for ancillary services to manage the security and quality of electricity supply. Ancillary services are available

to keep the frequency of the grid within its normal band; to provide additional electricity in the event of failure; to reduce injection of electricity to stop an unplanned rise in system frequency; to inject power into the system to boost voltage; and to restore operation in the event of a major power outage. (Electricity Authority, 2016, p. 16)

Businesses decide on the location and type of investment in generation after considering the prospective profits and risks from selling electricity and ancillary services. Two such risks are operating in fewer periods than expected and volatile income streams. Generators must meet technical requirements for connection to the grid (administered by Transpower) and comply with market rules, including prudential requirements.

Domestic-scale consumers, who have a choice of retailers, usually receive an invoice with all of the costs of supply bundled together. Costs include distribution, transmission, energy, an emissions price, retail overheads, metering, market administration and Goods and Services Tax (GST).

Consumers can install their own generation and batteries “behind the meter”. Distribution charges may take this into account. Some retailers offer incentives to consume at times of the day that will reduce the costs to both the EDB and the retailer. Increasing numbers of consumers are taking up these options.

A market for firm energy is developing

Stevenson et al. (2018) raise the issue of the strength of incentives to retain plant purely to manage extreme hydro shortfalls (known as hydro-firming) in a system with a high proportion of renewables. They argue that investors in such plant would have to be rewarded with very high prices when it did operate, given the infrequency of use. They question whether, at some time in the future, New Zealand will require a market for firm energy (alongside the market for energy) to address this issue.

Yet a useful market for firm energy already exists, though it mostly operates among the large generators and gentailers. In particular, Genesis has retained the Huntly Rankine plants for use under a voluntary “swaption” agreement with Meridian (which runs hydro and wind generation) (New Zealand Herald, 2016). Meridian also has demand response arrangements with the Tiwai Point aluminium smelter that effectively provides it with firm energy in the event of a dry year. In addition, Huntly provides Genesis with firm-energy cover for its retail base.

The EA has been working to get financial products that cap electricity prices listed and traded on the Australian Stock Exchange. These products will further facilitate the development of voluntary markets for firm energy in New Zealand. The initiative seeks to bring greater transparency and robustness to pricing of capacity and dry year risks. It will provide a means for any electricity retailer or consumer to insure against large spikes in wholesale prices. The trading of these products will reward investors for holding plant to provide firm energy when required.

The EA anticipates undertaking further initiatives to encourage demand-side participation in the market for firm energy (section 13.5 and section 13.6). The EA expects that this approach, by starting early, will provide time for market participants to learn from events and evolve their risk management practices (pers. comm., 13 April 2018).¹⁷⁵

Transpower submitted that “maintaining security of supply [especially in dry years] with greater penetration of weather-dependent renewables combined with the retirement of fossil-fuel plant is a critical issue that must be addressed through coordinated planning, innovation and investment” (sub. DR305, p. 3). On the other hand, the EA puts more reliance on the operation of a well-designed voluntary market for firm energy:

For over 20 years the spot market has operated effectively in providing signals for efficient generation investment, including to manage dry years. This has been supported in more recent years by well-functioning hedge and futures markets that provide parties with the means to enter into forward contracts ... without the prescription of a formal capacity mechanism that can be readily gamed. Key Authority initiatives—including the development of cap hedge products, and introduction of more accurate prices and nodal scarcity prices through real-time pricing—will provide further support for parties to forward contract to manage risks, including dry year risk, into the future. These latter initiatives are good examples of how the Authority is able to continue to evolve the design of the market to ensure that it delivers long term benefits to consumers. (sub. DR384, p. 3)

13.4 Future low-emissions electricity supply pathways

This section looks at possible pathways to an electricity system with very low emissions, the emissions prices that might be needed to incentivise those pathways, and the effect on electricity prices. It mostly assumes current technology and technology prices. In reality, technology and prices are changing rapidly and will certainly continue to do so over the next thirty years. As a result, the analysis in this section is only a starting point for thinking about how to achieve electricity generation that produces very low emissions. Even so, current technologies and technology prices will likely influence some long-lived investments in generating plant that will need to be made in the next decade.

Current emissions

Current electricity emissions come mainly from five sources:

- fossil-fuelled co-generation (electricity generated in conjunction with an industrial process, such as the gas turbines operated by Contact at Fonterra’s Te Rapa dairy factory);
- coal- and gas-fired generation from the Huntly Rankine station (HLYR);
- generation from combined-cycle gas turbines (CCGTs) at Huntly (HLY5) and in Taranaki (TCC);
- gas generation from flexible peaking turbines in Taranaki and Huntly; and
- geothermal generation (Box 13.1).

¹⁷⁵ A market for firm energy is viable because consumers place a high value on security of supply and are prepared to pay high spot prices or a high “insurance premium” for cap products. This, in turn, means generators will be well remunerated for having resources available. (See Electricity Authority (2013) for data on the value that consumers place on security of supply.)

Box 13.1 Emissions from geothermal generation

Geothermal energy, a renewable source, generates a significant and growing proportion of New Zealand's electricity. Yet using geothermal fluids to generate energy causes "fugitive" carbon dioxide (CO₂) and methane (CH₄) emissions. The emissions depend both on the technology used and on field chemistry. The emissions intensity of New Zealand's most intensely emitting geothermal plant (Ngawha) was higher than that of a gas-fired plant, though its emissions intensity is progressively declining. Even so, six of New Zealand's seven developments have substantially lower emissions intensity than any gas plants. The volume-weighted average emissions intensity across all developments is approximately a quarter of that of gas.

Geothermal technology is currently chosen for its economic efficiency. Binary units (which use a second fluid in a heat exchanger) are more efficient in fields of low-energy intensity, and can reinject nearly all extracted fluids back into the field (including potential GHG emissions). Double or triple flash plants (which flash off the dry steam from the geothermal fluid, to drive the turbines) are more efficient in other circumstances, but release GHG emissions along with dry steam. It is feasible to use heat exchangers in fields of high-energy intensity; but, with current technology, this causes efficiency losses. A rising emissions price may shift the advantage towards binary units, new heat-exchange technology and lower emissions in the future. This would be reinforced by pricing actual emissions rather than using average emissions factors for geothermal generation.

Economic cost-effective carbon capture and storage (CCS) methods for geothermal fields may also emerge in the future (Chapter 14). Iceland is already demonstrating such a method, though it requires the location of geothermal plant near large basalt formations and an ample source of water.

To put geothermal emissions in perspective, the New Zealand Geothermal Association submitted that

in the long run, the quantity of naturally occurring greenhouse gases released from geothermal fluid when it comes to the surface will be the same more-or-less whether the surface discharge is natural or from a geothermal power station. The difference is that it occurs over a much shorter timeframe when discharged from a geothermal power station. (sub. DR267, p. 1)

Source: Stevenson et al. (2018); Orkuveita Reykjavíkur (2018); Contact Energy, sub. 29; New Zealand Geothermal Association (2018), sub. DR267; Kevin Rolfe, sub. DR187.

Most of current electricity emissions (with the exception of geothermal) result from the use of fossil-fuelled plant to provide resource adequacy (section 13.1). Yearly emissions depend on the extent to which plant is used in this way, which, in turn, mostly depends on weather patterns.

Future pathways

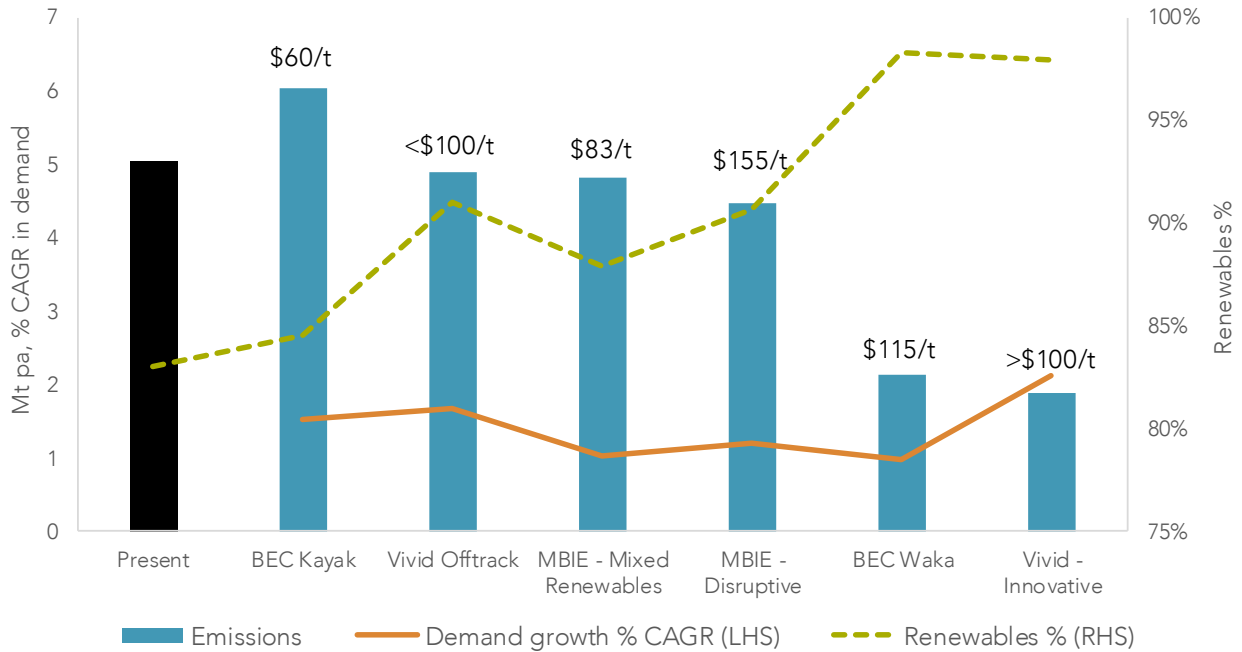
The Commission engaged electricity system analysts from consulting firm Sapere to identify the opportunities and risks for electricity supply in New Zealand that arise from moving to an electricity system with very low emissions. Sapere analysed different electricity supply and demand scenarios developed over the last several years to look at possible future electricity system outcomes (Stevenson et al., 2018). Separately, the Commission also engaged a consortium led by Vivid Economics to model pathways to a low-emissions economy, which included an electricity system module developed by Concept Consulting (see Chapter 3). This section draws primarily on the Sapere analysis, but also briefly covers the Concept Consulting et al. (2018a) model.

Sapere chose six scenarios for analysis. Two, "BEC Kayak" and "BEC Waka", were developed for the Business New Zealand Energy Council (BusinessNZ Energy Council, 2015). The Ministry of Business, Innovation and Employment (MBIE) developed a further two – "MBIE Mixed Renewables" and "MBIE Disruptive". Vivid Economics developed the remaining two – "Vivid Offtrack" and "Vivid Innovative" (Vivid Economics, 2017a). The BEC and MBIE scenarios are produced from models that explicitly build in investment decisions motivated by minimising lifetime costs.

Stevenson et al. (2018) note that the scenarios served different objectives, yet all incorporated an emissions price. They used this diversity to analyse the relationship between cost and emissions outcomes under different assumptions. They also tested four of the scenarios (but not the two Vivid scenarios) to see if, irrespective of emissions and cost, they would satisfy current market objectives for energy adequacy and capacity adequacy (expressed in the WEM and the WCM).

Figure 13-3 shows the relationship between emissions, the percent of generation from renewable sources, demand growth and emissions prices as at 2050 for each of the scenarios.

Figure 13-3 Electricity sector emissions, renewable %, demand growth, and emissions prices in 2050

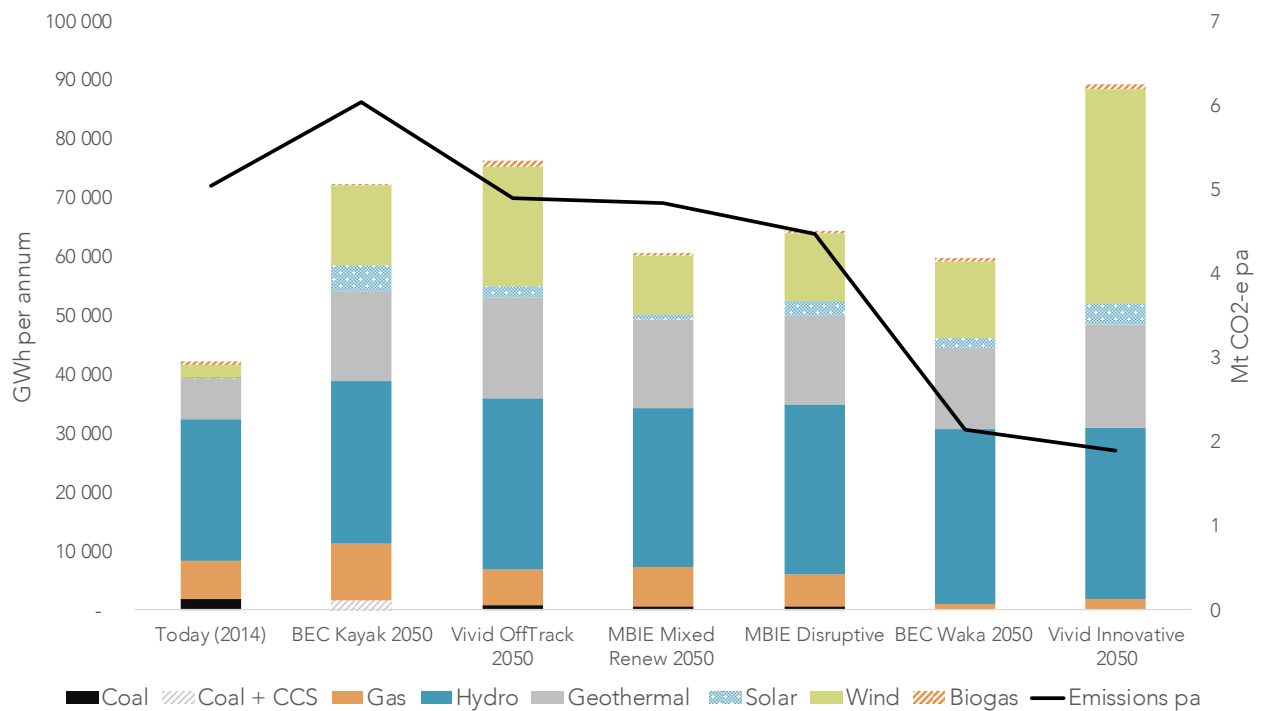


Source: Stevenson et al. (2018).

Notes:

1. CAGR refers to compound annual growth rates.

The percentage of renewable generation and the level of carbon emissions are broadly related, but growth in demand and the mix of generation, particularly the proportion of geothermal, have an influence on emissions (Figure 13-4). Each scenario assumes particular drivers of demand in 2050 (Box 13.2).

Figure 13-4 Breakdown of total generation by fuel and emissions, 2050

Source: Stevenson et al. (2018).

Notes:

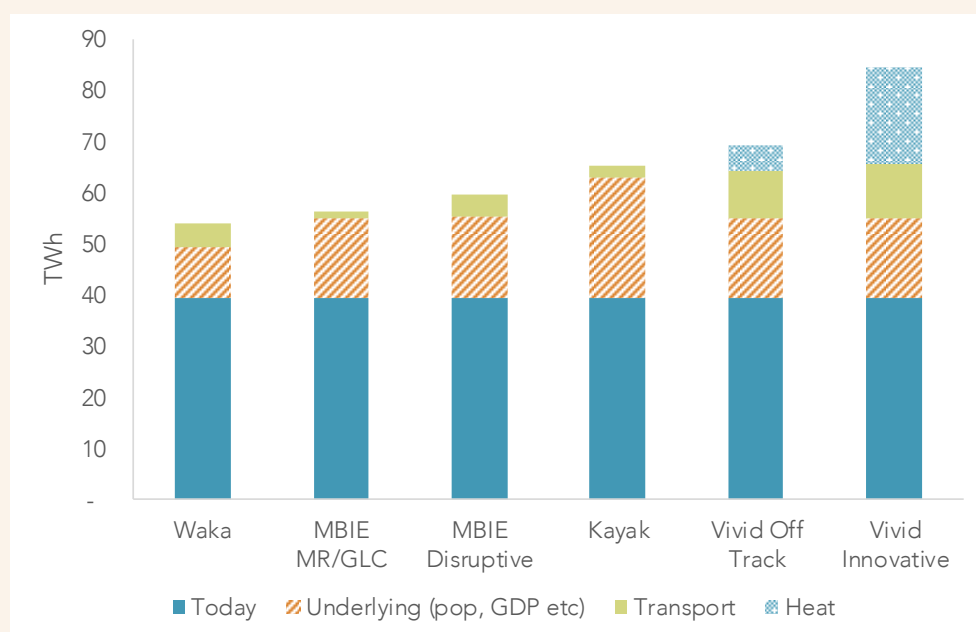
1. MBIE Mixed Renewables and MBIE Disruptive scenarios both include very small amounts of generation and emissions from wood – these are too small to be visible in the figure.
2. Though Vivid Innovative employs more fossil-fuelled and geothermal generation than BEC Waka, it has lower emissions. This is because Vivid Innovative assumes that new technology will be employed to reduce the intensity of geothermal emissions.
3. Though geothermal generation is classified as “renewable” in this data, Dr I G Mason (sub. DR215) makes the point that “geothermal fields used for commercial energy production eventually become depleted and recovery times of decades to hundreds of years are reported” (p. 4).

Box 13.2 Drivers of future demand for electricity

Population growth, rising incomes, the uptake of electric vehicles and electrification of process heat in industry will be the main drivers of future demand for electricity (see Chapters 3, 12 and 14). Each of the six scenarios examined in the modelling for this chapter has different assumptions about the drivers of future demand (Figure 13-5). Transpower (2018b) envisages that demand for electricity will more than double by 2050.

As a result, the projected growth in demand for electricity varies from a 0.9% compound annual growth rate (CAGR) in the BEC Waka scenario to 2.1% CAGR in the Vivid Innovative scenario. By 2050 this difference represents 30 terrawatt hours (TWh) or 75% of today’s total yearly demand. The differences across scenarios have potentially significant impacts on the profile of demand over a day or year and, as a result, on the mix of generating capacity required to ensure resource adequacy.¹⁷⁶

¹⁷⁶ The models reported in Chapter 3 all assume that demand for electricity will grow by at least 45% over the period 2015 to 2050. This is similar to the rate of growth in demand assumed in the Vivid Innovative model.

Figure 13-5 Components of demand for electricity in 2050**Notes:**

1. The two MBIE scenarios incorporate assumptions about the electrification of heat into their underlying growth assumptions.

Improving energy efficiency, particularly in the design and operation of buildings (see Chapter 16) and in the use of energy in industry, will play a role in tempering demand (see Chapter 14). Average household demand for electricity has already been falling substantially since 2007, roughly offsetting the effect on electricity demand of the increasing number of households.

The future of the Tiwai Point aluminium smelter (the largest single user of electricity in New Zealand, consuming nearly 5 TWh each year) creates further uncertainty (Mercury, sub. 49; Transpower, sub. 81). All the scenarios examined for this chapter assumed the continued operation of Tiwai Point.

Demand-side technology (distributed-energy resources and demand response) will also offset a rise in demand from a growing population and electrification of transport and process heat (section 13.5).

Source: Stevenson et al. (2018).

Reductions in emissions are mostly due to the retirement of fossil-fuelled plant, motivated by a rising emissions price and the availability of more economic alternatives such as wind and geothermal. Scenarios vary on when, and the extent to which, retirement of fossil-fuelled plant happens. All scenarios close the Huntly Rankine plant in the early to mid-2020s. The BEC Waka scenario closes the Taranaki and Huntly combined cycle plants and coal co-generation around 2030, while MBIE Disruptive retires the Taranaki combined cycle plant a few years later. The Vivid Innovative scenario also assumes that new technology reduces emissions from geothermal generation. All six scenarios retain flexible gas-peaking turbines in Taranaki and Huntly, to provide resource adequacy, falling to as low as 1.0 TWh in the BEC Waka scenario (Figure 13-4).

All scenarios involve substantial increases in wind and geothermal generation, modest additional investments in hydro and a modest-to-moderate increase in solar generation. The Vivid Innovative scenario anticipates a very large 34 TWh increase in wind generation. Only the MBIE scenarios explicitly include the potential for better management of demand to reduce the need for fossil-fuelled generation to cover resource adequacy (section 13.2). Transpower (2018b) envisages a much larger increase in solar generation by 2050, particularly through behind-the-meter and utility scale generation. The MacDiarmid Institute (sub. DR312) also submitted that solar generation could play an important role in a low-emissions electricity

system. Te Rūnanga o Ngāi Tahu submitted that more attention should be given to the potential role of grid-scale solar generation (sub. DR362). If solar generation displaced other options such as geothermal or wind, this would increase the challenge of meeting dry-year resource adequacy (section 13.2).

I. G. Mason et al. (2013) investigated the technical feasibility of eliminating all fossil-fuelled generation from New Zealand's electricity system, while maintaining resource adequacy under climatic conditions that pertained in the years from 2005 to, and including, 2010. Their full model uses a combination of wind, pumped hydro and over 600 MW of geothermal generation, which run at variable output to manage the variation in generating inflows (and, implicitly, in demand). Without the use of pumped hydro, which has a high capital cost and is probably environmentally and economically infeasible, Mason et al.'s model achieves 99.8% renewable generation.¹⁷⁷

Variable output geothermal is technically feasible, but its lower utilisation rate (60%) drives up the unit cost of energy generated. Stevenson et al. (2018) calculate that the Long Run Marginal Cost of geothermal power would rise by at least \$40 a MWh if the plant is used flexibly (this compares with the current yearly average wholesale price of around \$80 a MWh).¹⁷⁸ For flexible geothermal generation to compete with a CCGT plant, the emissions price would have to reach at least \$130 over the investment period. Even so, under current technologies, geothermal emissions would still be in the order of 1.2Mt CO₂e. The New Zealand Geothermal Association submitted that variable output (or "load following") "is an unlikely scenario for geothermal power stations" (sub. DR267, p. 3).

Climate change itself is another factor that will influence New Zealand's path to an electricity system with very low emissions (Box 13.3).

Box 13.3 Climate change and future electricity generation and demand in New Zealand

Changing rainfall, wind and temperature patterns caused by climate change will affect future electricity generation and demand in New Zealand.

While estimates are very uncertain, temperatures are predicted to rise across the country, with relatively more warming in the north. Overall, rainfall is predicted to fall in the north and east of the North Island and to increase everywhere else, especially on the west coast of the South Island. There will be more rainfall in the South Island hydro catchments in the winter and less snowfall. There will also be, on average, stronger westerly winds in winter over central and southern New Zealand.

If these changes eventuate, they may reduce seasonal demand peaks (particularly through milder winters in Auckland) and increase winter hydro flows, potentially making the problem of providing for winter and dry years less severe than at present. Yet hydro reservoir operators will still face uncertainty about weather patterns in particular years and will need to conserve water accordingly. This uncertainty could be made worse by more frequent and longer droughts. Wind generation is likely to increase, but severe storms may challenge the resilience of generation, transmission and distribution.

Source: MfE (2016a); Stevenson et al. (2018); Meridian Energy, sub. 55; Vector, sub. 63; Auckland Council, sub. 97; Wise Response Society, sub. 102.

¹⁷⁷ Earl Bardsley submitted that pumped hydro storage may be necessary to provide dry-year resource adequacy in a future system with a high percentage of intermittent, weather-dependent, renewable generation. He urged the Commission to evaluate a specific proposal for a pumped hydro storage scheme in the Onslow basin in Central Otago. He noted that such a scheme would have flow-on benefits by allowing better management of the environmental impacts of existing hydro-generating schemes throughout New Zealand (sub. DR156). The Commission obtained high-level advice on such a scheme from Sapere, a consulting firm. The advice confirmed that such a scheme, involving a storage lake of 120 square kilometres and a fall of 60 metres between high and low storage levels, would have challenging environmental impacts that would make obtaining resource consents extremely difficult. Impacts on the economic viability of existing hydro-generators would likely motivate strong additional opposition. Costs of generation might be comparable to those of variable generation geothermal, but the environmental and economic risks for a single project of such a magnitude would make it unattractive to private investors (Sapere, pers. comm., 13 July 2018). Dr I G Mason submitted that pumped seawater hydro energy storage "has been proven at full scale as an option" (sub. DR215, p. 3).

¹⁷⁸ The Electricity Engineers' Association points to the challenges of high maintenance costs and the potential for well loss associated with using geothermal for backup generation (sub. DR250).

New investments in transmission and distribution line capacity

All of the identified pathways to a very low-emissions electricity system involve a large expansion of wind generation in the lower North Island. A future system would require transmission upgrades to transport this energy to load centres, particularly Auckland. Stevenson et al. (2018) estimate that the cost of this investment could be as high as \$5 billion, with flow-on effects to consumer electricity prices of \$5 a MWh.

In one scenario (for which they estimate the cost), Stevenson et al. (2018) envisage wind energy from the lower North Island and geothermal from the central North Island replacing fossil-fuel energy from Taranaki and Huntly. Under certain conditions, large amounts of wind energy would need to be exported northwards and southwards. This would require significant upgrades and extensions of the current high-voltage direct current (HVDC) infrastructure, with new terminals. Uncertainty around new transmission technology suggests delaying this investment. Stevenson et al. (2018) consider that if extra geothermal generation was built before most of the extra wind generation was installed, a decision to upgrade transmission could be delayed until the 2030s (as the location of geothermal generation will be closer to centres of demand in the upper North Island).

Transpower (sub. 81) notes the “challenges around coordinating commitment to investment across multiple parties in the supply chain” (p. 8). It refers specifically to proposals to install wind farms with a combined capacity of 1 gigawatt (GW) in the Wairarapa. The required initial investment in transmission would impose high per-unit costs on new generation for years to come as the wind farms are progressively developed. Transpower notes “[u]nder current industry arrangements there is no clear path to resolution of this, or similar, investment coordination challenges” (p. 8). Contact (sub. 29) and the NZ Wind Energy Association (sub. 40) also identified issues around how the costs of transmission and distribution for newly connected users should be allocated.¹⁷⁹

The EA told the Commission that, as upgrading the transmission grid can be costly, it would be efficient for those who benefit from an upgrade to face the costs (pers. comm., 25 July 2018). Those who benefit may, for instance, have alternatives that reduce emissions at a lower cost. The EA’s transmission pricing methodology currently distinguishes between “connection assets” and “interconnection assets.” Connection assets are dedicated assets connecting a particular customer to the interconnected grid. Those benefiting gradually pay for connection assets over the life of the asset through connection charges. The costs of interconnection assets are spread across EDBs and grid-connected industrial consumers.¹⁸⁰ The EA is currently reviewing its methodology as it considers that socialising the cost of upgrades is both inefficient and an obstacle to reducing emissions across the economy. The EA proposes to move to benefit-based transmission pricing. Meridian Energy encourages the EA to progress work to improve the efficiency of the “locational signals for new load and generation” (sub. DR253, p. 13).

Some EDBs consider that charging large numbers of electric vehicles (EVs) could require substantial and costly increases in the capacity of distribution lines serving households (Vector, 2018b). This would depend on the size of car batteries and chargers, the number of EVs in a locality and the time of charging. Yet other companies consider that they are able to accommodate a large increase in charging off-peak, consistent with their customers’ preferences for their off-peak EV tariff – though it is not clear whether this takes into account constraints on local distribution-line capacity (Mercury, 2017). The Nordic countries should provide a useful guide on problems for the distribution grid resulting from high EV uptake. Norway, with a current EV penetration of 40%, has experienced some issues, but these may ease as its electricity system moves to smart metering and dynamic electricity pricing (IEA, 2018c).

Emissions, resource adequacy and cost in a future low-emissions electricity system

A trade-off exists between resource adequacy, cost and emissions in a future low-emissions electricity system (Figure 13-6).

¹⁷⁹ A number of submitters also identified uncertainties around transmission and distribution pricing methodologies as a dampener on investment (Contact Energy, sub. 29; IEGA, sub. 58; NZ Wind Energy Association, sub. 40; Major Electricity Users Group, sub. 45; and Transpower, sub. 81).

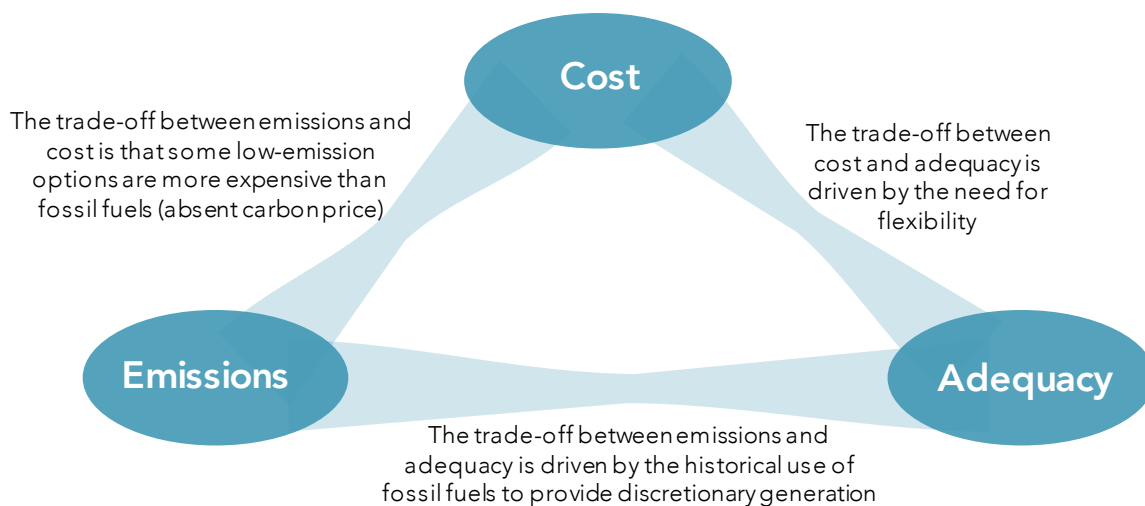
¹⁸⁰ Complexities surround the definition of “connection” and “interconnection” assets; and some industrial plants may be connected to a distribution network, in which case they would probably have to bear the cost of a capacity increase (EA, pers. comm., 25 July 2018).

An electricity system cannot rely only on intermittent renewable energy sources while maintaining resource adequacy at all times. New Zealand faces the added difficulty of having to provide for dry years (section 13.2). Yet, with currently available technology, providing resource adequacy through low-emissions sources operated flexibly (such as on-call geothermal) greatly increases unit energy costs.

As a result, all six scenarios analysed by Stevenson et al. (2018) retain at least some fossil-fuelled generation in 2050 (ranging from 1.0 TWh in the BEC Waka scenario, to 11.2 TWh in the BEC Kayak scenario). The Vivid Innovative scenario assumes technological improvements to reduce geothermal emissions. As a result total emissions range from 1.9 Mt of CO₂e in the Vivid Innovative scenario to 6.0 Mt of CO₂e in the BEC Kayak scenario (Figure 13-3). The emissions prices required to achieve these emissions levels range from \$60 per tonne of CO₂e (/tCO₂e) under the BEC Kayak scenario to \$155/tCO₂e in the MBIE Disruptive scenario (Figure 13-4).

In comparison, Chapter 3 reports the early results of new pathway models. Like the Vivid Innovative scenario, all the new scenarios modelled involve substantial growth in electricity demand, which is provided mainly by wind and geothermal. Even so, fossil-fuelled plant (particularly gas peakers and CCGT) continues to contribute an important resource adequacy role. By 2050, emissions from electricity generation will range from 2.1 Mt of CO₂e to 3.1 Mt of CO₂e and the emissions prices required to achieve these emissions levels will range from \$75/tCO₂e to \$250/tCO₂e depending on the stringency of the economy-wide emissions reduction target.

Figure 13-6 The cost–emissions–adequacy trade-off



Source: Stevenson et al. (2018).

One feature of the models described in Chapter 3 is that the large amount of wind generation employed leads to “spill” (either from wind or from hydro). This is commercially viable because the models assume that the cost of wind generation for each MWh will continue to fall (though at a slower rate than in the past). In contrast, the scenarios reported by Stevenson et al. (2018) assume that the cost of wind generation will rise over time, as more favourable wind generation sites are used first, and remaining sites raise the cost, because of some combination of less reliable wind, lower wind speeds and higher construction costs (pers. comm. 27 April 2018).¹⁸¹

Even the I. G. Mason et al. (2013) model, which entirely dispenses with fossil-fuelled generation, still entails geothermal emissions. As previously noted, under current technology and demand conditions, total emissions would amount to around 1.2 Mt of CO₂e and an emissions price of at least \$130/tCO₂e would be required to make this commercially viable (Stevenson et al., 2018).

¹⁸¹ The “levelised” cost of generation is driven by the cost of the underlying technology, the site-specific cost of construction, and the site-specific yield. While the cost of the underlying technology may be falling, construction costs may be rising and site-specific yields of new plant may be falling. The magnitude and direction of change in each of these factors over the next 30 years are highly uncertain. As a result, different assumptions can legitimately produce different conclusions about future changes in the levelised cost of generation (Sapere, pers. comm., 22 May 2018).

Stevenson et al. (2018) use their analysis of the four scenarios that consider resource adequacy and the I. G. Mason et al. (2013) model to assess the impact of reducing electricity emissions on wholesale electricity prices. They use their data on the generation mix, the lifetime costs of investments in generating capacity, fuel costs and emissions profiles to do so. The scenarios, themselves, generate the emissions prices that will incentivise the adoption of low-emissions technology.

Under current technology and costs, reducing emissions appears to increase wholesale electricity prices. For instance, in 2050, a reduction in emissions of 3 Mt of CO₂e from today's level under the BEC Waka scenario requires an emissions price of \$115/tCO₂e. In turn, this entails an increase of more than 35% in the average yearly wholesale electricity price over today's levels. In contrast, with their assumption of falling costs in wind generation, and other costs spread over a greater total amount of generation, the Chapter 3 models envisage wholesale electricity prices remaining stable or increasing slightly.

An analysis based on current technologies and costs requires strong qualifications. The assumption that today's technologies and technology prices will remain unchanged is not consistent with recent and anticipated experience. For instance, prices for wind turbines and solar panels have fallen rapidly over the last several decades. While uncertain, new technologies, for instance in tidal and biomass generation, CCS, and grid-scale batteries and DR, are developing rapidly (Box 13.4). In addition, the medium- and long-term future volume and mix of generation needed to meet demand, consumer responses to prices, and investors' choices of technology are all highly uncertain.

F13.1

The future mix of electricity generation by 2050 in a low-emissions electricity system and its effect on wholesale prices are both very uncertain. For example, different models envisage different paths for the cost of wind generation for each megawatt hour of electricity produced. This, in turn, leads to a different role for wind versus geothermal generation in the system, and different effects on wholesale electricity prices. In the most favourable scenarios, prices fall; while in other scenarios, they rise.

Box 13.4 **Future generation, demand response and storage possibilities**

Current technology and technology prices are a very imperfect guide to the best available technology for low-emissions generation in future decades. For instance, the cost of wind and solar generation has been falling rapidly and both are now commercially competitive with fossil-fuelled generation in New Zealand (see Chapter 6, Box 6.1). Importantly, new generating and electricity storage technology continues to be explored, developed and trialled, and will almost certainly be commercially available within a decade or two. With higher emissions prices, some existing possibilities may become economic.

- Some coal-fired plants in the United Kingdom are already being partly or fully converted to use biomass. Biomass may become economic in New Zealand as peaking plants. Even so, continuity and guarantee of feedstock supply would need to be solved; and other uses will compete with electricity generation for this feedstock.
- Battery storage capacity is improving and prices falling. As a result, grid-scale batteries and behind-the-meter batteries (including in EVs) will likely play a role in smoothing the daily electric demand profile and compete with gas for the peaking role. In the more distant future, batteries may become suitable for managing resource adequacy in dry years.
- Additional hydro storage in Lake Pukaki could be made available with some re-engineering and changes to resource consent conditions. This would improve the capacity to shift fuel storage from summer to winter and reduce the need for on-call, fossil-fuelled generation.
- Hydrogen can be produced by electrolysis of water when electricity prices are low, stored and used to generate electricity, either through a gas turbine or using fuel-cell technology, when demand

peaks. The fuel efficiency of this process, though, is only around 25% to 35%, and it would require very large storage capacity to make a significant contribution. Storage as ammonia is possible. Resource consents would likely be needed for the water used. Direct use of hydrogen for heat would be more efficient.

- While costs are currently high, tidal generation could develop to a point where it plays a similar role to geothermal in the generation mix. The Scottish Government is partnering with Atlantis Resources to install commercial-scale tidal power generators near the Orkney Islands. Later phases will explore new technologies to reduce the costs of generated electricity.
- Buffering technology is in development that, if successful, would allow an aluminium smelter pot-line to operate with lower electricity consumption (up to 30% lower) for periods of up to 48 hours. The Tiwai Point smelter could then be incentivised to help smooth demand peaks and reduce the need for on-call fossil-fuelled generation.
- Low-cost wind generation could be installed at a high-level of redundancy, and, for instance, paired with hydrogen manufacture (or some other discretionary use) when electricity demand and prices are low. This would increase the availability of low-emissions capacity to meet peaks and to reduce the need for hydro storage to provide for dry years.
- Connection to international transmission grids via Australia may eventually become technically and economically feasible.

Source: Stevenson et al. (2018); The Guardian (2016); Atlantis Resources (2018); Power Project Limited (2008); Rhodes et al. (2017); Dorreen et al. (2017); Contact Energy, sub. 29; Matheson (2017); NERI, sub. 53; Transpower, sub. 81; Auckland Council, sub. 97; Wise Response Society, sub. 102; Dr I G Mason, sub. DR210; Transpower (2018b); Bioenergy Association, sub. DR352; and Scion, sub. DR366.

The experience of the United Kingdom suggests that, given rapid changes in technology and prices, governments should be cautious about favouring particular technologies as a route to an electricity system with very low emissions (Box 13.5). Using subsidies and other policies to encourage early commercial adoption at scale of particular technologies may lock in unnecessarily high prices for years to come (Mercury, sub. 49; Meridian Energy, sub. 55).

Box 13.5 Subsidies for renewable technologies in the United Kingdom and Australia

Many European countries and the United Kingdom have provided incentives to increase the proportion of renewable electricity generation. The United Kingdom introduced a “renewables obligation” in 2002 to provide a market-based incentive to build renewable generation. The obligation required suppliers to supply, each year, a specified and increasing proportion of electricity from renewables. Ofgem, the market regulator, issued tradable certificates for the renewable electricity generated. The scheme is now closed to new generating capacity.

The United Kingdom government also introduced feed-in tariffs for micro-generation from 2010 that encouraged a large increase in photovoltaic installations to over 11.5 GW by the end of 2016. More recently, contract-for-difference feed-in tariffs have been introduced to set a fixed-price tariff for energy generated from low-emissions sources. The contract-for-difference is funded from levies imposed on electricity suppliers and intended to increase investor confidence in low-emissions technology. Meanwhile, the costs of renewable generation options has fallen to the point where they are now similar to those for fossil-fuelled generators (Rhodes et al., 2017).

A recent review of the cost of energy in the United Kingdom (Helm, 2017) looked at the growing legacy costs of financial support for renewable technology. Helm estimated that the accumulated cost will exceed £100 billion by 2030. He noted that, despite the falling costs of renewables, these legacy costs

still need to be met, and recommended that the relevant contracts be grouped into a legacy bank (so that current costs are transparent).

The United Kingdom Climate Change Committee put forward an alternative view on the high legacy costs of renewables. It argued that early subsidies for then high-cost investment in renewables has stimulated the technological advances and scale economies that have led to current falling costs. Even so, they agreed with Helm's advocacy for letting the various technologies compete, and to rely on an emissions price to guide low-emissions choices both within the electricity sector and across the economy (Thompson, 2017).

Other countries have experienced similar effects of subsidies for renewable energy on electricity retail prices. For instance, the Australian Competition & Consumer Commission found in a recent review of electricity retail pricing in Australia that

[m]ost state governments put in place excessively generous solar feed-in tariff schemes with a view to encouraging consumers to install solar photovoltaic (PV) systems. Under these schemes, the subsidy paid to consumers for the energy produced by their systems outweighed, by many multiples, the value of that energy. Take up of the schemes exceeded all expectations, in part due to dramatic declines in solar PV installation costs. The substantial cost of the schemes continues to be spread across all electricity users. (Australian Competition & Consumer Commission, 2018, p. v)

F13.2

Technologies that generate low-emissions electricity are advancing rapidly with falling costs, changing design and new options emerging. If governments favour particular current technologies (for instance through subsidies), they risk locking in higher electricity costs without commensurate benefits in reducing emissions.

While financial support for renewables may have some benefits (such as stimulating technology development, economies of scale in production and falling prices), New Zealand is likely, for the most part, to be a technology follower in technologies that generate low-emissions electricity.¹⁸²

Recent and prospective developments suggest that technology will develop to enable generation of very low emissions in the future. Yet, in the short term, two factors together have weight:

- large-scale generating capacity is long-lived and decisions to replace some existing capacity and increase capacity will need to be made over the next decade (so, locking in emissions profiles and costs into the future); and
- electricity prices will affect incentives to adopt emissions-reducing technology elsewhere in the economy, especially in process heat and transport. Reducing emissions in electricity at the expense of larger gains elsewhere would be inefficient.

F13.3

Under current technology and technology costs, reducing emissions from electricity generation will likely entail an increase in wholesale electricity prices. Rising electricity prices, if substantial, could dissuade adoption of emissions-reducing technology in process heat and in transport, as well as increasing costs throughout the economy. Yet rapid advances in, and falling prices for, low-emission electricity technology may make this trade-off less acute in the future. An effective emissions price will help weigh the efficiency of reducing emissions in electricity against possibly lower-cost options to do so in other sectors.

¹⁸² Support for innovation in geothermal generation technology is one possible exception. New Zealand has been an early adopter of geothermal electricity generation and relies, to a greater extent than most other countries, on geothermal generating capacity (Kevin Rolfe, sub. DR187; Engineering Leadership Forum, sub. DR280). GNS Science has an active research programme on the sustainable use of geothermal resources (GNS Science, 2018). New Zealand may also have advantages in innovating in other energy technologies such as biomass. Chapter 6 argues that direct Government support for research and development is the best way to stimulate innovation in technologies in which New Zealand may have an advantage.

R13.1

Given rapid changes in electricity-generation technology and potential effects of rising electricity prices on adoption of low-emissions technology in other parts of the economy, the Government should not use subsidies or regulation to favour particular technologies that generate low-emissions electricity.

R13.2

The Government should rely on an effective emissions-pricing system as the main instrument to achieve an efficient trade-off between emissions reductions in electricity and emissions reductions in other parts of the economy. The Government should be cautious in specifying targets for emissions within the electricity sector, and make sure that technology is available to meet them without significantly increasing wholesale electricity prices above the levels achieved with current technology.

Many submitters supported one or both of these two recommendations (Meridian Energy, sub. DR253; Major Electricity Users' Group, sub. DR314; New Zealand Wind Energy Association, sub. DR274; Vector, sub. DR287; Genesis Energy, sub. DR301; PEPANZ, sub. DR328; Straterra, sub. DR383; Todd Corporation, sub. DR373; BusinessNZ, sub. DR347; and Electricity Engineers' Association, sub. DR274).

National Policy Statement for Renewable Electricity Generation 2011

The Government issued the National Policy Statement for Renewable Electricity Generation (NPS-REG) in 2011 to

drive a consistent approach to planning for renewable electricity generation in New Zealand [in particular by giving] clear government direction on the benefits of renewable electricity generation and requir[ing] all councils to make provision for it in their plans. (MfE, 2011b)

The NPS-REG recognises the proportion of New Zealand's electricity generated from renewable energy sources as a matter of national significance within the ambit of the Resource Management Act 1991 (RMA). It explicitly recognises the benefits of reducing greenhouse gas emissions (New Zealand Government, 2011b). Under the NPS-REG, councils have to provide for renewable electricity generation activities in their regional and district plans and regional policy statements, and recognise their national significance when making resource management decisions.

Submissions on the NPS-REG almost invariably agreed that decisions under the RMA unduly constrain investment in renewable electricity generation and related transmission and distribution networks (Tilt Renewables, sub. DR218; Independent Generators Association, sub. DR222; Blueskin Resilient Communities Trust, sub. DR222; Trustpower, sub. DR249; Electricity Engineers' Association, sub. DR211; Meridian Energy, sub. DR253; Environment Institute of Australia and New Zealand, sub. DR260; New Zealand Wind Energy Association, sub. DR274; Genesis Energy Limited, sub. DR301; Transpower, sub. DR305; and Mercury, sub. DR320). The Wellington Regional Council commented that the NPS-REG could give clearer guidance on how the importance of renewable electricity generation weighs against visual amenity (sub. DR195).

Most submissions were from electricity industry interests and reinforced these views.

- The NPS-REG is not firm enough in its policy direction to encourage decisions makers under the RMA (councils and the Environment Court) to give sufficient weight to the benefits of renewable electricity generation, especially when weighed against other priorities set out in national and regional policy statements, and in regional and district plans. Some submitters made specific drafting suggestions to address these perceived deficiencies (Tilt Renewables, sub. DR222; Trustpower, sub. DR249). Meridian Energy submitted a complete redraft of the NPS-REG (sub. DR253).
- In any case, local authorities have been tardy in giving effect to the requirements in the NPS-REG (Policy E1- E4, F and G) to provide for renewable electricity generation in their policy statements and plans, with many having failed to do so within the 7 years since the NPS-REG was gazetted. Policy H requires that they should have done so within two years.

Several submissions pointed to the findings of a 2016 evaluation of the NPS-REG.

A review of councils sampled shows that the introduction of the NPS-REG has not noticeably increased the consistency of REG planning provisions across regional policy statements or regional or district plans. District plan REG provisions are generally no more specific than the NPS-REG provisions. ...

The NPS-REG does not appear to have had a major influence on the consent requirements for the sampled REG projects for timeframes, activity status, numbers and reasons for consent, amount of work required to prepare consent applications, or the need for notification. Generators consider that applications made after the NPS-REG came into effect still need to provide the same amount of information, engage similar specialists and put the same amount of time and effort into preparing the consent application package as they did before the NPS-REG. (MfE & MBIE, 2016, pp. 5-6)

F13.4

The National Policy Statement for Renewable Electricity Generation 2011 (NPS-REG) is not well-reflected in the planning documents of local authorities and has made no difference to the time, complexity and cost of obtaining consents for renewable electricity generation investments (particularly wind- and hydro-generation). The language of the NPS-REG is not sufficiently directive to give weight to the central role of renewable electricity generation in New Zealand's transition to a low-emissions economy over the next several decades.

Obtaining resource consents could hinder expanding renewable electricity generation

These deficiencies are likely to become more acute as demand for electricity increases to support electrification of transport and process heat. The Commission's modelling foresees at least a 45% increase in demand by 2050; while Transpower's models even predict at least a 100% increase (section 13.4). Further, many of the current consents for unbuilt wind farms will expire over the next decade, and, in any case, more efficient technology may require consents for taller turbines than covered by the original consent (New Zealand Wind Energy Association, sub. DR274; Genesis Energy Ltd., sub. DR301). The costs of consenting for smaller community-scale wind farms are high relative to the economic benefits, and difficulties may easily stymie a project (Blueskin Resilient Communities Trust; sub. DR249).

Particular issues emerge around decisions under the RMA for hydro-generation (Meridian Energy, sub. DR253; Genesis Energy, sub. DR301):

- The preamble to the NPS-REG explicitly excludes its application "to the allocation and prioritisation of freshwater" on the basis that these "may be subject to the development of national guidance in the future".
- Consistent with this, Appendix 1 of the National Policy Statement for Freshwater Management 2014 (NPS-FM) (amended in 2017) lists suitability of water for hydro-electric power generation as a (non-compulsory) national value. Even so, while Appendix 3 is intended to list existing infrastructure (and so allow exceptions from meeting the "national bottom lines" set out in Appendix 2), it is empty (New Zealand Government, 2017b).

Hydro-generators point out that confidence about water rights that must be periodically renewed has a critical impact on the economic viability of their investments (Trustpower, sub. DR249, Meridian Energy, sub. DR253). Decisions involve ramp rates,¹⁸³ minimum river flows, water allocation, minimum and maximum lake levels, flushing requirements for the purposes of water quality, and flushing for sediment removal or flood management. Trustpower notes that these decisions have the potential to reduce hydro resilience and flexibility, and that it is important that the framework for regulatory decision making not undermine these decisions. Yet water rights have proven highly contentious in the New Zealand context, and successive governments have been cautious in working out how to proceed.

¹⁸³ Ramp rate refers to the increase or reduction in output per minute usually expressed as megawatts per minute. Hydro plant, unlike thermal plant, can ramp almost instantaneously.

F13.5

Uncertainty about water rights has the potential to reduce the economic viability of, and so dissuade, further investment in maintaining hydro-electric generating capacity. Allocation of water rights in New Zealand is controversial and successive governments have been cautious in taking steps to increase certainty about them.

A large expansion of electricity generation will also increase the need for new transmission and distribution capacity (even allowing for an increased proportion of distributed energy resources in the total generation mix). Two national instruments provide guidance to councils on decisions affecting electricity transmission:

- The National Policy Statement on Electricity Transmission 2008 (NPS-ET), which intends to facilitate the operation of the existing transmission network and establishment of new transmission services (New Zealand Government, 2008); and
- The National Environmental Standards for Electricity Transmission Activities 2009 (NES-ETA), which set out permitted or otherwise controlled, restricted discretionary or non-complying activities relating to existing transmission lines (New Zealand Government, 2009).

Some submitters noted that the Ministry for the Environment (MfE) and MBIE are conducting a review of the NPS-ET. Transpower (understandably, as the party with particular interests in transmission investments) raised issues about its operation. Transpower noted that “uncertainty, conflicting interpretation and debate is markedly increasing risk to grid investment projects” (sub. DR305, p. 7).

F13.6

Investments in transmission grid and distribution network upgrades will be needed to complement the expansion of renewable electricity generation to meet increasing demand for electricity. The National Policy Statement on Electricity Transmission 2008 (NPS-ET) is currently under review. The owner of the transmission grid, Transpower, reports that despite the provisions of the NPS-ET, decisions on resource consents for grid investment projects are highly time consuming and costly and increase uncertainty and risk. Similar types of costs and risks are likely to apply to upgrades of the distribution network, though at a smaller scale.

Strengthening planning instruments to provide for renewable energy generation

Submitters raised three broad approaches to providing greater consistency and certainty for local authority decisions influencing renewable electricity generation.

- The language of the NPS-REG could be stronger, so that it carries greater weight with decision makers in the face of priorities identified in other national, regional and district policy instruments and plans. Much of the discussion revolved around the particular wording of the NPS-REG and how this differed from other national planning instruments (eg, Tilt Renewables, sub. DR218; Meridian Energy, sub. DR253). MfE and MBIE (2016) commented that the NPS-REG focuses on the weight to be given to renewable energy generation in decision making rather than on outcomes. Other instruments such as the NPS-FM and New Zealand Coastal Policy Statement use very directive language in some circumstances.
- National policy statements should provide more clarity (eg, through additions to their preambles) about how councils should weigh priorities across different instruments. Yet the RMA provides for the broad relative weight of different priorities to be set out in Part 2 of the Act; with section 6 defining matters of national importance which decision makers must recognise and provide for; and section 7 setting out other matters (including renewable electricity generation) to which decision makers must have particular regard.
- National Environmental Standards could specify when particular activities relating to the development and operation of renewable electricity generation are permitted. This could, for instance, be limited to sub-categories of renewable electricity generation such as community-scale wind generation (where the

costs of gaining consents are high relative to the economic benefits; but where the environmental impacts are potentially relatively small).

Some submitters also pointed to the importance of a suitably strong NPS-ET to complement a strong NPS-REG, and to ensure that connection to the distribution network is included in the ambit of one or both of these instruments.

The Commission considers that the Government should prioritise strengthening the NPS-REG and the NPS-ET and prioritise supplementing them with a national environmental standard that will speed decision making on renewable energy generation consents under the RMA. Reasons for some urgency exist.

- Electrification of transport and process heat over the next several decades will play a large role in meeting New Zealand's emissions reductions targets. This will require a large expansion in renewable electricity generation capacity. Many of the investment decisions will need to be made within the next decade to bring this capacity on stream.
- The 2016 MBIE and MfE review of the NPS-REG found that it had almost completely failed to effect significant changes in local authority planning tools, and that, in practice, it had made no difference to the time, complexity and cost of obtaining resource consents for renewable electricity generation investments. These concerns have been reinforced by submissions to this inquiry.
- A large increase in renewable generation capacity will also require new investments in transmission grid and distribution network capacity. Similar issues apply for obtaining resource consents for these as for renewable electricity generation.
- Local authority planning cycles means that it takes up to a decade for the provisions of a National Policy Statement to be effectively incorporated into planning tools (if at all).

In its urban planning report, the Commission recommended that spatial plans should be a mandatory part of the planning system. Among other functions, spatial plans would make high-level provision for land for infrastructure, while protecting high-value ecological and cultural sites (NZPC, 2017a). The Commission considers that such a mechanism would give greater certainty that local authorities would adequately provide for the expansion of renewable electricity generation. Councils would then need to make provision at a broad level, rather than just waiting for particular resource consent applications to get their attention.

R13.3

The Government should give priority to revising both the NPS-REG and the NPS-ET to ensure that local authorities give sufficient weight to the role that renewable electricity generation and upgrades to the transmission network and distribution grid will play in New Zealand's transition to a low-emissions economy. This will likely require making the language of the NPS-REG and the NPS-ET more directive, and to be more explicit about how the benefits of renewable electricity generation should be recognised and given effect in regional and territorial authority planning instruments.

R13.4

The Government should issue a new National Environmental Standard for Renewable Electricity Generation that sets out the conditions under which renewable energy activities are either permitted, controlled, restricted discretionary or non-complying activities under the Resource Management Act 1991. This should be drafted to increase the speed, and lower the cost and uncertainty for obtaining resource consents for a significant proportion of renewable electricity generation projects that have only minor environmental and social impacts.

13.5 Demand-side options

Demand response (DR) and distributed energy resources (DER) will play an important role in reducing the need for fossil-fuelled peaking in a future electricity market. First, DER and DR have the potential to add to grid-scale wind generation to reduce the need to use hydro to balance demand at peaks or when wind is unavailable. This will make it easier to store water and reduce the use of fossil-fuelled generation to meet dry-year resource adequacy needs (section 13.2). Second, increasing the contribution of DER and DR will lower the need for investment in additional grid-scale generation and transmission capacity, and so lower costs for consumers.

The Energy Efficiency and Conservation Authority (EECA) submits that energy efficiency measures could have similar effects to those of DR and DER in reducing the need for fossil-fuelled generation at peaks (sub. DR326). The National Energy Research Institute (NERI) also points out that DER can take forms other than electricity and be material in reducing emissions. These dimensions are discussed further in Chapters 14 and 16.

The technology to support DR and DER is changing rapidly, and is being implemented or trialled in many jurisdictions.

A future electricity system will need to find the right balance between:

- flexibility and openness to new technology and market players;
- establishing technology and service standards for platforms to support multidirectional interconnections between consumers, other distributed generators and large-scale generators (section 13.6);
- providing a stable and predictable regulatory environment to encourage investment; and
- maintaining competition for providing contestable services as, facilitated by new technology, the mix between monopoly and contestable services changes.

Demand response

The United States Federal Energy Regulatory Commission (2017) defines “demand response” as:

Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.

DR can work in different ways and serve different purposes.

- In *scheduled demand response*, consumers can contract to reduce or drop their load for a pre-determined time under defined circumstances. In New Zealand, for example, EDBs regularly used ripple control of hot water heating to manage peaks in demand. Currently, large consumers (such as industrial users of electricity) can offer, into the wholesale market, the capability to reduce load.
- *Frequency-armed demand response* (or “*interruptible load*”) is an ancillary service to protect the stability of the system when frequency falls to critically low levels, for instance because of a generator or the HVDC failing.
- *Voluntary demand response* is based on price signals. Consumers exposed to high transmission, distribution or energy prices may drop load if the price is sufficiently high and the inconvenience is correspondingly low. The extensive rollout of smart meters in New Zealand facilitates this sort of DR, which can include full exposure of household consumers to half-hourly wholesale prices. Third-party aggregators may manage this type of DR for consumers, potentially using automated responses to price changes.

By dampening demand at peaks, DR has the potential to reduce the use of on-call, fossil-fuelled generation. Yet none of these types of DR, by themselves, are suited to dealing with energy shortages in dry years (though they could help conserve hydro resources when the risk of a dry year is high). Conservation

campaigns have, in the past, been a response to energy shortages during a dry year in New Zealand, most recently in 2001, 2003 and 2008. Because of concerns about how these campaigns unfolded, the EA amended the Code to provide for conservation campaigns based on pre-defined hydro storage levels. In the event of a campaign, retailers must compensate each residential or other small consumer (but not those already paying spot prices) at the rate of \$10.50 a week. No campaign has been required since these measures came into force despite several dry years occurring, indicating that the Code incentives have been effective.

Distributed energy resources

DER includes behind-the-meter solar panels and battery storage and distributed grid-scale wind and solar energy sources and batteries. Behind-the-meter DER could include using EV batteries as a source of energy during peak demand (Vector, 2018b). Utilities, businesses or households can use batteries to store electricity when demand and prices are low; and use them as an energy source when demand and prices are high. Only two of the scenarios of New Zealand's future electricity system summarised in section 13.4 (the MBIE scenarios) explicitly assume an increased contribution from DER to electricity generation.

Distribution-network-scale DER (such as community wind farms) would likely be more efficient than behind-the-meter DER because it would allow a group of consumers to:

- share the benefits of common batteries and associated electronic equipment;
- coordinate and optimise injections of DER into the system, coordinate DR systems; and
- trade energy surpluses and shortages within the group.

Even so, the economics and physics of battery storage are only suited to transferring energy intra-day or across a few days at most. Solar power is intermittent and is not directly available during nightly peak demand and is less available during periods of higher demand in winter. While DER can reduce the need for fossil-fuelled or other on-call generation at daily or seasonal peaks and help conserve hydro resources, it cannot directly solve the dry-year problem. If not well managed, an increase in DER can also cause instability in the operation of an electricity system – for instance through high-voltage problems and the lack of inertia (Box 13.6).

The role and capability of power electronics

The three important types of power electronics for connecting DER to networks are:

- rectifiers (that convert alternating current (AC) to direct current (DC));
- converters (that convert one DC voltage to another); and
- inverters (that convert DC to AC, or one specification of AC to another).

Inverters are essential for connecting photovoltaics and batteries to the grid, and vary considerably in their specification and capabilities. High-specification inverters can manage frequency and voltage, smooth power flow, and (in combination with batteries) provide active stabilisation of the network. A high-specification solar/battery/inverter package can provide all the services of a grid-scale generator (Stevenson et al., 2018). It follows that the specification of power electronics will make a big difference to the role that DER can play in a future electricity system. Yet most households who choose inverters for their photovoltaic installations do not consider the benefits of a higher specification. The EA is considering this issue, and whether EDBs could require certain inverter settings, as part of its work programme on integration of hosting capacity (pers. comm. 17 April 2018).

13.6 Regulation for a low-emissions electricity system

An efficient electricity system with very low emissions will require a much greater proportion of generation from intermittent renewable sources and the integration of DR and DER into the system. Some form of on-call generation will be required for peak loads and to cover the risk of dry years. This section looks at regulatory, governance and pricing issues that will likely arise in such a system.

Managing a greater proportion of generation from intermittent renewables

Unless well designed and managed, an increasing proportion of intermittent renewable energy can pose significant challenges for transmission system operation (Box 13.6).

Box 13.6 Grid stability in South Australia

Increasing the proportion of intermittent renewable generation in a system can cause network instability, due to a reduction in what is known as inertia. In systems with thermal- and hydro-generation, inertia is usually provided by large synchronously spinning turbines. These provide inertia by buffering the system against sudden fluctuations in frequency caused, for instance, by the failure of a generator or transmission line.

For example, high winds caused loss of transmission lines in South Australia, resulting in a state-wide blackout in September 2016. South Australia's system lacks inertia, because it generates 70% of its electricity from intermittent renewables (mostly wind and solar) and has closed two coal-fired plants. The lack of inertia was a large contributor to the blackout (Harmsen, 2017).¹⁸⁴ A well-configured system, even with intermittent renewables, should be able to cope with emergencies caused by component losses.

In response to the blackout, the Australian Energy Market Commission now requires each state's transmission network to provide and maintain a defined level of inertia at all times. In the longer term, it is investigating whether to establish a market for inertia as an ancillary service (Australian Energy Market Commission, 2018). The South Australian Government has installed a large grid-scale battery paired with a wind farm. The battery can provide system inertia as well as firming the supply of wind energy (McConnell, 2017). With the right technology to connect to the grid, wind turbines can also provide inertia directly (Harmsen, 2017).

Stevenson et al. (2018) identify challenges in a system with a high proportion of intermittent renewable energy, including:

- reduced inertia in the system so that relatively small shocks could cause large frequency deviations and large shocks could become unmanageable;
- a need for instantaneous under- and over- frequency reserves to deal with the risk of failure in HVDC transfers (particularly in the transfer of large amounts of electricity between islands);
- increased voltage management problems because of transmission of renewable energy over long distances to large sources of demand (such as in Auckland); and
- a need for more fast, standby reserve to deal with the volatility of wind generation and the risk of a generator or line trip.

Stevenson et al. (2018) recommend that the EA addresses these challenges by investigating a market for inertia and more sophisticated markets for frequency management, voltage management and standby reserve.¹⁸⁵ They recommend that these markets should be open to DER as well as to the major generators. DER, for instance, could provide inertia through incorporating ultra-fast response characteristics in batteries and inverters, or the direct connection of industrial motors. It could provide voltage stability through inverters.

¹⁸⁴ Failure of an interstate connector that helped stabilise South Australia's grid was also a contributor (Harmsen, 2017).

¹⁸⁵ The Electricity Council of Texas is currently considering a market for "inertia" and has implemented an operating reserve demand curve to strengthen scarcity pricing (Stevenson et al., 2018).

Integrating distributed energy resources and demand response to benefit consumers and lower emissions

As argued by a number of submitters, more active management of distribution networks than at present is needed to realise the potential contribution of DER and DR (Orion, sub. 6; Vector, sub. 63; Auckland Council, sub. 97). This, in turn, will require a substantial shift in current regulatory and institutional arrangements.

Managing two-way energy flows and system stability and quality of supply

In the future, distribution systems and the market arrangements will need to:

- provide rewards to DER and DR that reflect their supply of energy and ancillary services in particular locations and at particular times;
- provide a platform to give equal access to diverse participants (including consumers) to competitively buy and sell services;
- manage the safe and secure sharing of information between participants to facilitate service design and targeting to meet consumer needs;
- maintain the quality of energy supply and a balance between supply and demand, while using intermittent DER at greater volumes than at present; and
- integrate DER and DR services with the requirements of the transmission grid.

The current system has primarily developed to distribute electricity from large generators through the national grid and distribution networks to customers safely and reliably. The physical lines network is configured radially to perform this function, transmitting electricity through successively smaller substations until it reaches consumers. A future distribution system will need to overlay this radial physical network with a platform for multidirectional local and national trading relationships. Telecommunications provides a rough parallel, where Chorus supplies and owns the physical lines and infrastructure that are then used by many competing service providers.

To address these issues, Stevenson et al. (2018) propose a reform of distribution arrangements, based on the current transmission-level arrangements (section 13.3). This would require the creation of the role of a distribution system operator (DSO), distinct from the ownership of distribution networks, to oversee the trading of unbundled energy and ancillary services over a common distribution platform.

A DSO would:

- ensure all power system resources (including DER) have competitive access to a well-configured common distribution infrastructure, at a reasonable cost for monopoly assets;
- coordinate DER (including smart, flexible demand) to meet participants' preferences for security, quality and reliability; and
- provide rewards and allocate costs commensurate with each load's and generating source's marginal costs and benefits.

A DSO role therefore has the potential both to better realise the benefit of smart technology and to enable competition between traditional (predominantly supply-side) solutions and DER (storage, distributed generation and/or flexible demand).

The UK National Infrastructure Commission (2016) looked at the DSO role.

First, a DSO with a clear idea of what the local network needs at each moment in time will be able to purchase or procure these services to manage its system, creating revenue streams and market signals to suppliers... This change will also incentivise the development of new and innovative business models, and save money for consumers by reducing or deferring the need for costly physical enhancements to the grid...

Second, better visibility of the network, combined with more monitoring, control and smart technologies means that network operators will be able to adapt to more complex and unpredictable electricity flows. This means that more distributed and intermittent generation will be able to connect to the networks at a lower overall cost to the system...

Third, it will enable better coordination between the transmission and distribution networks. A set of DSOs could have a role in ensuring the effective management of the interface with the transmission network and a coordinated system-wide approach. They could work with the transmission system operator to ensure that the benefits of new technologies such as storage and demand flexibility are maximised across the system as a whole, helping to coordinate what deploys when to ensure no detriment to local services. DSOs could operate local balancing markets, linked to the national balancing markets run by the SO [system operator]. (pp. 68–69)

A DSO role could be added to the current network-ownership role of the EDBs. This would parallel the arrangements by which the Transpower's roles of system operator and owner of the transmission network are kept separate within the same organisation. Adding a DSO role is one possible outcome of the current work programme of the EA (described below).

Even so, the IEA (2017a) points out that there are

considerable risks associated with adapting the legal and governance framework [for electricity distribution], given the substantial uncertainty around the nature and timing of this transformation [in the roles and activities undertaken in electricity distribution]. Hence an incremental and proportional approach may be the most appropriate way to proceed. As roles and functions change, or new ones emerge, it will be important to ensure that they are appropriately allocated among distribution sector participants. (p. 144)

Yarrow (2018) also argues for a pluralistic approach through “supervised experimentation” (p. 17). The Commission agrees that, with rapidly changing technology and fluidity in the way services are organised, a more evolutionary approach to regulation is desirable. The EA's work programme is consistent with this.

Pricing should reflect the contribution of DER and DR at particular times and places

The value of DER and DR to other consumers varies by the location and time of input. This reflects a combination of network congestion effects and transmission losses. The wholesale electricity market already prices energy according to the transmission node and time at which it is supplied (section 13.3). Distribution network pricing has the potential to vary in a similar way by time and location. This need not be through published prices (as in the wholesale market); it could be through smart grid systems automating responses to demand conditions.

To fully realise its potential scale, DER should enjoy the same incentives as grid-scale generators to provide energy services and (with high-quality inverters and/or batteries) ancillary services such as frequency and voltage stability (Stevenson et al., 2018; John Crook, sub. 31). Currently DER, unlike grid-scale generators, are only paid the average cost of energy and cannot access markets for ancillary services (such as frequency and voltage control) – even if they meet the requirements.

Other problems with current distribution pricing models exist. Transpower noted that “[m]ost end users today have pricing structures that over-stimulate self-production, under-stimulate efforts to moderate peak usage, and overly deter electrification” (sub. 81, p. 7). For instance, a number of participants submitted that the low-fixed charge regulations, while well-intentioned, have the effect of dissuading the adoption of new energy technologies, particularly EVs (Box 13.7; Contact Energy, sub. 29; Vector, sub. 55; Meridian Energy, sub. DR253).¹⁸⁶

¹⁸⁶ Some submitters raised issues about electricity pricing methodologies that are arguably mostly outside the scope of this inquiry. For instance, the Energy Trusts of New Zealand (sub. DR259), the IEGA (sub. DR222), and the New Zealand Wind Energy Association (sub. DR274) questioned the EA's decision to amend the Electricity Participation Code 2010 to remove the old Avoided Cost of Transmission (ACOT) and related provisions. Energy Trusts of New Zealand argued that the removal of ACOT could inhibit the growth of solar energy. Even so, the EA noted that “the ACOT regime favoured distributed generation as a supplier of network support to Transpower, when in fact often that network support was not needed or there were cheaper ways to provide it. The new arrangements were a significant step to put distributed generation on a level-playing field ...there is no effect on emission reductions because distributed generation is no more renewable than grid-connected generation” (sub. DR384, p. 2).

Box 13.7 The low-fixed charge regulations and new energy technologies

The Electricity Retailers' Association of New Zealand (ERANZ) and the Electricity Networks' Association (ENA) commissioned Concept Consulting to assess (among other matters) the potential effect of the Low Fixed Charge (LFC) tariff option regulations on the adoption of new technologies (sub. 8, DR211). The regulations were introduced in 2004 with both social and energy efficiency objectives.

Concept Consulting looked particularly at the adoption of behind-the-meter solar power and electric vehicles (EVs). The regulations set an LFC for distribution and retail costs (30 cents each day in total) that retailers must offer. Customers on the LFC must, as a result, pay higher variable costs for their energy use. The level of the LFC and the variable charges are set so that North Island customers who consume 8 000 KWh a year would have the same yearly bill under the LFC as under the standard tariff. (The threshold is set at 9 000 KWh for South Island customers.) Customers who use less electricity than the threshold each year will be better off on the LFC than on the standard tariff.

Concept Consulting shows that to recover revenue lost from low-user customers, retail companies must charge customers on the standard tariff more, with a higher variable charge than would otherwise be the case. Because some low-income households are big and use more electricity, the LFC means that they effectively subsidise other households (some of whom may be comparatively well-off).

The higher variable charges mean that the costs of charging an EV are higher than the true costs of supply, reducing incentives to purchase EVs. Conversely, behind-the-metre solar panels allow households to avoid the higher variable charges while making it more likely that they will benefit from adopting the LFC. High-income households who own their own house are more likely than other households to install solar panels, therefore further distorting the intended targeting of the LFC to low-income households.

Solar power, even with batteries, does not suit New Zealand's need to meet winter demand peaks. As a result, Concept Consulting argues that increasing the use of solar power does not offer any particular benefits in reducing overall emissions. Instead, as the NZ Wind Energy Association (sub. 40) and Mercury (sub. 49) point out, increased solar power generation slows the growth in more efficient grid-scale wind generation (and leads to more fossil-fuelled generation in the longer term than would otherwise have been the case).

The Electricity Authority (EA) considered submissions on the LFC regulations as part of its work on enabling mass participation (Electricity Authority, 2017). It concluded that "the competition, reliability and efficiency effects of the LFC Regulations are not as material as has been assumed" (p. 9). The EA noted instead that

distributors' and retailers' preference for consumption-based charges is as much a barrier to efficient pricing as the LFC Regulations, and distributors could improve pricing efficiency by introducing variable capacity-based or peak-based charging or time-of-use charges. (p. 9)

Even so, on the evidence presented, the LFC Regulations do not appear to achieve their intended social and energy efficiency objectives. They are also a barrier (though possibly a minor one) to efficient pricing and the adoption of some new technologies.

Technical and data-sharing standards

A fit-for-purpose distribution system moving to more dynamic cost-reflective distribution pricing is likely to need mandated electrical standards for consumer connections. The standards should reflect the possibility that a consumer may be able to provide some generation and other services for themselves while meeting the standards. Not all components of the service need to be provided from the bulk supply power system. Transpower submitted that the "regulatory agencies [should] consider and give effect to technical standards relating to behind-the-meter technologies, including in relation to their correct installation" (sub. DR305, p. 10).

Standards for data sharing among market participants need to be updated to facilitate the efficient provision of responsive services (Orion, sub. 6; Vector, sub. 63). Transparent, good quality and timely data will, for instance, enable participants to identify where the transmission and distribution network may need reinforcement, where they could offer more competitive alternative services, or where consumers are having supply or power quality problems. This data would allow providers of DER or their agents to market their services directly to consumers or groups of consumers who would benefit. Data-sharing standards should provide for appropriate levels of data security, meet privacy standards and give consumers control of personal data.

Consequential effects on the business models of lines companies

Technology is rapidly changing the potential mix of monopoly and contestable services that EDBs and competitors may offer. Below are four examples.

- Powerco (an EDB) has installed a standalone power unit at a rural property near Matahiwi as an alternative to replacing ageing power lines. The unit combines solar power with batteries and a backup diesel generator. They could also be powered by wind or water (Powerco, 2018).
- emhTrade (a market trader) provides services for micro-grids (a group of energy sources and loads which can operate autonomously from the local network) and embedded networks to help with billing, market reconciliation and optimisation services and drive fuller use of renewables (emhTrade, 2018).
- Vector (an EDB) offers residential network batteries with a range of benefits for consumers, and owns and operates a large-scale battery energy storage at its Glen Innes substation as a means to manage network congestion (Vector, 2018a, 2018c).
- Contact (a gentailer) with Wellington Electricity (and EDB) and the Wellington City Council are trialling household solar panels paired with batteries to form a “virtual power plant”. Around 30 homeowners in the trial have agreed to share their stored power with neighbours in the event of a disaster or prolonged outage. In the meantime, excess stored power is fed back into the grid (Devlin, 2017).¹⁸⁷

These developments mean substitutes that deliver energy which do not rely on distribution are increasingly available; as are service inputs that can provide a partial substitute for poles and wires. So, while EDBs must provide the monopoly services of poles and wires, other parties can provide a growing proportion of contestable services. The changing mix of monopoly and contestable services poses a challenge (discussed below) for the two regulatory agencies in ensuring competition for the benefit of consumers (particularly more so, as the agencies operate with different definitions of “consumer”).¹⁸⁸ Both agencies aim to promote competition that stimulates innovation that will result in lower-cost and better-quality services for consumers in the long run. To achieve this, the regulatory regime needs to be flexible enough to allow the regulatory agencies to respond appropriately to the changing mix of monopoly and contestable services.

F13.7

With rapidly changing electricity distribution technology, including distributed energy resources and demand response capabilities, the mix of monopoly and contestable electricity distribution services is also changing rapidly. These changes are posing challenges to the role of the regulatory agencies (the Commerce Commission and the Electricity Authority) in promoting competition that will stimulate ongoing innovation in electricity distribution and in services that use electricity distribution networks as a platform. This innovation will likely both benefit consumers through lower-cost and better-quality services and reduce the need for fossil-fuelled generation.

¹⁸⁷ Collaboration across different electricity sector businesses could accelerate innovation, as discussed below. SRD Consulting (sub. DR173) notes that the distribution industry needs to take the lead in innovation and that the larger electricity distributors have already started so that “collaboration, demonstration at scale and good knowledge sharing is starting to appear” (p. 3).

¹⁸⁸ The Commerce Commission administers Part 4 of the Commerce Act 1986, which aims to promote the long-term benefit of consumers of regulated goods and services; while the Electricity Authority administers the Electricity Industry Act 2010, and has the objective of promoting competition for the long-term benefit of consumers who are defined as any person who is supplied with electricity.

The greater integration of DER into networks could also require a shift in EDB pricing models. According to the IEA,

evidence is emerging [globally] of a potential “death spiral” associated with traditional volumetric-based pricing models which may result in under-recovery of regulatory revenues where substantial volumes of distributed generation are present...

Several [New Zealand] distributors have registered growing concern about the revenue and costs risks posed by distributed generation, with one distributor responding by increasing connection charges for all new residential rooftop solar systems and batteries installed within its service area. (IEA, 2017a, p. 140)

The IEA considers that the balance between fixed and incremental charges may need to be adjusted (to give more weight to the fixed element) and that, conversely, “efficient, cost-reflective network pricing will need to more accurately reflect time-of-use” (IEA, 2017a, p. 157).

Also, if rapid penetration of EVs requires increased distribution line capacity in some locations, a pricing model will need to allocate the costs of upgrades equitably among customers. Higher-income households will likely adopt EVs first, so charging may be concentrated in particular suburbs (Vector, 2018b).

The electricity system regulators are working to facilitate mass participation

The electricity system regulators – the Commerce Commission and the EA – have been working on reducing barriers to, and incentivising, a wide range of participants in an innovative electricity market. The work includes a focus on DR and DER. For instance, in 2016 the Commerce Commission made changes to EDB input-pricing methodologies to better incentivise technological innovation in short-lived investments (Commerce Commission, 2016).

The EA is sponsoring or leading five projects to improve distribution regulation. The projects cover:

- how to shift to more efficient distribution pricing to encourage efficient investments by consumers and line companies and the development of DR;
- how to support multiple trading relationships to reduce barriers to consumers using services provided by more than one party at the same time;
- developing more fluid data exchange between retailers and EDBs to support more participation and choice for consumers;
- developing a default distribution agreement between EDBs and retailers to support competition, efficiency and innovation in retail and related markets; and
- amending the definition of participants in the Electricity Participation Code to include consumers becoming active buyers and sellers of electricity and related services (Electricity Authority, 2017).

In addition, the recently formed Innovation and Participation Advisory Group is undertaking a project for the EA on equal access of participants to electricity networks (Electricity Authority, 2017).

The EA’s work programme, in particular, includes work on:

- **Integration of hosting capacity:** ensuring network hosting requirements are technology and participant-neutral and pave the way in the future for merit-based dispatch within distribution networks...
- **Improving accuracy of spot price forecasts:** reducing barriers to parties employing new technology and business models to deliver demand-response to the wholesale electricity market.
- **Participation of new generating technologies in the wholesale market:** removing barriers to different forms of generating technologies in the wholesale market, in particular new grid-scale battery energy storage systems.
- **Enhancing dispatchable demand:** enabling aggregators of demand response to participate in the spot electricity market in more circumstances than currently occurs. (sub. DR384, p. 4)

Several submitters supported a move to more flexible and cost-reflective pricing, particularly to reduce demand peaks (John Crook, sub. 31; Meridian, sub. 55; NERI, sub. 53; Vector, sub. 63; Transpower, sub. 81). Meridian Energy submitted that distribution pricing reform is becoming increasingly urgent and that regulatory intervention may be required if EDBs are not visibly committed to such reform (sub. DR253). Genesis Energy strongly supports ensuring “a level playing field for competition in the emerging technology space, which can be achieved by drawing clear lines under what are contestable and non-contestable activities for regulated monopolies” (sub. DR301, p. 7).

F13.8

Integrating distributed energy resources (DER) and demand response (DR) into the electricity system will require significant adjustment to the current distribution pricing and regulatory regime. The Electricity Authority is leading or sponsoring a substantial programme of work to address the need for pricing and regulatory adjustment. The programme covers changes to pricing to better incentivise investment in DER and DR capability; and changes to regulation to provide for:

- consumers to be involved in multiple trading relationships;
- more fluid data exchange between retailers and electricity distribution businesses;
- a default distribution agreement between EDBs and electricity retailers to support competition, efficiency and innovation in retail and related markets;
- consumers to become active buyers and sellers of electricity and related services; and
- equal access of participants to electricity networks.

R13.5

The Electricity Authority should continue its programme of work to update pricing and regulation to facilitate the integration of distributed energy resources (DER) and demand response (DR) into the electricity system. The programme should cover changes to pricing to better incentivise investment in DER and DR capability; and changes to regulation to provide for:

- consumers to be involved in multiple trading relationships;
- more fluid data exchange between retailers and electricity distribution businesses;
- a default distribution agreement between EDBs and electricity retailers to support competition, efficiency and innovation in retail and related markets;
- consumers to become active buyers and sellers of electricity and related services; and
- equal access of participants to electricity networks.

Facilitating competition in network-based services

Competition among service providers across the distribution system will stimulate innovation, increase efficiency and lower costs to consumers. The IEA argues that regulation should give assurance to market participants that system development and operating decisions “are objective, non-discriminatory and comply with relevant rules and standards” (IEA, 2017a, p. 151). As noted above, emerging technology and business models in New Zealand, as elsewhere, are posing a challenge to regulating for competition in the provision of competitive services associated with electricity distribution networks.

The IEA identified two alternative models for EDBs that were emerging globally in response to rapid technological change. In one model, distributors provide value-adding services (such as owning or selling

rooftop solar-panels or operating EV charging stations) to provide additional revenue streams to supplement their regulated cashflows. In the other model, the distributors act as neutral facilitators for other businesses (retailers and aggregators) to provide services. In this model, distributors provide information, operate the system by managing the quality of energy flows, and establish, maintain and manage the network infrastructure.

The IEA considers that the latter “platform-for-services” model is more suitable to meet the challenges facing the sector because it will increase competition and innovation, reduce transaction costs and more effectively integrate a diverse range of suppliers and new technologies. In addition, it will maintain a more effective separation of contestable and natural monopoly functions.

The IEA notes that policy changes in 2010 allow some New Zealand EDBs to be involved in retailing in specified circumstances. It argues that these changes could hinder the distribution structure efficiently moving into a platform-for-services model (IEA, 2017a). The Commerce Commission, in considering input pricing methodologies for EDBs, also thought that boundaries between different segments of the electricity market may be blurred and require changes to regulation or legislation (Commerce Commission, 2016, pp. 2-3).

In any case, under current arrangements, the distribution system is still largely orientated towards minimising distribution investments and supplying a bundle of network services within a constrained set of possibilities. Current regulation fits this approach, but is unlikely to successfully accommodate the contribution of large amounts of small-scale, distributed renewable energy in the future (Stevenson et al., 2018). A more efficient and dynamically innovative system would provide access and competitive neutrality for all DER and DR providers (Pioneer Energy, sub. 44; Vector, sub. 63).

Adjusting the statutory framework to better reflect changing technology

The “equal access” leg of the EA’s work programme is addressing the question of competitive neutrality for services using the electricity distribution network as a platform. The EA considers that evolutionary adjustments to the statutory framework of regulation would assist (pers. comm., 1 August 2018).

In particular, the EA notes that Part 4 of the Commerce Act 1986 (administered by the Commerce Commission) applies monopoly regulation to the lines services distributing electricity. On the other hand, the Electricity Industry Act 2010 (administered by the EA) governs competition in the wider electricity market. With changing technology and experimentation with new business models, the boundary between monopoly and contestable services is shifting. Yet the EA notes that this boundary is shifting in complicated ways “as it is increasing for some service dimensions and some geographical service areas quicker and more effectively than others” (pers. comm., 1 August 2018, p. 5). In the EA’s view, this requires a statutory framework that enables the scope of monopoly regulation to adjust in a timely way to the changing configuration of services, so that the EA can more readily undertake its responsibilities as market regulator.

Several approaches to enabling a more flexible response to a changing mix of monopoly and contestable services are possible. The EA suggests that section 52O of the Commerce Act could be amended to allow the Commerce Commission (subject to undertaking an inquiry and parties having recourse to the courts) to more easily remove components of electricity lines services from monopoly regulation. Also, the definition of “consumer” in the two Acts could be better aligned: while, currently, Part 4 of the Commerce Act narrowly focuses on the consumer of monopoly services, the Electricity Industry Act focuses on the consumers of electricity more generally.

Further, section 32(2) of the Electricity Industry Act prohibits the EA from including provisions in the Code that cover anything that the Commerce Commission is required to do under the Commerce Act. Depending on the outcome of a current case in the Court of Appeal, the EA thinks this overarching provision may need to be amended so that the EA can

pursue initiatives that are intended to achieve more efficient reliability outcomes for electricity consumers due to technology changes that make competitive provision of network support services and distribution services feasible. (pers. comm., 1 August 2018, p. 7)

Part 3 of the Electricity Industry Act sets out certain thresholds above which EDBs are prohibited from owning electricity generating and retail businesses. It also specifies that the businesses of connected generators and retailers must be carried out at arm's length from the distribution business. The EA suggests that the scope of these provisions could be widened to cover other contestable electricity services that rely on access to the distribution network to be competitive. A wider scope, with more effective checks and balances against a misuse of a distributor's monopoly position, would reinforce and give more specificity to the provisions of "use-of-systems" agreements currently required under section 77 of the Electricity Industry Act. Consistent with this, Meridian Energy (sub. DR253) submitted that "distributors should be required to keep new technology services separate from their regulated businesses and that networks should openly tender for network services based on new technology" (p. 13).

The EA also thinks that the statutory provisions should make it easier and lower-cost for the competitors (and potential competitors) of EDBs to hold them accountable for providing equal access. Currently, seeking redress for anticompetitive behaviour requires court action. This is likely to be costly and time-consuming as well as potentially damaging to longer-term relationships with the EDB (EA, pers. comm., 1 August 2018).

The Commerce Commission prefers a cautious approach to changing the statutory framework governing the regulation of monopoly and contestable services in electricity distribution (pers. comm., 30 July 2018). It considers that it is important to establish stable rules that support investment and innovation by EDBs in the interests of providing more efficient services to consumers over time (as the current framework does). It believes that its current regulatory approach provides strong incentives for EDBs to consider whether it is more efficient to provide network input services in-house or obtain them from another party. It thinks that the best option is to give EDBs flexibility to make these choices for themselves, as they will have better information than regulators on the most efficient approach. The Commerce Commission is currently gathering information on how EDBs are using emerging technologies, to better inform its judgements on these matters (Commerce Commission, 2018).

Even so, the Commerce Commission agrees that some scope may exist to improve the current framework (pers. comm., 30 July 2018). In particular, the purpose of Part 4 of the Act could be amended to refer specifically to promoting competition in adjacent markets. For instance, clause 23 of the Telecommunications (New Regulatory Framework) Amendment Bill 2018 contains a provision that the Commission, in undertaking monopoly regulation in relation to fibre, fixed-line access services, must also consider, if relevant, the promotion of workable competition in telecommunications markets more generally. The Commerce Commission also agrees that provisions that enable the boundary between monopoly and market regulation to shift to keep pace with changing technology and business models could be helpful.

The EA identifies several specific provisions in the Commerce Act that it considers overly encourage EDBs to own contestable assets. The Productivity Commission thinks that section 54Q, in particular, deserves attention. This provision requires the Commerce Commission to promote incentives, and avoid imposing disincentives for EDBs to invest in energy efficiency and demand-side management, and to reduce energy losses. The Productivity Commission agrees with the EA that "[t]he effect of this provision is to favour distributors over other parties wanting to provide energy efficiency or use demand side management" (pers. comm., 1 August 2018, p. 8).¹⁸⁹

Overall, any amendments to the statutory framework should maintain robust incentives for EDBs to make investments and innovate over time in the provision of their services. At the same time, the statutory framework should allow regulation to adjust appropriately and in the interest of consumers to the changing mix of monopoly and contestable services. While maintaining a stable investment environment,

¹⁸⁹ Energy Trusts of New Zealand (sub. DR258) (ETNZ) takes a different view of this provision. ETNZ argues that it could play a significant role in advancing progress towards a low-emissions economy. It considers that the Commerce Commission was acting in a way that was not consistent with section 54Q when the Commission issued guidance for EDBs on the regulatory treatment of the costs and revenues of EV chargers (Commerce Commission, 2018). The guidance covered which capital costs should be included in the EDBs' regulatory asset base, and which operating costs and revenues should be included in the Commission's regulatory input methodologies. A key question was whether the activity is part of the service of conveyance of electricity by line (as defined in the Commerce Act).

[t]here are many potential business models that could emerge in the future and the premature adoption of one, for the entirety of EDBs would serve to put barriers in the way of the development of other, alternative ways of doing things, i.e. of institutional innovation. (Yarrow, 2018, p. 7)

R13.6

The Government should review and amend the legislative framework for regulation of electricity distribution network businesses to:

- ensure that the regulatory agencies (the Commerce Commission and the Electricity Authority) are able to respond in a flexible and timely manner to technology-driven changes in the mix of monopoly and contestable electricity-distribution services, network-support services and activities where regulated firms are competing with non-regulated firms;
- clarify and provide stronger checks and balances on regulated electricity distribution businesses (EDBs) owning contestable activities which erode their neutrality in operating electricity distribution networks; and
- provide simpler, quicker and lower-cost methods for holding regulated EDBs accountable for equal access to their networks of parties providing contestable services.

Strengthening capability in distribution services

The EA work programme covers a broad front of potential change in electricity distribution arrangements. It should result in a substantial shift in regulation, roles and relationships to match rapid, yet complex and uncertain, changes in technology. This shift is likely so profound that it raises the question of whether the current electricity distribution has sufficient capability to meet the challenge.

EDBs, because of asset ownership and historical arrangements, are currently in the strongest position to manage and/or provide a platform for DER services. Vector submitted that “EDBs must play a central role in leading the roll out and infrastructure enablement for DERs as they will have a significant impact on the security and resilience of the electricity network for which EDBs are responsible” (sub. DR287, p. 3).

In its review of New Zealand’s energy policies, the IEA (2017a) looked particularly at electricity distribution arrangements. After noting the challenges of rapid technological change facing the sector, the IEA comments that

the relatively small size of some distributors may limit their capacity to efficiently and cost-effectively invest in the monitoring, management and control systems required to maintain reliability as distribution systems become more complex and subject to more dynamic real-time power flows. (p. 160)

The IEA argues that EDBs are likely to need new business management systems “to support the increased level of engagement with distribution system users” that integrating DER and DR into the wider system involves.

Real-time co-ordination and communication capabilities may need to be enhanced, especially with the transmission system operator and possibly with other distributors, reflecting the more dynamic and increasingly multidirectional nature of power flows within and between distribution systems and the transmission system. As a result, more effective and coordinated real-time system planning and management is likely to be required to ensure that reliable and secure electricity services are maintained at the distribution level over time. (IEA, 2017a, p. 149)

The IEA also noted concerns (raised by the Auditor-General) about the governance and decision-making capability of some EDBs. In particular, the Auditor-General had warned about the risks in EDBs making investments outside their core business and the need to maintain the mix of skills to manage these (Office of the Auditor-General, 2016).¹⁹⁰ Transpower (sub. 81) also raised questions around the capacity and capability

¹⁹⁰ One EDB had invested in an 80% share in a vineyard; the majority of the revenue of another was from non-core business, including commercial property leases and a share in a joint venture with a sock manufacturer. Energy Trusts of New Zealand (sub DR258) points to a subsequent report of the Auditor-General which found that the asset management practices of EDBs were generally sound, though the report urged more focus on the longer-term

of the EDBs to undertake the required distribution system investments. Meridian Energy (sub. DR253) notes that some EDBs have made little progress in reforming their pricing, despite support, since 2009, from the Electricity Networks Association and the EA.

On the other hand, EDBs themselves, generally believe that they have the capabilities required to carry out their current and prospective roles (eg, Counties Power, sub. DR331). The Counties Power Consumer Trust (the owner of the assets of Counties Power) submitted that their “local focus and community relationships have given it added impetus in seeking cost-effective developments [with emerging technologies]”. The Trust argues that EDBs have established very advanced control systems, which means that New Zealand is “well ahead of the game compared with many countries” (sub. DR262, p. 1). Counties Power recounted how it used these systems to manage the April 2018 storm event that resulted in one third of consumers losing power. It has also used its acquired knowledge “to create a big data analytics company, Ampli, in a joint venture with Axos Systems” (sub. DR331, p. 2).

Even so, the combination of current questions about the capability of EDBs, the increasing sophistication required to operate new distribution service models, and ambiguities in the EDB role, suggests the need for a fresh look at EDB capabilities, and developments to improve them. Working alongside the Commerce Commission, the EA is undertaking a review of the distribution sector. This will

[l]ook at the capabilities of distributors to meet the challenges of evolving technology, including making sure power system resources have competitive access to a well-configured common distribution infrastructure, coordinate DER and provide rewards and allocate costs efficiently. (sub. DR384, p. 4)

Meridian Energy (sub. DR253) and Genesis Energy (sub. DR301) strongly support this review. Transpower submitted that the review should also look at the capability of EDBs to coordinate “new distributed energy technologies with national transmission system operations in order to most effectively enable a low-emission economy” (sub. DR305, p. 9).

F13.9

The Electricity Authority, in conjunction with its work programme to update pricing and regulation of the electricity distribution sector, is undertaking a review of, and developing measures to raise, the capabilities of the electricity distribution businesses to:

- ensure all power system resources (including distributed energy resources – DER) have competitive access to a well-configured common distribution infrastructure, at a reasonable cost;
- coordinate DER (including smart, flexible demand) to meet participants’ preferences for security, quality and reliability; and
- provide rewards and allocate costs commensurate with the marginal costs and benefits of each load and generating source.

One approach to strengthening the collective capabilities of EDBs is to encourage collaboration. The IEA (2017a), for instance, suggested that, to take advantage of economies of scale, EDBs could enter into regional shared-services and management agreements, or form joint ventures to manage and operate distribution assets (as some are already doing). For instance Orion coordinates load management across seven other networks in the upper South Island (sub. DR210).

Yarrow (2018), in a report for the Energy Trusts of New Zealand (sub. DR258), criticises the IEA analysis. He argues that there is little evidence of economies of scale in electricity distribution services, or in the management of such services. Further, he argues, no evidence reveals that small organisations lack innovation. Even so, as noted above, he argues for a pluralistic, experimental approach. Such experimentation could include collaboration in designing and implementing approaches that can best take

maintenance and replacement of assets (Office of the Auditor-General, 2017). Yarrow (2018) acknowledges that “diversification into unrelated activities is often linked to weaknesses in corporate governance,” though he says this has nothing to do with the size or corporate form of the entity (p. 18).

advantage of emerging technology, for the benefit of consumers. This will likely require (as described above) locally tailored, sophisticated systems to manage two-way energy flows with multiple trading relationships and real-time, cost-reflective pricing. Sharing the costs of developing and implementing these systems is likely to be more efficient than if every EDB did it alone. The EA notes that “it may be difficult for some distributors (especially smaller ones) to invest in and operate the systems necessary to undertake more complex management and operation of networks that has significant DER” (pers. comm., 1 August 2018, p. 7).

The EA considers that EDBs require stronger incentives to collaborate more effectively and deeply among themselves and with others to respond more effectively to the opportunities and challenges from changing technology. The EA suggests this might be achieved by legislation requiring it to undertake studies of the competition, reliability and efficiency benefits of joint ventures. The Commerce Commission would, after due process, use the results of these studies to adjust the maximum allowable revenue for the EDBs included in the study (pers. comm., 1 August 2018).

R13.7

More collaboration among electricity distribution businesses (EDBs) could increase their efficiency and their collective capability to use emerging technologies for the benefit of consumers. The Government should review and, if appropriate, amend the legislative framework for regulation of electricity distribution network businesses to provide clearer incentives for EDBs to collaborate where this will deliver net benefits for consumers.

Should the Electricity Authority consider emissions reductions in its activities and decisions?

The EA has a statutory objective of promoting “competition in, reliable supply by, and the efficient operation of, the electricity industry for the long-term benefit of consumers” (Electricity Industry Act 2010, s 15). Some submitters argued that reducing GHG emissions should form part of the EA’s statutory objectives (NZ Wind Energy Association, sub. 40, sub. DR274; IEGA, sub. 58; Trustpower, sub. 59; Vector, sub. 63; and Energy Trusts of New Zealand, sub. DR258). Yet, unless carefully formulated, an additional objective may not help reduce emissions efficiently across the economy.

Effective emissions pricing should incentivise emissions reductions in the electricity sector where this is the most efficient way across the economy to do so. If a statutory objective for electricity causes emissions reductions that are more costly than in other parts of the economy, this would be inefficient. It would raise the cost of electricity unnecessarily, and also make it more costly to use electricity to lower emissions in other parts of the economy, such as in transport and process heat (section 13.1). Both Orion and Meridian agree with this analysis (sub. DR210 and sub. DR253).

Further, the Commission recommends that the emissions price should be guided by a fixed carbon budget or emissions trading cap (see Chapters 5 and Chapter 8). With a fixed budget or cap, any additional reductions in emissions in the electricity sector would be offset by lower reductions elsewhere in the economy.

Yet it is possible that regulatory barriers in the electricity sector increase the cost of reducing emissions, without producing commensurate benefits. If so, a statutory objective for the EA to address such barriers could have benefits in finding the most efficient way of reducing emissions across the economy. Relevant barriers could, for instance, be those that hinder the full integration of DER and DR into the electricity market. The Independent Electricity Generators Association (DR222) supported such a provision.

F13.10

With an effective emissions-pricing system, a statutory objective for the Electricity Authority (EA) to have regard to reducing greenhouse gas emissions in electricity is unlikely to incentivise efficient emissions reductions across the economy as a whole. There may be some case to amend the EA’s objectives to include minimising any regulatory barriers to efficient emissions reductions in the electricity sector.

13.7 Conclusion

New Zealand already has 85% of its electricity generated from mostly low-emissions renewable sources. In the longer term, new technology should enable even more electricity to be generated at reasonable cost from low-emissions sources even as electrification of transport and industrial heat push up demand. Yet providing on-call generation to meet peaks in demand, and most importantly to provide energy in dry years, will remain a challenge. Under current technology, assigning this on-call role to renewable sources such as geothermal generation will cause a substantial rise in electricity prices. The Government should be cautious about setting stringent targets for electricity sector emissions before technology becomes available to further reduce emissions at reasonable cost.

Globally and in New Zealand, electricity systems are increasingly incorporating distributed energy resources and demand response to provide more efficient and more responsive electricity services to consumers. These developments hold great promise for further lowering emissions and reducing the need for on-call generation to meet demand peaks and to provide energy in dry years. Yet they can also disrupt the efficiency and stability of the existing grid. Regulation and governance for electricity distribution need to be refreshed to enable these emerging developments to fully achieve their potential benefits. The Electricity Authority is leading work to update distribution regulation.

The Government also needs to review governance and operational capability in the distribution sector so that it can deliver the potential emissions reduction and efficiency benefits from innovation. Yet adjustments to regulatory, institutional and infrastructure arrangements for the electricity system carry risks (Meridian Energy, sub. 55). The system is complex and with many inter-related parts, all fast evolving with changes in technology that are hard to anticipate. This puts a premium on having strong and competent regulators. Getting regulation and prices right matters if New Zealand is to avoid costly and unintended consequences from changes to the electricity system.

14 Heat and industrial processes

Key points

- Industrial emissions come from two main sources: burning fossil fuels to generate process heat (for example, to dry milk powder), and “industrial processes” (the transformation of one substance into another, such as iron sands into iron). Together, they account for around 15% of New Zealand’s gross greenhouse gas (GHG) emissions. Combustion of fossil fuels for water and space heating are also a significant source of emissions.
- For many heat users, potential exists to materially reduce emissions through measures to reduce the energy requirements associated with a process, such as energy and process efficiency improvements. More substantive emissions reductions will require conversion to lower-emission fuels.
- Rising emissions prices will be central to driving emissions-reducing investments in industrial heat plant. However, given the long lives and high costs of boilers and other heat plant, decarbonisation of industrial heat processes is likely to occur gradually as these capital assets reach the end of their useful lives.
- The technical and commercial viability of low-emission fuels varies on a case-by-case basis depending on factors such as geographic location and the nature of heat required. However, electricity and biomass appear to be the two options with widest applicability.
 - Electrification can be a cost-effective mitigation option for low-temperature heat requirements at current prices, provided that it is applied using a technology with coefficient of performance (CoP) well above 1.
 - Sustainably sourced biomass is a low-carbon fuel source that is already widely used to generate process heat. Barriers to further uptake include concerns about the reliability of supply, higher (in most circumstances) costs per unit of heat, and sunk costs in incompatible infrastructure.
- The mandate of the Energy Efficiency and Conservation Authority (EECA) should be extended to focus on lowering GHG emissions and promoting low-emissions materials. As part of this mandate, EECA should continue work to address any information and coordination barriers that are hindering the uptake of low-emission fuels for heat.
- EECA and the Ministry of Business, Innovation and Employment should review statutorily required targets relating to industrial emissions reductions to determine whether a reduction beyond what is already forecast would be more helpful in driving emissions reductions.
- Government agencies should use procurement guidelines to limit the installation of any new fossil fuel-powered plant for low-temperature heat in publicly owned buildings.
- Barring technological breakthroughs, opportunities to significantly reduce industrial process emissions from iron, cement, steel and aluminium production are limited.
- Carbon capture and storage (CCS) is a rapidly evolving and potentially significant mitigation technology, which could be well-suited to large-scale, single-source emitters such as iron, steel and aluminium production.
- When and whether CCS will be viable in New Zealand remains unclear. Existing legislation is not adequate to manage the risks of CCS. The Ministry for the Environment should carry out policy work on new legislation to appropriately regulate CCS activities.

This chapter discusses options and opportunities to reduce emissions in process heat and industrial processes (such as the production of aluminium, iron, steel and cement). It also considers the potential of carbon capture and storage (CCS) and the suitability of current legislative frameworks for governing CCS activities.

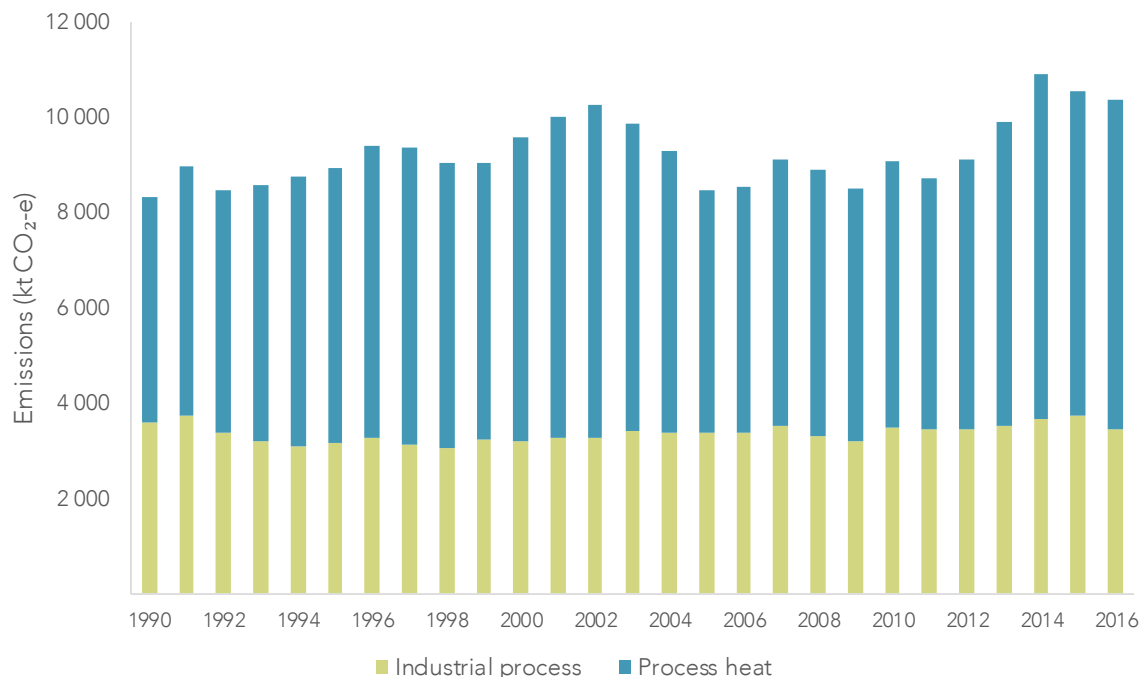
14.1 Industrial sources of emissions

Emissions from industrial sources made up 15% of New Zealand's gross greenhouse gas (GHG) emissions in 2016, and these have grown significantly in recent years. 8.8% of GHG emissions result from using fossil fuels in manufacturing, particularly to produce process heat;¹⁹¹ while industrial processes and product use (IPPU) produce 6.2% of New Zealand's gross emissions. IPPU emissions can be split into two broad categories:

- In 2016, around 70% of IPPU emissions resulted from industrial processes, largely the production of iron, steel, aluminium and cement.
- The remaining 30% of IPPU emissions come from hydrofluorocarbons (HFCs) used to replace ozone-depleting substances in refrigeration and air conditioning. A mitigation pathway for HFCs is described in Chapter 9 – the remainder of this chapter deals only with industrial process emissions.

Between 1990 and 2016, the combined emissions from the generation of process heat and industrial processes grew by 25% (Figure 14-1). Emissions from process heat grew increased by 45% between 1990 and 2016, much of which was due to the expansion of New Zealand's dairy industry (Concept Consulting, 2017a). The dip in process heat emissions between 2003 and 2013 was due primarily to fewer emissions from the chemicals industry – largely a result of changes in methanol production. Emissions from industrial processes have remained largely stable since 1990.

Figure 14-1 Emissions from process heat and industrial processes (1990–2016)



Source: MfE (2018e).

Notes:

1. Product uses (HFCs) as substitutes for ozone depleting substances are excluded from the industrial processes category.

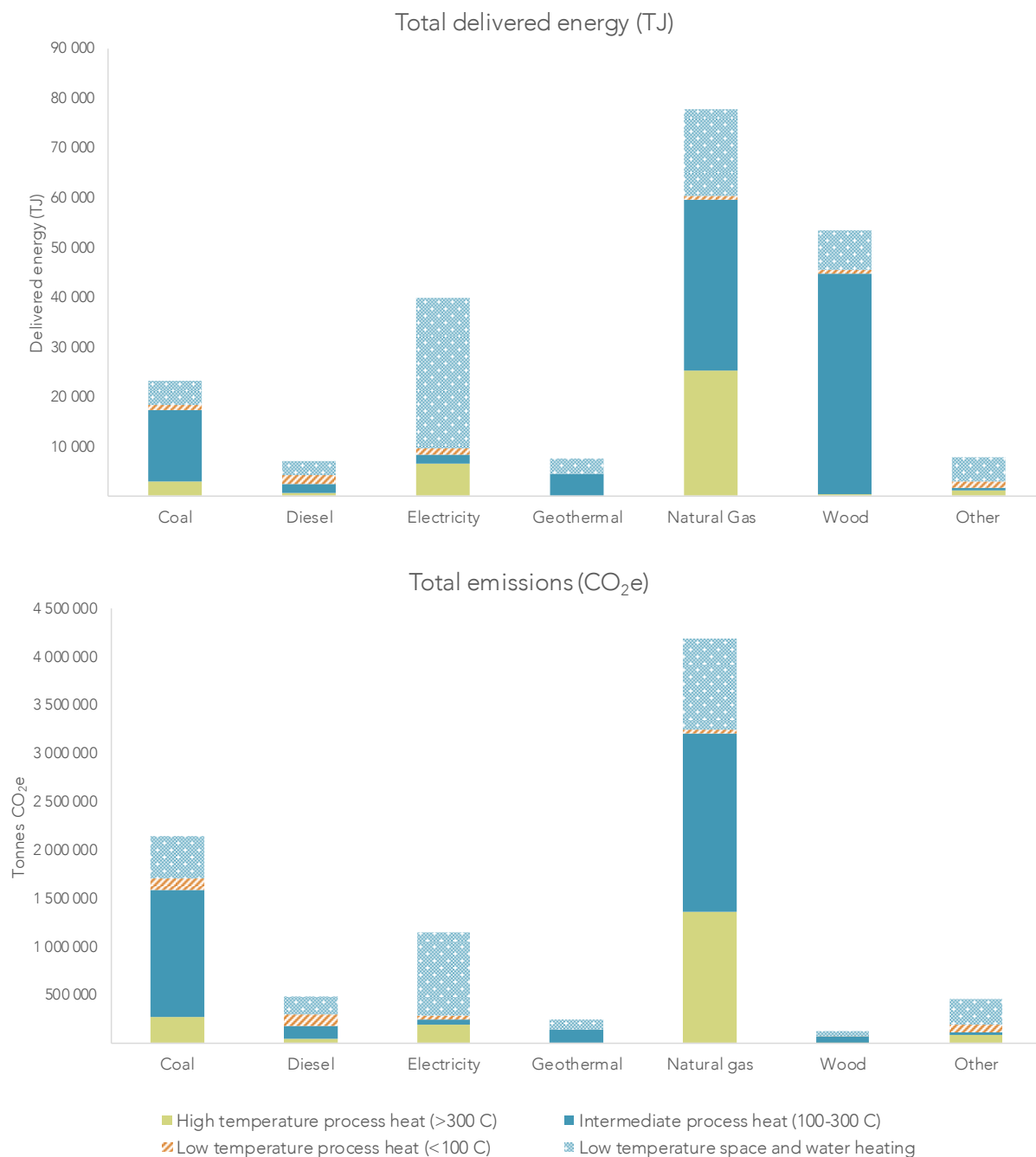
Emissions from process heat and industrial processes are almost entirely carbon dioxide (CO₂), comprising 98% and 95% of carbon dioxide equivalent (CO₂e) respectively in 2016.

¹⁹¹ This excludes any fossil fuels used to generate electricity used in manufacturing and fossil fuels used in petroleum refining.

14.2 Process heat

Process heat is generated for a number of purposes, including converting raw products such as liquid milk into powder and wood pulp into paper, and chemical production. Figure 14-2 shows a breakdown of the energy sources used to deliver process heat and space and water heating and their associated emissions. Over 50% of energy is delivered through the combustion of fossil fuels. Wood (which includes black liquor – a waste product from the conversion of wood to wood pulp) is a significant non-fossil fuel heat source.

Figure 14-2 Delivered energy and emissions from heat generation in New Zealand (2016)

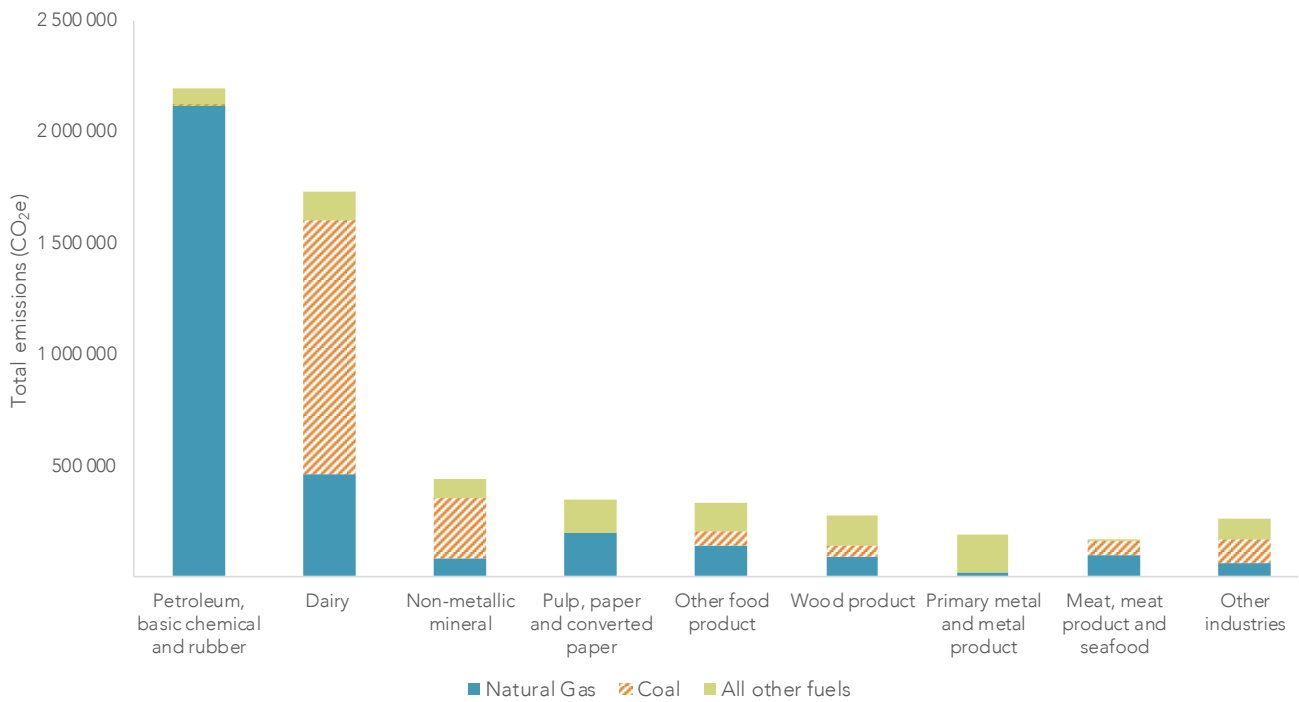


Source: EECA (2018b).

Note: Other fuels are biogas, fuel oil, LPG, petrol, and solar.

Most process heat emissions are produced by “a relatively small number of super-large heat plant fuelled by coal and gas” (Concept Consulting, 2017b, p. 19).

The largest sources of process heat GHG emissions are the production of petroleum, basic chemicals and rubber (largely methanol production), followed by the production of dairy products. Natural gas and coal account for 84% of process heat emissions (Figure 14-3).

Figure 14-3 Process heat GHG emissions by sector (2016)

Source: EECA (2018b).

Notes:

1. Other fuel sources are diesel, electricity, fuel oil, geothermal, liquefied petroleum gas (LPG), petrol and wood.

14.3 Opportunities to reduce emissions from process heat

The Royal Society estimates that GHG emissions from industrial process heat could be reduced by approximately 35% by 2035 (RSNZ, 2016), and the International Energy Agency (IEA) has argued that heat use in New Zealand industry “offers excellent opportunities for further decarbonisation” (2017a, p. 207). The viability of abatement opportunities depends on the nature and location of the production process, the scale of heat required, and the level of emissions price.

GHG emissions reduction options for process heat can be separated into measures to reduce heat demand and measures to reduce emissions from heat supply (Atkins et al., 2018). Demand reduction involves measures to reduce the energy requirements associated with a process, such as energy and process efficiency improvements, and adoption of alternative low-energy processing technologies. Supply reduction measures involve changes to the way in which energy is supplied, such as fuel-switching and carbon capture and storage.

Reducing energy demand and improving energy efficiency

Dr Martin Atkins, Fonterra and SRD Consulting suggest that the first priority in terms of mitigating process heat emissions should be to optimise energy demand:

Energy demand should always be optimised first before the supply of that energy is optimised. If demand reduction is ignored or not undertaken comprehensively, overall energy and emissions reduction costs will be much higher than need be. Rigorous thermodynamic based approaches exist (such as Process integration and Pinch Analysis) and have been employed overseas in emission reduction programmes (e.g. Switzerland) to first reduce industrial heat demand. (Martin Atkins, sub. DR 361, p. 1)

Improvements in energy efficiency of operations are typically the first activity that should be deployed to reduce emissions as they have a lower abatement cost than fuel switching. (Fonterra, sub. DR355, p. 9)

Before we can look at the best integration of renewable process heat, we should understand and integrate the emerging electro-technologies to improve the energy productivity of our processes. (SRD Consulting, sub. DR173, p. 4)

In a study that assessed the marginal abatement costs of different mitigation strategies across two major industrial processes in New Zealand, Atkins et al. (2018) found that the two most cost-effective options were heat recovery and process electrification. These are both economically viable at current carbon prices, and their adoption in the two processes would result in a total GHG emissions reduction of around 0.6 MtCO₂e (6% of total industrial emissions for the two processes). Advanced Materials Technologies (DR136) also noted scope for greater heat recovery, while the Energy Efficiency and Conservation Authority (EECA) suggested that re-engineering heat supply and distribution can reduce heat requirements:

A large, but unquantified amount of medium temperature heat (100 - 300°C) is driven by the use of steam for transporting heat rather than for end-use requirements. Re-engineering the heat supply and distribution system can enable the substitution of medium temperature heat with low temperature heat and make low carbon options (such as high temperature heat pumps) viable. (EECA, sub. DR326, p. 16)

Atkins (sub. DR361) notes that energy reductions between 15 – 40% are achievable. Fonterra (sub. 88) notes that it has made a 16% improvement in the energy intensity of production since 2003, which is consistent with the notion that material reductions in energy demand can be achieved.

In addition to comprehensive demand management mechanisms, opportunities also exist to reduce energy use through ongoing energy efficiency improvements. For example, Concept Consulting (2017b, p. 19) concludes that some cost effective abatement opportunities are possible through efficiency improvements such as “boiler tuning”, but notes that these are relatively small. A number of submitters noted that emissions reductions from energy efficiency alone are relatively small.

There is always potential for incremental improvements, particularly with the advancement of control systems. However, in many cases, step change improvements in efficiencies have already taken place. (Graymont, sub. 33, p. 6)

For Ballance the low hanging fruit was captured a long time ago, with efforts now chasing single percentile improvements eg, as computing power in control systems, catalysts and equipment improves. (Ballance Agri Nutrients Limited, sub. 34, p. 8)

F14.1

For many industrial heat users, opportunities exist to materially reduce emissions through demand reduction measures such as energy and process efficiency improvements. Some of these mitigation options are already economically viable at current emissions prices.

Fuel switching

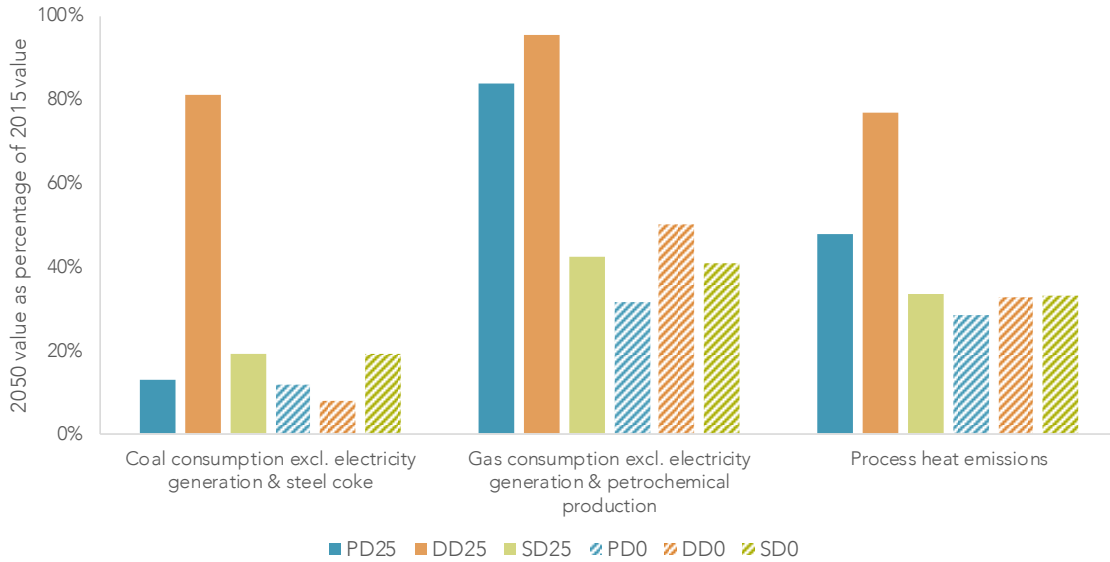
While demand reduction measures present a commercially and technically viable opportunity to reduce emissions for many heat users in the short- to medium-term, a transition away from the combustion of fossil fuels will be required in the longer term.

The Commission’s modelling (Chapter 3) examines pathways that lower net GHG emissions from current levels to 25 Mt CO₂e and to a more ambitious target of net-zero emissions by 2050. For each target, the modelling considers three scenarios with differing assumptions on how future technology could evolve (giving a total of six scenarios).

Across all the pathways, achieving a net-zero target involves switching nearly all coal-fired and most gas-fired boilers to low-emissions fuels (Figure 14-4). Although not shown in Figure 14-4, nearly all diesel-fired boilers switch to low-emissions fuels, followed by coal and then gas. This reflects the relative costs of fuel-switching and a rising emission price. For the less stringent emissions target modelled (25 MtCO₂e), outcomes are more varied depending on the scenarios’ assumptions about technology and the effect this has on required emission prices. In the ‘Disruptive Decarbonisation’ scenario, where innovation disrupts existing industries (eg, rapid adoption of electric vehicles (EVs) and plant-based alternatives to meat and dairy), the target is

achieved with minimal process heat fuel switching occurring.¹⁹² Alternatively, meeting either target in the ‘Stabilising Decarbonisation’ scenario, where existing industries prevail (eg, EV uptake is slow and a methane vaccine enables higher dairy production), would involve switching most fossil fuel-powered boilers (particularly coal) to low-emissions fuels.

Figure 14-4 Coal and gas consumption and process heat emissions in 2050 relative to 2015 (modelled scenarios)



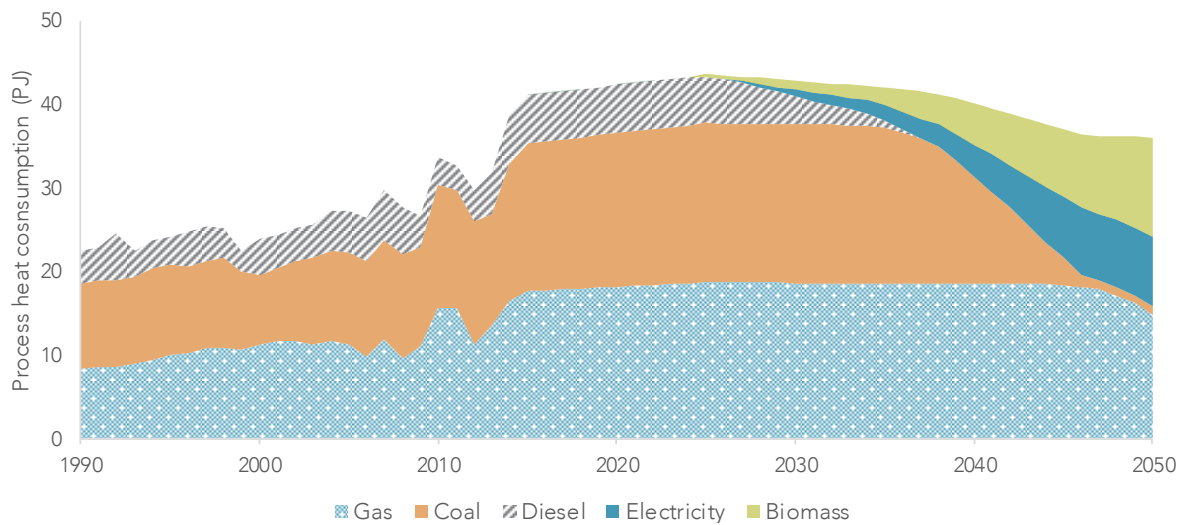
Source: Concept Consulting et al. (2018a).

Notes:

1. A description of the six modelled scenarios is contained in Chapter 3.
2. Gas use for petrochemical production (methanol and urea) is not shown here as most of this is used as a feedstock rather than combusted for energy.

Biomass and electricity displace fossil fuels and add significant new process heat supply by 2050. Most of this occurs in the food processing sector. For example, under the Stabilising Decarbonisation scenario with a 25 MtCO₂e emissions target, biomass increases to around 20 PJ of heat supply in 2050 while electricity increases to around 14 PJ (Figure 14-5).

Figure 14-5 Fuel sources for process heat in dairy and food processing, 2015–2050 (SD25 scenario)



Source: Concept Consulting et al. (2018b).

¹⁹² This is for two main reasons: first, rapid adoption of EVs delivers very large emission reductions in transport, reducing pressure on other sectors; second, competition from plant-based meat and milk alternatives sees lower dairy demand, which reduces direct agricultural emissions, increases afforestation, and reduces downstream energy demand for food processing.

Notes:

1. This figure shows fuel switching results under the Stabilising Decarbonisation scenario with a 25 MtCO_{2e} emissions target. The trends in switching are broadly similar across the six scenarios but differ in magnitude.

Fuel switching – high-temperature process heat

The main high temperature (over 300°C) heat users in New Zealand are methanol producers and manufacturers of products such as steel and cement. Methanol heat is fuelled by natural gas, while other manufacturers use a mix of gas, electricity, diesel, coal and wood.

Concept Consulting (2017a, p. 66) suggests that high-temperature heat users have limited fuel switching opportunities.

The vast majority of the chemicals sector emissions are from the use of gas to raise process heat in the manufacture of methanol – which also uses significant quantities of gas as a feedstock for the creation of methanol. Methanol manufacture is a specialised process, and converting to an alternative fuel source such as biomass would require considerable capital expenditure and increased operating costs – plus would incur significantly higher fuel input costs. As such, it is not considered a feasible option for cost-effective transition to lower greenhouse alternatives.

Likewise, high-temperature furnaces have many process-specific requirements that dictate to a significant extent the fuel choice, and which would incur significant costs from switching to a lower greenhouse alternative such as biomass.

However, submitters presented several examples of mitigation initiatives already in place. For example, in June 2017, the former government announced a grant of \$18.6 million to replace coal with waste tyres as the primary heat source for cement production. One grant recipient, Golden Bay Cement, will burn 3.1 million waste tyres a year, reducing its CO₂ emissions by 13 000 tonnes each year. Where tyre waste is unable to be recycled or reused, combustion for energy is generally considered a beneficial use (US EPA, 2016). In addition to waste disposal benefits, the emissions factor for tyre combustion is lower than coal, because tyres typically have a higher energy content, and they contain between 18% and 29% biomass (Lechtenberg & Diller, 2012).

Golden Bay Cement has also invested in alternative fuel programmes.

The prime example of this focus is the success of the wood-waste biomass fuel for coal substitution (coal is the prime thermal fuel) in the pyro processing plant. The initial project in 2004 targeted a 10% replacement level, however fine tuning of the operation lifted the substitution rate to nearer 30%. (Golden Bay Cement, sub. DR197, p. 3)

In 2012, the combustion of waste wood at Golden Bay Cement reduced CO₂ emissions by 58 000 tonnes (EECA, 2012). However, the Commission understands that the company's use of waste wood has subsequently declined owing to increased demand for waste wood in the upper North Island.

EECA (sub. DR326) notes options are available to produce high-temperature heat with electricity, although these technologies are likely to only be cost-effective in certain situations given the relatively high cost of electricity.

A number of electro-technologies (induction, infra-red and microwave heating, mechanical vapour recompression) can meet existing high-temperature heat requirements... However, because of high electricity prices, these opportunities are more likely to be cost-effective in non-energy intensive companies, where fuel cost is a small proportion of overall cost, than for large heat users. (p. 14)

F14.2

Substantial emissions reductions will be challenging for high-temperature heat users in the short term. Smaller, but material, emissions reductions are likely to be possible through measures such as demand reduction, efficiency improvements, and co-firing with lower-emissions fuels.

Fuel switching – low and intermediate heat users

The dairy industry is the single largest source of emissions from intermediate process heat (100–300°C), resulting from its use of coal and gas boilers to dry milk. Coal is also used for some lower-temperature heat uses, such as heating glasshouses for horticulture. The following sections examine the potential of different fuel sources (natural gas, geothermal heat, electricity, solar heating, and biomass).

Natural gas

Although natural gas is a fossil fuel, it has a lower emissions profile than coal. According to the guidelines of the Intergovernmental Panel on Climate Change, combustion of natural gas releases about half as much CO₂ per unit of energy as coal; however this does not account for any fugitive emissions (Box 14.1). Replacing coal with gas as a fuel for industrial heat would therefore contribute to emissions reductions. As such, natural gas is often suggested as a “bridging fuel” in the transition toward a low emissions economy (Zhang et al., 2016).

Box 14.1 Fugitive emissions from natural gas

Fugitive emissions are distinct from the emissions caused when gas is combusted, and instead refer to leakage that can occur at any stage of natural gas extraction and delivery: field production, processing, transportation and storage, and distribution (Lazarus et al., 2015).

Recent studies in other countries have found that these emissions (and therefore the overall emissions intensity of gas) are much higher than previously thought. For example, Alvarez et al. (2018) estimate that leakage is equivalent to 2.3% of gross gas production in the United States – 60% higher than the US inventory estimate. Other studies have shown that in certain scenarios (time- and region-specific) leakage can be up to 15% of production, and under these circumstances natural gas becomes significantly more emissions intensive than coal (Lazarus et al., 2015).

Fugitive emissions from natural gas production and distribution are recorded in New Zealand’s GHG inventory, and were a relatively minor emissions source in 2016, making up around 2% of emissions from the energy sector. Yet the inventory indicates significant uncertainty (plus or minus 100%) regarding most categories of fugitive emissions (MfE, 2018d).

In its submission, First Gas estimated the reduction in CO₂ emissions that would result from replacing coal with natural gas in five industrial process heat plants located in the North Island. Switching all of the plants to natural gas would reduce CO₂ emissions by around 120 000 tonnes, or 41%, with nearly half of that coming from the largest plant alone (First Gas, sub. 47).

However, the ability to convert coal-based heat production to gas is currently an option only in the North Island, as no reticulated supply is available in the South Island.¹⁹³ Even in the North Island, the ability to switch depends on proximity to the existing distribution network. Conversion to gas-based energy production is reasonably capital-intensive and may see a firm left with stranded assets or less able to change to even lower- or zero-emissions fuels over the medium term.

Taranaki District Council (sub. DR188, p. 3) suggested that for “major industrial processes the arguments for continued use of natural gas or for fuel switching from coal to natural gas are also strong”. Golden Bay Cement mentioned switching from coal to gas, but noted the importance of supply certainty:

Fuel switching from coal to natural gas would deliver a major emissions reduction however supply certainty into the medium term future must be in place to allow project investigation and possible investment in plant change. (Golden Bay Cement, sub. DR197, p. 3)

¹⁹³ However, New Zealand Oil and Gas noted that exploring gas reserves off the South Island is being considered (sub. 56).

Fossil Fuels Aotearoa Research Network raised several arguments in opposition to the use of gas as a bridging fuel.

- Replacing coal with gas will not reduce emissions sufficiently to stay below 2°C warming
- The negative environmental and climate impacts of ... gas and oil are scientifically well documented
- Fugitive methane emissions from gas production and distribution are greater than initially reported, poorly managed and unregulated
- Long-term commitment to gas locks in fossil fuel emissions and inhibits the development of renewables
- Renewable energy technologies are becoming cheaper and more reliable faster than predicted
- Negative emissions technologies (NETs) such as bioenergy or afforestation linked with CCS are unproven, have environmental issues and most are currently not scalable. (Fossil Fuels Aotearoa Research Network, sub. DR178, p. 3)

Sims (2018) raises similar concerns about the use of gas as a bridging fuel, noting that switching from coal to gas would contribute a little toward New Zealand's 2030 reduction targets, but that reaching net-zero emissions by mid-century will ultimately require gas being entirely phased out. Sims argues therefore that New Zealand should not seek to explore and develop new gas resources and instead should ensure that existing reserves of natural gas are used wisely to maximise the return on investments already made, and to reduce emissions by displacing coal. This is broadly consistent with the results of the Commission's modelling, which shows (for both 25 MtCO₂e and net zero emissions targets) use of coal for process heat falling substantially by 2050. While gas is not phased out entirely, significant reductions are required.

F14.3

Reducing the use of coal is particularly important, as it has roughly double the emissions intensity of natural gas. However, in order to reach New Zealand's emissions targets the use of both fuels will need to decline significantly.

Hydrogen

Over the medium to long term, options to significantly transition away from natural gas will need to be developed. Hydrogen is one option that is generating interest both locally and overseas (Staffell et al., 2017). Some heating technologies that currently combust natural gas can be converted relatively easily to hydrogen and hydrogen can be safely mixed in small quantities with natural gas and injected into existing gas networks. The Northern Gas Network in the UK is currently undertaking a project which aims to convert the city of Leeds's gas network entirely to hydrogen (Lempriere, 2017). However, in many cases new combustion technology (eg, "fundamentally new furnace designs" in the iron and steel industry) will be required to facilitate switching from natural gas to hydrogen (Staffell et al., 2017, p. 90).

In New Zealand, hydrogen has recently received renewed attention as a potential low-emission fuel for transport (Chapter 12). Additionally, Vivid Economics is currently undertaking a study (commissioned by First Gas and Powerco¹⁹⁴) which will develop scenarios for net zero emissions in New Zealand with a special focus on the gas sector. This study will examine previously published scenarios in greater detail and explore the potential for hydrogen and biogas to replace natural gas (Vivid Economics, forthcoming).

Geothermal energy

Geothermal energy has a lower emissions profile than natural gas, although this can vary depending on the source. First Gas stated that the "amount of carbon emissions from New Zealand geothermal plants varies widely and can range from as low as 9kg/GJ to as high as 166 kg/GJ" (sub. 47, p. 3). Geothermal energy is also a proven energy source for intermediate heat supply: for example, Miraka's plant in Mokai uses geothermal steam to dry milk; and Asaleo Care, in partnership with the Ngāti Tuwharetoa Trust, began using

¹⁹⁴ First Gas Limited is a natural gas transmission and distribution company and Powerco is a gas and electricity distributor.

geothermal steam to produce tissue paper at Kawerau in 2010, resulting in a 46% reduction in GHG emissions (GNS Science, 2017). Mercury Energy noted that the

displacement of gas/coal generation by geothermal is the single-biggest reduction to date in NZ's emissions profile with over 2 million tonnes CO₂-e per year permanently reduced. (sub. 49, p. 3)

As with natural gas, the ability to switch to geothermal energy depends on proximity to the heat sources, most of which are located in the central North Island and Northland. Geothermal energy also typically involves relatively high capital expenses and economies of scale (East Harbour Energy, 2014), meaning that it is likely to be more suitable for larger-scale operations.

Electricity

Although electricity is a low-carbon source of energy in New Zealand, Atkins (sub. DR361) cautioned against assuming that a large portion of process heat demand can be easily electrified using renewable electricity. In most circumstances, for electricity to be a cost-effective fuel source for process heat, it needs to be applied using a technology that has a coefficient of performance (CoP) well above 1. CoP is a ratio of useful heating or cooling provided to energy required. For example, a heat pump operating at a CoP of 3.5 will provide 3.5 units of heat for each unit of energy consumed.

Electricity will be economic where it can be applied such that it has a Coefficient of Performance (CoP) of at least about 2 – 3. The use of heat pumps and mechanical vapour recompression technologies can provide this. Producing steam in an electrode boiler or direct heating using heating elements has a CoP equal to no more than 1. The cost of electrical energy on a per unit basis is around 4 to 6 times the cost of current fuels and also still significantly higher than biomass. (pp. 2–3)

Fonterra (sub. DR.355) raised a similar point, noting that process electrification will require the installation of heat pumps and other technologies that deliver thermal energy at a higher efficiency than direct electrical use to offset the relatively high cost of electricity.

Despite the high costs associated with electrification, dairy processing company Synlait has recently announced they will install a 6 MW electrode boiler at its Dunsandel plant in late 2018. Synlait notes that, on a 10-year basis, the total investment – including network upgrades and running costs – will be about twice what would have been spent on a coal system. However, Synlait's Chief Executive stated that expected increases in carbon costs and the country's increasing investment in low-cost renewable power supply made the electric boiler a "sound economic decision" (Evans, 2018). EECA contributed to the cost (\$250 000) and provided technical advice on the grounds that the project is expected to provide a demonstration site for the wider food processing industry (Evans, 2018).

F14.4

Electrification can be a cost-effective mitigation option for process heat at current prices, provided that it is applied using a technology that has a coefficient of performance (CoP) well above 1. Electricity is currently a relatively high-cost fuel for process heat when it is applied using a technology that has a CoP of 1.

A further potential barrier to the electrification of process heat is the cost involved in building the necessary capacity in, and connections to, the transmission network (Atkins, sub. DR355; Fonterra, sub. 88; and Contact Energy, sub. 29). Costs for new connection assets vary on a case by case basis but can be significant. Costs are usually paid off by those that will benefit from the infrastructure over the life of the asset. As discussed in Chapter 13, some changes to the methodology for recovering the costs of upgrades to the transmission grid are being considered as part of the Electricity Authority's review of transmission pricing methodology.

Solar heating

Horticulture NZ observed that, for some greenhouses in the South Island, solar heating may be an alternative to coal (sub. 41, p. 7). SRD Consulting (sub. DR173, p. 4) also noted the potential for solar to provide low- to intermediate-process heat:

There are huge opportunities to take advantage of solar thermal and storage technologies which will displace the use of fossil fuels in boilers for our process heating needs below 250°C. Our process engineering challenge is to integrate these solar technologies onto sites but also the energy storage onto our smart grid of the future.

The Commission is not aware of any examples where solar technologies are used to generate process heat in New Zealand. High up-front costs and the large land area required for industrial-scale solar collection are likely barriers to uptake. Even so, as discussed in Box 14.2, solar technologies are well-developed overseas, and may become an option in coming years.

Box 14.2 Concentrated solar power

Concentrated solar power (CSP) is a technology that uses lenses and mirrors instead of photovoltaic panels to generate energy. In some versions, the mirrors collect the sun's rays and reflect them onto a receiver pipe filled with oil. The oil can be heated to temperatures over 300°C, creating:

- heat that can be used for industrial or residential purposes; and
- energy that can be used to generate electricity.

CSP allows even relatively sun-starved areas to use solar energy, and is being used at a number of locations in Denmark to generate heat. In other variants of CSP, the solar energy is reflected onto tanks of molten salt. The heat generated during the day is used at night to drive steam-powered turbines.

A number of CSP projects are in place in Australia, including one in South Australia that uses seawater to fuel the Sundrop horticultural farm. The seawater is heated by the solar lenses, generating heat for the 200 000m² of glasshouses in winter, powering a steam turbine to produce electricity, and providing freshwater (once desalinated) for irrigation. The Sundrop project has been estimated to avoid 16 000 tonnes of CO₂ every year.

Source: Aalsborg CSP (2015); Euronews (2018); Hiscock (2014); Ross (2018).

Biomass

Biomass refers to organic material that can be converted into energy, generally by combustion. Where biomass is sourced from forestry that is replanted after harvest, it is generally considered carbon-neutral, because the carbon that is released during combustion has previously been sequestered from the atmosphere and will be sequestered again as the plants regrow. When considering the full supply chain, biomass typically involves some emissions through the use of fossil fuels in harvesting, transport and processing. However, "fossil energy used in the supply chain is generally a small fraction of the energy content of the bioenergy product, even for woody biomass transported over long distance, e.g. between North America and Europe" (IEA, 2018a).

Biomass is already a significant source of energy for process heat, with wood and black liquor delivering 45 500 TJ of energy in 2016 – this amounts to 31% of total delivered energy for process heat (EECA, 2018b). The vast majority of biomass energy for process heat is used in the wood product and pulp and paper manufacturing industries (EECA, 2018b).

Several inquiry participants noted that biomass as a fuel for process heat is a mature technology in New Zealand and other jurisdictions.

In Sweden and Finland numerous cogeneration plants, up to 400MW electric capacity have been operating for decades using forest residues as fuels, and in Denmark and Germany using cereal straw, to provide industrial process heat, district heat, and electricity to meet demand from local towns and urban communities. The technology and logistics systems are well understood including the integrated harvesting and chipping of forest residues at the same time as log extraction. (Ralph Sims, sub. DR199, pp. 1–2)

Highly efficient and sophisticated modern woody biomass heating technology has been available globally for more than twenty years, with a large range of providers servicing this market. (Venture Southland, sub. DR336, p. 2)

Technology to use biomass to produce process heat exists now, off the shelf and is already in use in New Zealand. (Scion, sub. DR366, p. 93)

[T]here is no significant technology improvements required to utilize biomass, the boiler technology is more advanced than coal combustion and it is often being installed. In fact the strength of using biomass energy is that the technology is proven and research and development is not required. (Bioenergy Association, sub. DR352, p. 22)

Submitters also provided examples where biomass is already being used in New Zealand for industrial process heat and other heating requirements:

Oji FS ... is New Zealand's largest producer of biofuel renewable energy, with over 80% of our process energy needs derived from renewable sources. On an annual basis, we utilise over 21 PJ [petajoules] of energy from wood-based biomass (Kraft black liquor and wood residues). (Oji Fibre Solutions, sub. 71, p. 1)

Azwood Energy has about 24 small-medium wood energy supply contracts across New Zealand, each one of them makes economic sense, reduces emissions and adds benefits to communities. (Azwood, sub. DR168, p. 6)

Several inquiry participants also noted potential to reduce emissions through co-firing – when biomass (usually a high energy wood fuel) is blended with the current fuel (usually coal) to supplement energy requirements (Azwood, sub. DR168, p. 5). Fonterra has recently announced that it will co-fire its Brightwater processing site with 25% biomass (sub. DR355). Pioneer notes that it has successfully co-fired coal boilers for some time:

Pioneer has successfully co-fired biomass wood fuels with coals in their Dunedin Energy Centre for more than 8 years. This energy centre is 28MWth and has for decades supplied the University of Otago, Southern District Health and Cadbury's process factory. The co-firing conversion was relatively low cost, at less than \$2m per 8MW boiler, and a converted boiler will operate on biofuels through summer months. Reductions of fossil fuel emissions can then be made progressively as new wood fuel supply chains are developed. (Pioneer Energy, sub. DR221, p. 6)

The three main barriers to adopting biomass as a fuel source for process heat are costs (which includes transport and storage costs), incompatibility with existing heat plant, and concerns about the security of supply.

Biomass cost

In many cases, on a cost per unit of energy delivered, coal remains a lower cost option than biomass. Submitters noted that increases in the emissions price would be needed to put biomass on a level footing.

The cost of biomass as a delivered fuel would be in the order of \$10 per GJ at many heat using sites. Gas already costs this depending on the size of the demand. Coal ... would be in the order of \$6 to \$7 per GJ, more if transport distance are in excess of 100km. The cost of coal will rise per around \$1 per GJ for every \$10 of carbon price. A significant driver is that industrial users have not been paying for their carbon emissions... If the playing field is levelled and the cost of carbon gets to around \$50, then biomass as heat fuel will be able to compete. (Ian Hall, sub. DR205, p. 6)

Because biomass typically has a lower energy density than coal, transport and storage costs can be higher. Estimates provided by Ralph Sims (sub. DR199) show that in most cases coal has a superior energy content to woody biomass:

If air-dried to around 40-50% moisture content (wet basis), it [woody biomass] has a net energy content of around 13-16 MJ/kg. This can range from ~18 MJ/kg for pellets to ~8 MJ/kg for freshly harvested chips. Coal has an energy content ranging from around 15 MJ/kg for lignite (brown coal) to ~30 MJ/kg for bituminous (black coal). (p. 4)

Graymont observed that "[w]oody biomass has a low energy density and so efficiency and transportation (eg, increased truck movements) can be a barrier to implementation" (sub. 33, p. 6). Scion (sub. DR366)

indicated that users would need around three truck-loads of woody biomass to generate the same output as one truckload of coal:

Assuming a truck has a maximum payload of 29 tonnes (44 tonne GVM [gross vehicle mass]) carrying coal with a NCV [net calorific value] of 21 GJ per tonne (optimistic) it will deliver 609 GJ per load. A typical chip truck (with a high volume configuration, not requiring any special permits) can deliver 29 tonnes of wood chip at 6.9 GJ per tonne, or 203 GJ per load. (p. 91)

However submitters also noted cases where biomass has been economically viable at current emissions prices:

Pioneer has implemented more than \$70m in biomass heating solution investments on large process heating sites at normal private sector commercial returns, even with ETS carbon prices below \$15 per t_c [tonne of carbon]. The Commission's report assumes emissions costs will be well above \$30 t_c so a much broader uptake of bioenergy is possible. Pioneer (sub. DR221, p. 4)

Incompatibility with existing heat plant

Industrial heat plant (such as boilers), typically has a useful life of at least 25 years (Bioenergy Association, sub. DR352). In most cases it is uneconomic to switch to alternative fuel sources until a boiler has reached the end of its life – although it is sometimes possible to co-fire an existing boiler with biomass.

The medium to low grade industrial process heat especially for dairy processing are very suitable for biomass utilization. The main hurdles for this sector are the significant sunk capital costs in existing coal boiler equipment which is not suitable for direct utilization of low cost forest residual biomass fuel. (Bioenergy Association, sub. DR352, p. 21)

Concerns about the security of supply

A final barrier to adopting biomass relates to concerns about the security of supply. Several submitters noted that enough biomass is available in New Zealand to substitute a large share of existing coal use. Oji Fibre Solutions stated that there is "enough recoverable woody biomass available throughout New Zealand that 60% of current coal use in heat plant could be replaced with biomass fuel" (sub. 71, p. 7). Scion (sub. DR366, p. 93) suggests that "there is at least 10 PJ (and maybe as much as 15 PJ) of coal demand that could be substituted by these [woody biomass and other lignocellulosic residues] residues. The GHG reductions from this substitution would be between 1.3 M tonnes and 1.7 M tonnes of CO₂-e per year".

P. Hall (2017b) has assessed the availability of woody biomass resources in New Zealand by volume, type, energy content and region. Looking at residues with a cost of up to \$12 a GJ, the study identifies available gross energy of about 32 PJ a year. Not all of this biomass is recoverable – using the more conservative of two recoverability scenarios, the gross amount of recoverable energy available reduces to around 17 PJ (P. Hall, 2017b).

Inquiry participants also noted that the additional afforestation required for New Zealand to meet emissions reduction targets could significantly increase available biomass feedstocks.

[T]hrough the increase in investment of New Zealand in the plantation of trees through programmes such as the One Billion trees, Beef and Lamb's and other stakeholder's plan to aim towards Zero Carbon, planting trees to offset carbon and at the same time providing a fuel source is becoming an increasingly popular option. Through the growth of the wood energy market, significant additional gains in terms of cost and logistics can be achieved to make it viable to recover wood by-products currently left unrecovered in the forests by forestry operations. (Venture Southland, sub. DR336, p. 2)

The 1 Billion Trees programme will start to deliver significant volumes of new wood fuel once the stage of thinning and pruning is reached approx 10 years after planting. (Living Energy, sub. DR339, p. 3)

Peter Hall (sub. DR205) noted that large-scale afforestation can have multiple benefits, including the supply of a significant amount of wood for energy. For example, the sustainable harvest of a 1.4 million hectare forestry estate will generate a resource of around 39 million cubic metres a year, with a primary energy value

of 270 PJ – this amounts to a substantial share of New Zealand’s total consumer energy, which was 970 PJ in 2017 (Peter Hall, sub. DR205).

However some submitters remain concerned about the reliability of biomass supply.

[C]overed crop tomato, capsicum, lettuce and cucumber producers in the South Island (close to South Island urban centres for consumption) are reliant on coal as opposed to North Island counterparts with access to natural gas... In most cases there is no commercially viable alternative, especially given limited availability of quality biomass in NZ. Growers report that they are not confident of securing a consistent supply, and that the considerable volume increase that would be required for wood chip compared to coal would be difficult to manage. (Horticulture New Zealand, sub. DR394, p. 3)

Golden Bay Cement noted that the biomass fuel market has become “scarcer and more costly” as more end users have switched to biomass (sub. DR197, p. 4).

F14.5

Sustainably sourced biomass is a low-carbon fuel source that is widely used to generate process heat in New Zealand. Concerns about reliability of supply, higher (in most circumstances) costs per unit of heat, and sunk costs in incompatible infrastructure are the main barriers to further uptake.

14.4 Policies to reduce emissions from process heat

The impact of increasing emissions prices

Arguably the most powerful policy for promoting fuel switching and other emissions reductions in industrial energy is a significantly higher emissions price. The Commission’s modelling (Chapter 3) finds that fuel switching away from diesel (to biomass and electricity) begins at emissions prices of around \$40 per tonne, and virtually all current diesel-fired boilers switch by the time the price reaches around \$80. For coal, fuel switching begins at prices of around \$60 per tonne and all coal-use switches by the time the price reaches around \$120. For gas, fuel switching begins at prices around \$120 per tonne. In most of the modelled pathways, emissions prices in 2050 exceed \$150.¹⁹⁵

As noted in Chapter 3, the Commission’s modelling has limitations and it does not constitute a prediction about the future. It is a simplified representation of reality based on key elements and relationships, and there are details and complexity that are not captured in the model. Accordingly, the timing of fuel switching relative to rises in the emissions price will almost certainly vary from the results indicated in the modelling, reflecting the limitations of the model, and the varying situations and preferences of heat users. Expectations of future price increases would affect current and upcoming investment decisions and tend to move firms towards lower-emissions heat sources.

F14.6

Rising emissions prices will be central to driving emissions-reducing investments in industrial heat processes.

The role of EECA in promoting industrial emissions reductions

The Energy Efficiency and Conservation Agency (EECA) is the main conduit for government support to reduce emissions from industrial heat users. EECA works directly with large energy users, and through energy management experts with medium-sized businesses, to promote more efficient and lower-emissions energy options. EECA provides advice to other businesses through industry associations and web-based information and tools (EECA, 2017c).

EECA’s submission outlined three of their current projects that focus on process heat:

- research to provide guidance on specific applications where electric heating may be economically viable;

¹⁹⁵ Except in the combination of disruptive innovation occurring and a less stringent emissions target (25 MtCO₂e).

- a heat pump pilot project to support broader application of high temperature heat pumps for industrial heating processes and building heating; and
- a pilot heat plant optimisation project to obtain credible information on a range of opportunities applicable to a wide-range of fossil fuel heat plant (EECA, sub. DR326).

The following sections examine in greater detail EECA's statutory functions and recommend some additional measures that EECA could take to support process heat emissions reductions.

Ensure emissions reduction is part of EECA's statutory function

Under the Energy Efficiency and Conservation Act 2000, EECA's statutory function is: "to encourage, promote, and support energy efficiency, energy conservation, and the use of renewable sources of energy". The Parliamentary Commissioner for the Environment has argued that EECA's current mandate regarding renewable energy is outdated, and should be changed to lowering GHG emissions.

In recent years, it has become clear that the finiteness of fossil fuels is not the problem; rather the problem is the carbon dioxide emitted when fossil fuels are burned. The real scarcity is the limited ability of the atmosphere to absorb greenhouse gases without substantially changing the climate. EECA's mandate should now be changed to working to reduce carbon dioxide emissions. Often renewable energy is low carbon, but this is not always the case. (sub. 54, p. 9)

The Productivity Commission's draft report recommended that EECA's statutory functions should be changed to make lowering GHG emissions its primary mandate.

EECA noted that "while the Act does not explicitly mention the reduction of carbon emissions as part of EECA's functions, the nature of our activities and programmes produce this as a co-benefit" and "EECA's work programme is also guided by the New Zealand Energy Efficiency and Conservation Strategy 2017-2022 (NZECS), which provides a clear carbon focus" (sub. DR326, pp. 16–17). EECA also noted no mandate exists "for any agency to focus on minimising the use of materials with high embodied energy and carbon used in infrastructure and buildings construction".

Other submitters noted that energy efficiency is a key mitigation strategy and that this should remain a priority.

If EECA's mandate changes to focus on lowering GHG emissions...energy efficiency improvements will still be the lowest cost abatement option and should be a continued focus area for EECA. (Bioenergy Association, sub. DR352, p. 19)

Energy efficiency is a key contributor to lowering emissions and delivering overall productivity improvements. This contribution should not be devalued by changing the primary focus of EECA. Emissions reduction should become part of EECA's remit... (Energy Management Association of New Zealand, sub. DR242, p. 7)

While we agree that emissions reductions are very important and should be a primary consideration, we worry that without also retaining a mandate to also promote energy efficiency, there will be no organization in New Zealand leading energy efficiency efforts, with the result that energy efficiency can get lost. (American Council for an Energy Efficient Economy, sub. DR163, p. 5)

Reflecting these views, the Commission considers that a good case exists for EECA to retain its functions relating to energy efficiency and conservation. However, EECA's function relating to renewable energy should be replaced with a function that promotes low-emissions energy sources.

A good case also exists to extend EECA's functions to include the promotion of low-emissions building materials. As discussed in Chapter 16, the differences in embodied emissions between different building materials and practices can be significant. However, obtaining information about the relative emissions intensity of different materials can be costly, as can determining how emissions embodied in materials interact with other emissions throughout the lifecycle of a building. This cost is likely accentuated by the large number of small businesses in the New Zealand's building and construction industry.

Several government agencies have existing responsibilities that overlap with the promotion of low-emissions materials. These agencies include the Ministry of Business, Innovation and Employment, which is responsible

for oversight of building regulations and energy policy advice; and the Ministry of Primary Industries, which has previously managed programmes to encourage the use of wood in construction (Chapter 16). However, EECA appears best-suited to adopt this role because it has significant experience in disseminating advice and information, and already has programmes in place to promote energy efficiency in buildings (and the choice of materials and operational efficiency have important links).

R14.1

The statutory functions of the Energy Efficiency and Conservation Authority should be changed to encourage, promote, and support the use of low-emissions energy sources and materials. Functions relating to energy efficiency and conservation should be retained.

In addition to examining EECA's statutory functions, the Commission has also considered whether EECA should refocus its support for emissions reductions in the process heat space toward smaller firms. There are some good reasons to work with both large and small firms, and ultimately EECA will be best positioned to establish where its resources will have the greatest benefit in terms of emissions reductions (Box 14.3).

Box 14.3 Targeting EECA's resources based on firm size

EECA does not distinguish between the size of firm or its capability to self-fund any emissions reductions activities. In the draft version of this report, the Commission recommended that EECA should refocus its support for business towards smaller firms, on the grounds that the information and capability barriers adopting emission-reducing techniques are likely greater for smaller firms.

EECA did not support this recommendation, noting: "While small firms face barriers to improving energy efficiency, the barriers facing large firms remain significant. Large emitters currently offer greater abatement opportunities at lower transaction cost" (EECA, sub. DR326, pp. 17–18). Other submitters (eg, Bioenergy Association, sub. DR352 and Venture Southland, sub. DR336) argued that support should be extended to smaller firms, alongside continued engagement with larger firms.

Given its limited resources, EECA should prioritise those activities that it sees making the greatest contribution to emissions reductions. Given that emissions from process heat are heavily concentrated among a small number of large heat-users, a good case may exist for EECA to continue to work with large business. Also, some instances of EECA working with large firms could have positive spillover benefits for smaller firms. One example would be if EECA could accelerate the uptake of biomass by a large industrial heat user. This might help to establish the biomass supply industry in the region, which would in turn reduce concerns about future supply among smaller firms.

Crown loans

EECA administers Crown Loans – interest free loans to fund energy efficiency and renewable energy projects for publicly funded organisations such as schools, local councils, universities and polytechnics, government departments and hospitals. Inquiry participants raised two concerns about Crown Loans. The Bioenergy Association (sub. DR352, p. 23) suggested that the criteria for loans should change as it is currently "based only on energy savings and there is no consideration of the benefits of greenhouse gas emission reduction". Nature's Flame suggested that the five-year payback period on energy cost savings should be reviewed, noting that "the benefits for all come on a longer view" (sub. DR245, p. 2).

The first of these concerns has recently been addressed. In April 2018, EECA extended the criteria for Crown Loans to include projects that move from fossil fuel heating to electricity, bioenergy or direct use of geothermal, provided that these projects result in a emissions reduction of at least 80% compared to fossil fuel energy (EECA, 2018a). EECA indicated that they will be conducting a review of Crown Loans in the 2018/19 financial year. As part of this review, EECA should consider extending the payback period on energy cost savings, given that the benefits of some efficiency measures accrue over a longer period.

Process heat emissions reduction targets

Under the Energy Efficiency and Conservation Act 2000, the Government must establish a *National energy efficiency and conservation strategy*. The purpose of the strategy is to “give effect to the Government’s policy on the promotion in New Zealand of energy efficiency, energy conservation, and the use of renewable sources of energy”. The strategy must set out the Government’s policies and objectives along with “targets to achieve those policies and objectives”.

The current strategy, the New Zealand Energy Efficiency and Conservation Strategy 2017–2022 (NZECS) includes a strong emphasis on reducing emissions, including a target to reduce industrial emissions intensity (kg CO₂e/\$ Real GDP) by at least one per cent a year on average between 2017 and 2022 (MBIE, 2017d). The target will be supported through the development of a process heat action plan that will include using evidence to understand whether any market failures are preventing increased efficiency and use of renewable energy for process heat.

Well-specified targets for reducing emissions can deliver a range of benefits, including giving clarity about policy objectives, providing a signal about government intent and influencing decision making. But it is important that targets are carefully constructed. In the case of industrial emissions, the targets in the NZECS appear to lack ambition. A technical fact sheet, prepared by MBIE, about the proposed intensity target for industrial emissions suggests that the 1% reduction target is actually a continuation of previous trends:

[E]missions intensity fell by 1.0 per cent per annum on average between 1990 and 2014, and... [are forecast] to continue out to 2022. (MBIE, n.d.)

The fact sheet notes a range of uncertainty exists about the forecast changes in emissions intensity between 2017 and 2022, and “emissions intensity could instead rise by 0.8 per cent per annum on average or fall by 3.0 per cent per annum on average” (MBIE, n.d.).

The technical fact sheet gives no indication as to why a 1% reduction was considered an appropriate target. But, given that this reduction was forecast to occur anyway, the value of the target appears questionable.

R14.2

MBIE and EECA should review targets relating to industrial emissions reductions to determine whether a reduction in excess of that already forecast would be more helpful in driving emissions reductions.

Other policy to support emissions reductions

As discussed in section 14.3, the most promising mitigation strategies for process heat users are demand reduction and efficiency measures and switching to (or co-firing with) low-emissions fuels, particularly electricity (at lower temperatures) and biomass (low and intermediate temperature). While an emissions price will be a key driver in encouraging the adoption of such low-emissions fuels, and other mitigation opportunities, the adoption of emissions mitigation approaches faces some non-price barriers. Policies to address these barriers would work in tandem with the emissions price in reducing emissions from the generation of process heat.

Improving the evidence base

The optimal integration of proven technologies (eg. heat pumps) and adoption of efficiency improvements such as heat recovery can generate material emissions reductions. However, the Commission has heard that this can be done poorly, for example leading to increased energy requirements for cooling that erode the system-wide benefit. Therefore, some submitters suggested that while research into the technology itself is not required, applied research on integration is required.

[T]here is a lack of research funding available for applied research and modelling relating to energy transitions and emissions reduction because of the current requirements for funding through traditional mechanisms (e.g. Endeavour funding). This lack of funding needs to be addressed quickly so that policy and sector and national carbon budgets are based on good analysis. (Martin Atkins, sub. DR361, p. 3)

The Report notes that the national innovation system does not appear to support a transition to a low emission economy. We are aware of several bids to various programs that would address reducing emissions and improving the efficiency of industrial heat plants that have been unsuccessful. This relates to much needed research and development to help lower industrial emissions. (Fonterra, sub. DR355, p. 8)

Chapter 6 examines the role that innovation should play in supporting New Zealand's transition to a low emissions economy and recommends that Government should provide major public backing and funding support for innovation. That chapter recommends that innovation support should be targeted in areas relevant to New Zealand's emissions profile. The chapter also suggests that a greater proportion of funding be made available for projects that would improve New Zealand's knowledge of mitigation options through applying known technologies and processes, even if these projects do not generate new scientific discoveries. If implemented, these recommendations would likely increase the amount of funding available for research into the application of technologies to reduce emissions from process heat.

F14.7

Greater understanding of mitigation opportunities in the area of process heat could be facilitated through a stronger and better-resourced innovation system that makes funding available for research into the optimal application and integration of known technologies.

Address information barriers

For some heat users, particularly smaller firms and organisations, a lack of information and experience with alternative fuels can skew investment decisions in favour of the status quo, which in some cases precludes full consideration of low-emissions fuels. This issue can be compounded by the fact that new investments in heat plant are typically made when an existing asset reaches the end of its life. As such, replacement decisions are sometimes made under pressure due to the failure of an existing system, which can act as a barrier to full consideration of alternative technologies (European Commission, 2016).

In these cases, government can have a role in providing information needed to make informed decisions, and in some cases assist in interpreting this information. The Bioenergy Association suggested that EECA should take the lead in these activities.

Many of the barriers to the implementation of projects which can reduce emissions arises from the lack of information and experience ... EECA as the agency acting in the public good needs to step forward and provide the facilitation and assistance required. (Bioenergy Association, sub. DR352, p. 23)

The Commission understands that EECA is working with MBIE to establish a process heat action plan and that this will likely include specific policies to reduce emissions from process heat. This work should be afforded high priority given that the generation of process heat accounts for a significant share of New Zealand's emissions, and given the potential for emissions to be locked in as a result of near-term investments in long-lasting heating systems powered by fossil fuels. When developing the process heat action plan, EECA and MBIE should review existing initiatives related to information about fuel switching, co-firing, demand reduction and efficiency improvements for process heat, with a view to minimising any information-related barriers to mitigation opportunities.

R14.3

EECA and MBIE should review existing initiatives related to information about fuel switching, co-firing, demand reduction and efficiency improvements for process heat, to minimise any information-related barriers to mitigation opportunities.

Coordination barriers

Replacing existing fossil fuel boilers with lower or zero-carbon alternatives was identified as an important mitigation strategy by a number of submitters. As discussed earlier, electrification (primarily for low-temperature uses) and biomass are technically (and in some cases economically) viable low-emission fuel sources for many industrial heat users. In the case of electrification, the main non-cost barriers to adoption relate to the information and behavioural barriers discussed above.

In the case of biomass, submitters suggested that, in addition to information barriers, some other important coordination issues hinder uptake.

- *Coordination between buyers and sellers* – The biomass industry is not well established, except in the wood, pulp and paper manufacturing sectors, which account for nearly all of the biomass used for process heat. This can generate a situation where sellers are reluctant to invest due to concerns about the lack of buyers, while potential users of biomass are reluctant to invest in wood-fired boilers due to concerns about the reliable supply of fuel. This issue was noted by the Bioenergy Association (sub. DR352).

The main barrier is that the use of biomass by those who do not have a ready access to the fuel is in its infancy. This is a normal infant industry situation and requires normal startup industry support to encourage new entrants. The uncertainty creates a perception of risk as to the availability of biomass fuel. (p. 20)

- *Coordination around biomass supply* – Government may also have a role in coordinating the supply of biomass fuels. As discussed earlier in this chapter, several inquiry participants noted that additional forestry planting presents an opportunity to significantly expand the availability of biomass feedstocks. Benefits may emerge from providing information about regional demand for different biomass feedstocks, extraction techniques, and planting locations that are compatible with recovery of harvest residues.

Between 2014 and 2017, EECA ran the ‘Wood Energy South’ programme in conjunction with Venture Southland.¹⁹⁶ The programme focused on the transition of boilers to wood energy fuels in Southland. The interventions included subsidising feasibility studies, providing information and case studies on the use of wood energy, and providing capital grants and Crown loans to support the conversion of boilers.

Several inquiry participants suggested that there would be merit in establishing additional programmes to support the use of biomass, modelled on Wood Energy South:

Ahika believes a national operated-regional-led approach will be a more successful long-term strategy for biomass. (Ahika, sub. DR196, p. 2)

Policy support should be offered in the form of staggered roll-outs of regional wood energy incentive schemes, modelled on Wood Energy South. (Azwood, sub. DR168, p. 15)

Support regional development programmes similar to the Wood Energy South in the Waikato and Otago/Canterbury regions. (Bioenergy Association, sub. DR352, p. 33)

Because biomass supply and demand dynamics vary significantly across regions, and because transport distance can be an important determinant of uptake (one inquiry participant told the Commission that biomass was usually only viable if it was sourced within a 100km radius), initiatives might best be applied on a regional basis. Additionally, because fuel switching will usually only be commercially viable when heat plant fails or reaches its end of life, the number of switching opportunities in a given period of time may be relatively small. For example, in Southland, only two to five boilers over 100KW are due for replacement each year (MBIE, 2016d). The small number of opportunities points toward the need for ongoing intervention.

R14.4

EECA and MBIE should consider a wider roll-out of policy initiatives to support the supply and use of biomass.

Government leadership

The Commission does not see a compelling future for coal-based process heat, given its high emissions intensity. Over time, the existing coal-based boilers should be replaced with lower-emissions alternatives. In addition to the policies outlined above, a shift away from coal and other fossil fuels could be further accelerated by policy to regulate the type or performance of boilers that can be installed in future. The

¹⁹⁶ Venture Southland is an economic development agency that promotes development of the Southland region on behalf of the region’s three councils: Invercargill City, Southland District and Gore District.

Morgan Foundation noted that the Danish Government had prohibited new fossil fuel-powered boilers for low-temperature heat, and that New Zealand could take similar steps, for example:

[r]egulations such as emissions standards on new boilers, a requirement for new or refitted coal boilers to be capable of co-firing with biomass, or a ban on some types of boilers in certain applications. (sub. 127, p. 12)

Venture Southland (sub. DR336) made a similar suggestion recommending “changing the law to limit any new installation of coal operated boilers” (p. 4).

As an initial step towards phasing out fossil fuels for heat, government should take the lead in limiting the installation of new fossil fuel-powered heating systems for space and water heating in government-owned buildings.

There should be no reason that government-run and funded facilities can choose to burn coal with a new installation for the next 30 years in this current climate, as has been done in the last few years. (Azwood, sub. DR168, p. 6)

The two largest users of fossil fuels for space and water heating in the public sector are the education and healthcare and social assistance industries. Ahika Consulting has identified around 85 boilers in schools in the Otago region. More than 60% of these are coal-fired, and 50 will need replacing over the next five years (Ahika Consulting, 2017). Several inquiry participants noted that many public buildings use fossil fuel-powered heating systems, and some suggested that new fossil fuel-powered systems are still being installed.

Like many institutions Lincoln University is currently dependent on coal fired boilers for much of its space heating and hot water requirements and in winter time can burn over 300 tons per month. (Sustainability Action Group for the Environment, sub. DR286, p. 3)

Government owned institutions account for more than 1,000 existing coal or LPG fired boilers. (Pioneer Energy, sub. DR221, p. 5)

[D]id you know there are current LPG heat plant tenders out from a Government department that would be more cost and environmentally effective to use wood pellet boilers instead? (Nature’s Flame, sub. DR245, p. 2)

Several inquiry participants suggested that in committing to limit the installation of fossil fuel-powered heating systems, government should specifically prioritise biomass as an alternative so as to support the development of wood fuel supply chains (Pioneer Energy, sub. DR221; Nature’s Flame, sub. DR245). While biomass may in some cases be the most cost-effective low-emissions fuel, there will likely be many situations where electrification or other options are more cost-effective.

As such, the Commission considers a good case exists for public sector agencies to put in place procurement guidelines that limit the installation of coal and other fossil fuel-powered heating systems. Any guidelines should be neutral about which low-emissions fuels public sector agencies should adopt.

Some state sector agencies have already taken steps to limit the installation of fossil fuel-powered heating systems. For example, the Ministry of Education’s design guidelines for learning spaces recommends that “new coal-fired, fuel, oil, electric, and LPG boiler installations are to be avoided” (Ministry of Education, 2017, p. 14). Consideration should instead be given to “alternative and available fuel sources, eg natural gas and wood chip/pellet... air or ground source hot water heat pump along with underfloor heating or warm air fan coils [and] electric radiant heating” (Ministry of Education, 2017, p. 14).

R14.5

Government should take the lead in phasing out the use of coal and other fossil fuels for heating by limiting any future installation of fossil-fuel-powered heating systems in government buildings.

Dairy industry regulation

Sections 73 and 74 of the Dairy Industry Restructuring Act (DIRA) oblige Fonterra to accept applications to become new shareholders and to accept milk supplied by shareholders (subject to some conditions and exceptions). Fonterra generally collects milk at no cost regardless of location. These obligations are

designed to limit the ability of Fonterra to exercise market power, by reducing the risk to farmers of switching to an independent milk processor. Yet the obligation could have the effect of encouraging inefficient suppliers of milk (who are also likely to be more emissions intensive than other farmers). It could also have the effect of causing Fonterra to expand its processing capacity and therefore, possibly, to install new coal boilers in particular locations.

In the draft report, the Commission asked whether there would be benefit in giving Fonterra discretion to refuse milk supply in situations where this would lead to inefficient land use and/or increases in the company's GHG emissions. Submitters presented mixed views. Fonterra (sub. DR355), Christchurch City Council (sub. DR284), and Waimakariri District Council (sub. DR192) suggested that it would be sensible to provide Fonterra with discretion about whether to accept milk supplies. Ngai Tahu (sub. DR362, p. 11) argued that "facing costs of fossil fuel use, combined with an on-farm point of obligation are likely to be stronger drivers of change" while Federated Farmers (sub. DR310, p. 8) made a similar argument noting that "a farm level point of obligation would negate the need for Fonterra (or indeed any other dairy or meat processor) to consider land use efficiency or on-farm performance".

Since the publication of the draft report, the Terms of Reference for a comprehensive review of DIRA and its impact on the dairy industry have been published. The Terms of Reference provide a good basis for assessing whether Sections 73 and 74 of DIRA have negative consequences in terms of GHG emissions. In particular, they direct the review to consider the extent to which DIRA provisions impact on "the environmental performance of the dairy industry (both at the production and processing levels of the New Zealand based dairy supply chain)" (MPI, 2018b, p. 2). They also require the review to consider whether the requirement for Fonterra to accept all milk supply offers from shareholding farmers should be "removed, modified or replaced with some other regulatory tool" (MPI, 2018b, p. 3). The review will be led by the Ministry for Primary Industries and a final report setting out the overall findings of the review and policy recommendations for regulatory change is scheduled for early 2019.

In light of this process, the Commission has not undertaken any detailed assessment regarding potential amendments to Fonterra's obligation to accept milk supply.

14.5 Industrial processes

Industrial process emissions occur when one substance is transformed into another in an industrial setting. In New Zealand, GHG emissions are reported from eight industrial processes:

- calcination of limestone in cement production;
- calcination of limestone in burnt and slaked lime production;
- production of ammonia, which is further processed into urea;
- production of methanol;
- production of hydrogen in oil refining and for making hydrogen peroxide;
- production of steel, from iron sand and from scrap steel;
- oxidation of anodes in aluminium smelting; and
- use of soda ash and limestone in glass making (MfE, 2017f, p. 101).

95% of GHGs directly emitted by industrial processes are CO₂.

The metal industry (mostly iron, steel and aluminium production) contributes the largest proportion of industrial emissions (about 3% of New Zealand's total), although its total emissions and share of industrial process emissions fell between 1990 and 2016 (Table 14.1).

The other main source of industrial process emissions comes from the mineral industry (Table 14.1), although all emissions from this industry are generated by the calcination of limestone at high temperatures in the

manufacture of cement and lime. These emissions were just under 1% of New Zealand's total GHG emissions in 2016.

Table 14.1 Greenhouse gas emissions from industrial processes, 2016

Source	2016 emissions (kt CO ₂ -e)	Change 1990-2016 (%)	2016 share of industrial process emissions (%)
Mineral industry (cement)	726.8	29.4	21.3
Chemical industry	316.6	56.0	9.3
Metal industry	2300.2	-13.9	67.6
Other	61.1	36.3	1.8
Total	3404.7	-2.2	-

Source: MfE (2018d).

Notes:

1. Other includes emissions from non-energy products from fuels and solvent use, and manufacture of electrical equipment.
2. Emissions from product uses (HFCs) as substitutes for ozone depleting substances are not included.

Opportunities to reduce emissions from industrial processes

The emissions from industrial processes and products are intrinsic to the physical processes involved in production and in product use. Existing plants (such as steel mills and aluminium smelters) use technologies founded on these physical processes. In the long run, new low-carbon technologies to produce these materials, or shifting end use to other (perhaps new) low-carbon products, may be possible. A high enough carbon price will induce a search for low-emissions product substitutes, such as replacing steel with wood in construction, cement substitutes or low-emissions cement variants. It may also make the introduction of mitigation technologies viable. However, as discussed in Chapter 5, higher carbon prices raise viability and fairness issues for trade-exposed firms whose competitors are not subject to equivalent pricing. The closure of domestic firms, and the shift of production to less emissions-efficient producers offshore, would be a loss for New Zealand and globally.

Aluminium

Most of the direct GHG emissions from aluminium production in New Zealand result from the smelting process, during which aluminium oxide (alumina) is dissolved in cryolite and electrolysed within a cell. The process separates oxygen from the alumina by combining it with carbon to create CO₂. PFCs can also be produced from 'anode effects', when insufficient alumina is dissolved and inefficient production occurs. However, PFCs make up a very small share (0.07%) of New Zealand's gross emissions.

Barring any breakthroughs in production technologies, the potential for significant reductions in GHG emissions from aluminium production in New Zealand seems limited. Aluminium production processes are about 130 years old and no viable replacement technologies are yet available. New Zealand's sole aluminium producer (New Zealand Aluminium Smelter Ltd) already has a low-emissions production profile relative to overseas producers, due largely to its use of renewable hydroelectricity.

NZAS [New Zealand Aluminium Smelter Ltd] aluminium smelter at Tiwai Point has one of the lightest carbon footprints per tonne in the world. With less than 4 tonnes of CO₂ per tonne of aluminium compared to a global industry average of over 11.5 tonnes of CO₂ per tonne (cradle to gate assessment). (Metals New Zealand, sub. 120, p. 2)

Pacific Aluminium, which owns the majority share of NZAS, noted that it has taken a number of steps to reduce its carbon footprint and argues against increasing the emissions price it faces until its international competitors face a similar cost.

NZAS has already reduced its on-site emissions by 55% from ~4.5 tCO₂-e/t Aluminium to ~2 tCO₂-e/t since 1990 and this was achieved prior to the introduction of a price on carbon. (sub. 21, pp. 1, 3)

In the case of aluminium, it is critical that our international competitors face a similar price of carbon to the cost in New Zealand, before the transitional measures are wound back in the NZ ETS. It would not benefit the world or reduce global emissions to introduce more stringent carbon measures in a country that has one smelter using hydro-electricity and already struggling with high delivered energy costs, thereby handing a trade advantage to smelters in other countries using coal fired electricity. (Pacific Aluminium, sub. DR268, p. 2)

The most promising emissions reductions opportunities in the short term are likely to come from process improvements, although the impacts may be small. Such improvements typically improve energy efficiency and reduce waste, and the industry should therefore have sufficient incentives to pursue them. Alamdari (2017) outlines some recent research into process improvements, which includes trials of new, more environmentally-friendly materials for sealing the electrolysis cell and techniques for better identifying quality faults in anodes (which are made of carbon and consumed in the smelting process). The Columbia Climate Center (2012, p. 2) points to opportunities to “almost entirely eliminate anode effects and thus PFC emissions” through the use of prebaked anodes and retrofits to computer control and point-feeding systems.

At an international level, the aluminium industry has voluntarily pledged to reduce PFCs per tonne of aluminium by at least 50% by 2020 as compared to 2006 (IAI, 2010).¹⁹⁷ NZAS is a signatory to this pledge due to its ownership structure.

Over the medium term, technological advancements in the production of aluminium that does not release CO₂ as part of the underlying chemical reaction could present a significant mitigation option (Box 14.4).

Box 14.4 **Carbon-free smelting technology**

American aluminium producer, Alcoa, has been developing technology to produce emissions-free aluminium since 2009, and has successfully produced around 700 tonnes to date. The new process produces oxygen and does not release any GHG emissions from the traditional smelting process (Metal Bulletin, 2018).

To “advance larger scale development and commercialisation of the new process” Alcoa has combined with Rio Tinto to form a joint venture company, Elysis (Rio Tinto, 2018). The next phase of this project involves installing a larger-scale pilot plant in Quebec, to be followed by another scale-up to industrial size. By 2024, Elysis plans to have a technology package on the market which can be licensed for retrofitting existing facilities or for the construction of new plants (Metal Bulletin, 2018).

Pacific Aluminium (sub. DR268) identified the potential of advances in carbon-free aluminium, but also noted considerable uncertainty about the applicability and economic viability of the technology.

The applicability and economic viability of retrofitting this, as yet undeveloped, process to NZAS (or to any other site) is at this stage unknown. As with any major capital investment at an aluminium smelter, the possibility of retrofitting the process will depend on the ability of NZAS to secure a block of electricity at an internationally competitive price for an extended period beyond its current contract’s term. (Pacific Aluminium, sub. DR268, p. 2)

A further source of emissions reductions is greater recycling. Aluminium can be “infinitely recycled” and the recycling process “requires 5% of the energy used in primary production, and emits 5% of the GHGs” (Columbia Climate Center, 2012). According to Metals New Zealand, emissions

from the processing of recycled aluminium in New Zealand are exceptionally low by world standards, with New Zealand’s sole recaster of aluminium having a low carbon footprint of 1.21kg of CO₂ per kg of aluminium (based on a cradle to gate assessment). (sub. 120, p. 5)

¹⁹⁷ At present, global PFC emissions per tonne of aluminium production have reduced by approximately 30% since 2006; yet global emissions intensity has remained stable since 2009 due to significant aluminium production in China (World Aluminium, 2017).

Public policy can influence recycling rates, although the potential scale of increases in New Zealand is unclear. Most¹⁹⁸ of the aluminium produced in New Zealand is exported and is cast to customer requirements. A 2007 cost–benefit report prepared for the Ministry for the Environment found that 51% of household aluminium waste in New Zealand was recovered, and that 85% was “technically recoverable” (Covec, 2007, p. iii). However, the report also concluded that recycling “all aluminium containers provides net benefits even without the inclusion of external benefits”.

This raises the questions of why recycling rates are not higher. One likely reason is that, compared with other developed countries, New Zealand’s waste disposal levy is very low. The following chapter (Chapter 15, Waste) recommends applying the waste disposal levy to all known, consented waste disposal facilities, and steadily increasing that rate over time. The findings of a recent review of New Zealand’s current levy rate and structure (D. Wilson et al., 2017) indicate that these measures would increase overall recycling rates (the review did not assess the impact of a higher levy rate on aluminium recycling specifically).

Iron and steel

Most GHG emissions from the iron and steel subsector result from the production of iron, which uses coal as a reducing agent. CO₂ is created by heating and drying concentrated iron sand and coal, and by converting the oxide in iron sand into iron. Some carbon dioxide is also emitted from the use of limestone in iron and steel production.

Opportunities to directly reduce GHG emissions from iron and steel production are currently limited. Some submitters pointed to the potential to use lower-carbon alternatives to coal to produce heat for the steel-making process (sub. 37; sub. 68; sub. 127). However, this does not deal with the carbon produced by the coal reduction process. One development in this area came in 2013 when CarbonScape (a Marlborough-based New Zealand company) entered an agreement to provide New Zealand Steel with 9 000 tonnes of green coke (biomass that is converted into coke using microwave energy) (Scion, sub. DR366; New Zealand Steel, sub. 64). However recent reports note that CarbonScape “pivoted” from low-value products such as coke, to synthetic graphite in 2016 (Matt Brown, 2018).

Charcoal has been increasingly used as a substitute for coal in the Brazilian steel sector so as to reduce CO₂ emissions from fossil fuels. However, producing the 0.6 tonnes of charcoal needed to produce one tonne of steel requires between 0.1 and 0.3 hectares of Brazilian eucalyptus plantation. Accordingly, “hundreds of millions of hectares of highly productive land would thus be necessary to meet expected charcoal demands of the steel industry, and associated land use change emissions could outweigh avoided fossil fuel emissions, as has happened in Brazil” (S. J. Davis et al., 2018, p. 5).

Advanced Materials Technologies (sub. DR136) identified a collaboration in Sweden that is working to significantly reduce carbon emissions through applying completely new production technologies, but noted that this process will not become commercially viable for many years (Box 14.5).

Box 14.5 International advances in low-emissions steel production

With respect to steel, a significant reduction in carbon emissions resulting from iron and steel making requires that the industry takes a major step away from traditional blast furnace ironmaking. Using technologies that utilize other reductants, such as carbon-based fuels recovered from wood waste or hydrogen generated either using geothermal, electricity or biomass, or by using electrolytic decomposition to separate the iron from the oxygen, new steel plants will need to use completely different production technology to achieve anywhere near carbon neutrality.

Such a massive change requires input from many stakeholders and participation from a wide variety of industries. The best example of such a collaboration occurs in Sweden where mining, steelmaking and energy industrial giants such as SSAB, LKAB and Vattenfall, are collaborating to produce carbon dioxide emission free iron using Hydrogen Breakthrough Ironmaking Technology (HYBRIT) that utilizes hydrogen produced from renewable electricity as the reductant to convert

¹⁹⁸ Of the aluminium produced at the New Zealand Aluminium Smelter in 2016, 90% was exported (NZAS, 2017).

magnetite sands into iron. It is ambitious and not expected to create a commercially viable product for 20-30 years.

Source: Advanced Materials Solutions (sub. DR136, p. 6).

Recycling is another possible means of reducing GHG emissions. Steel is potentially infinitely recyclable, and the GHG footprint of recycled steel can be almost two-thirds lower than for new metal (IEA Greenhouse Gas R&D Programme, 2000). This does, however, rely on a sufficient supply of high-quality scrap and limits apply to the proportion of recycled material that can be used.¹⁹⁹ New Zealand Steel noted that approximately “70 000 tonnes of scrap steel is recycled each year in the steel making process” (sub. 64, p. 4).

Beyond changes to production inputs, the remaining options are the pursuit of greater process and energy efficiency and the capture and use of carbon dioxide. Sixty percent of the Glenbrook steel plant’s energy needs are met from the re-use of waste gases and heat, and carbon dioxide at the same plant has been converted into fuels using domestically-developed technology. Further efficiency gains are possible, although international commentary on the iron and steel sector indicates that the bulk of efficiencies in the developed world have already been achieved (Columbia Climate Center, 2012). Incentives to pursue efficiencies and adopt technological improvements in iron, steel and aluminium production will be strengthened by rising emissions prices and the gradual withdrawal of free allocations.

Lime and cement

Over 90% of emissions in the ‘minerals industry’ subsector in 2015 came from lime and cement production. To produce lime (a core input to cement), limestone (calcium carbonate) is baked at high temperatures (ie, higher than 1000° C), releasing CO₂. Fossil fuels such as coal and gas are often used to achieve the high temperatures required to calcinate lime.

The potential for breakthrough technological advances and associated carbon reductions may be higher for cement than other industrial processes. For example,

- scientists at the University of California Los Angeles reported in 2015 that they had successfully trialed a process to recombine the carbon dioxide released during lime calcination with calcium hydroxide to recreate limestone (S. Mason, 2015); and
- a British firm announced in 2008 that it had invented a magnesium-based cement that requires less heating than lime-based options and which “absorbs large amounts of CO₂ as it hardens, making it carbon negative” (Jha, 2008).

The viability and applicability of such new technologies in New Zealand will depend on their cost-competitiveness and scalability, and the ability of existing production facilities to accommodate them. In the shorter term, however, opportunities may emerge to reduce carbon emissions from cement by changing its composition and use. Beyond Zero Emissions (2017) in Australia identifies five strategies for “moving to a zero carbon cement industry in 10 years” (Table 14.2).

Table 14.2 Beyond Zero Emissions strategies for reducing carbon in cement

Strategy	Description	Estimated timeframe
Supplying 50% of cement demand with geopolymers	The reactions involved in making geopolymer cements do not generate GHGs. Geopolymer cements are made from fly ash (a by-product of coal-fired power stations) and ground-granulated blast-furnace slag (a by-product of steelmaking).	Within 10 years

¹⁹⁹ The presence of “undesirable residue metals” in scrap can make it unsuitable for high-quality steel products (IEA Greenhouse Gas R&D Programme, 2000, p. iii).

Strategy	Description	Estimated timeframe
Supplying 50% of demand with high-blend cements	Increasing the proportion of replacement materials (fly ash, slag, clay and ground limestone) in cement to 70%.	Within 10 years
Mineral carbonation	Waste CO ₂ is captured and chemically sealed within rock. The process can produce substances with commercial value, such as magnesium carbonate and silica.	Within 10 years
Using less cement	Designing structures to use concrete more efficiently, using high-strength cement and replacing concrete with timber.	Within 10 years
Carbon-negative cements	Developing magnesium-based cements that absorb CO ₂ .	30 years

Source: Beyond Zero Emissions (2017).

Some of the strategies outlined by Beyond Zero Emissions are less relevant in New Zealand. For example, the focus on geopolymer and high-blend cements partly reflects the heavily coal-based nature of power generation in Australia and the fact that fly ash (a key component of alternative cements) is a by-product of coal-fired generators. As discussed earlier, coal makes up a relatively small share of electricity production in New Zealand.

Fletcher Building submitted that cement standards allow for a high proportion of replacement materials, but noted several barriers to widespread use of these materials:

The primary standard for cement in NZ (NZS 3122:2009) references the AS/NZ 3582 series of standards for Supplementary Cementitious Materials (Flyash, Slag, Amorphous Silica) and allows for substitution rates up to 75 per cent in the case of Slag. The other substitution rates being at individual percentages lower than this.

However, the main impediment to the widespread use of these components is their high cost, whether they can be locally sourced, whether that local sourcing requires expensive extraction, processing or distribution (with its own associated carbon emissions)... New Zealand also lacks the industries or industrial processes that produce the by-products sought after as cement additives or extenders. (sub. DR349, pp. 3–4)

Golden Bay Cement also suggested that the BZE findings are not a good fit in the New Zealand context.

Geopolymer 'cement' binder testing undertaken by GBC [Golden Bay Cement] in the early 2000s concluded that the required raw materials had potential supply challenges and the application of the resultant geopolymer binder finished product had a very limited market uptake potential. High-blend cements are possible but again the option is filler/extender raw material dependant and has current market and standards limitations. Blended cements will remain in the industry emissions reduction toolkit. Mineral carbonation process options were considered in conjunction with a US research party and found to be a miss-match with the NZ concrete product range ratios; concrete 'masonry' products is a relatively small component of the NZ market. (sub. DR197, p. 3)

A McKinsey & Company review of decarbonisation options in the cement industry noted research into substitutes such as magnesium oxide, which would eliminate the use of limestone. This study concluded that these alternatives "are not yet practical to use on a large scale because they are scarce locally, they result from CO₂-emitting processes, or they could endow the finished cement with different and undesirable properties" (McKinsey & Company, 2018, p. 39).

F14.8

Barring technological breakthroughs, opportunities to significantly reduce emissions from iron, steel, cement and aluminium production remain limited.

14.6 Carbon capture and storage

For large, single-point sources of significant carbon emissions such as steel, aluminium and cement manufacture, carbon capture and storage (CCS) may be a suitable means of reducing or eliminating net emissions in the future (RSNZ, 2016). The future adoption of CCS in New Zealand will depend on a number of factors, including the location and type of industry, and regulatory and policy change.

Many key organisations predict that CCS technologies will play a significant role in meeting international emission targets. For instance, modelling from the IEA (2015a) predicts that CCS will deliver 13% of the emissions reductions needed by 2050 to limit the global increase in temperature to 2°C.

This is not quite correct – even after other means of emissions reduction (eg, increased efficiency, fuel switching and renewables), are implemented fully, the IEA’s modelling still shows a shortfall of 13%. This shortfall must be accounted for by other mitigation approaches. CCS is currently the only mechanism for viable large-scale reductions for this 13%. It will be an enormous challenge to implement CCS at that scale within a few decades, but any contribution from CCS towards emissions reduction should be supported.

CCS involves capturing, compressing, transporting and permanently storing carbon dioxide emitted from large point sources such as gas and coal-fired power stations and industrial plants. This process can be broken down into three stages.

- First, capture technologies **isolate and separate** the carbon dioxide. Depending on the nature of the emitting activity, this can occur before, during or after combustion, and use various methods. For instance, a coal-fired power station could separate the carbon dioxide after the coal has been burned. Separation is possible by bubbling the flue gases through an absorber column containing liquid solvents. Those solvents remove the carbon dioxide.
- Second, the carbon dioxide is **purified and compressed** into a supercritical state – at a pressure and temperature above its critical point – so it behaves like a liquid. This process allows the carbon dioxide to then be transported to a suitable location underground for storage. In most cases, the carbon dioxide is transported through a pipeline.
- Third, the carbon dioxide is **injected** into geological formations deep underground where it is **permanently stored**. Storage locations must be at least 800 metres below the earth’s surface to keep the carbon dioxide in a supercritical state.²⁰⁰ Examples of potentially suitable formations include deep saline aquifers, and depleted oil and gas fields.

A related concept is carbon capture and utilisation (CCU) “which covers a range of technologies that capture and convert CO₂ into viable commercial products, such as construction materials, chemicals, and fuels” (Kevin Rolfe, sub. DR187, p. 5). CCU has the benefit of making carbon capture more economical, by generating revenue from the sale of capture CO₂. However, McKinsey & Company (2018, p. 31) found that “converting CO₂ into useful chemicals consumes a great deal of energy, most prominently hydrogen, leading to high costs and strong demand for zero-carbon electricity”.

A selection of views from inquiry participants about the viability of CCS in New Zealand are set out in Box 14.6.

Box 14.6 Views from submissions about the viability of CCS in New Zealand

Some submitters were optimistic about the potential for CCS to be an effective mitigation approach in the New Zealand context.

New technologies developed (and to be developed) for capturing carbon and for storing or utilizing after capture provide the potential for great opportunities for New Zealand. This is predicated by the assumption that viable financial models and initiatives can be established and then put in place to facilitate investment, effort and innovation in this potentially hugely valuable

²⁰⁰ Suitable geological formations for storing carbon dioxide can be as deep as 3 500 metres below the earth’s surface.

space. The myriad of new solutions that could be developed provide a great opportunity for New Zealand to be an early adopter and innovators for Carbon Capture, Storage and Utilization technology solutions (especially for non-energy sector). (IBD Solutions, sub. DR167, p. 2)

However most submitters that commented on CCS cautioned against New Zealand relying on it as a significant mitigation strategy.

[N]egative emissions technologies (NETs) such as bioenergy linked with CCS are unproven, are not economically viable, have environmental issues, and are not scalable in time to reach the government's emissions targets by 2035 and 2050. A viable transition pathway to a low emissions economy for New Zealand should not place reliance on such technology. (Fossil Fuels Aotearoa Research Network, sub. DR178, p. 3)

Although CCS is an essential technology for meeting international climate change targets, and quicker deployment of CCS will achieve a cheaper transition to a low-carbon future, it does have practical difficulties. There are only 37 CCS projects worldwide, storing only 31m tonnes per year of CO₂. (Kevin Rolfe, sub. DR187, p. 5)

While CCS has conceptual appeal, NZS is cautious about placing considerable reliance on CCS as a removal mechanism for a number of reasons. Firstly, New Zealand's geological context raises considerable risks regarding the permanence and reliability of CCS. Secondly, the costs of early CCS projects have been extremely high and have resulted in very low uptake of CCS projects. (New Zealand Steel, sub. DR309, p. 15)

CCS has been given too much attention in the report by the Productivity Commission as an emerging technology. There are still major challenges before this technology can be commercialised and this is well outside New Zealand's influence. (SRD Consulting, sub. DR173, p. 5)

Use of CCS is slowly growing worldwide

The use of CCS technologies globally is slowly growing. By December 2017, 37 large-scale CCS projects worldwide were either in operation, under construction or being developed (Global CCS Institute, 2017). Twelve of these projects are located in North America. Australia's first CCS project, the Gorgon Carbon Dioxide Injection Project, is expected to be in operation later this year. Located off the coast of Western Australia, the project aims to separate carbon dioxide from natural gas streams, and store it in a deep reservoir unit more than 2 000 metres underground.

New Zealand currently has no CCS projects operating or under development. GNS Science noted that while no supercritical CO₂ has been deliberately stored in New Zealand, elements akin to CCS have been operating for some time.

[W]e do currently have a CO₂ capture plant operating (stripping CO₂ from natural gas at Kapuni, with deliberate release of Ktpa [kilo tonnes per annum] of CO₂ to the atmosphere), and CO₂-rich gas has been re-injected in the past to maintain pressure in the Kapuni Field. New Zealand has successfully injected natural gas underground for storage since 2011 at the Ahuroa Field in Taranaki. (GNS Science, sub. DR390, p. 5)

...and could be a viable option in New Zealand in future

Recent studies consider CCS to be a potentially viable option for several large emitters in New Zealand, and a number of potential sites for carbon storage have been identified.

GNS Science assessed the capacity of carbon dioxide storage around New Zealand (Field et al., 2009; Funnell et al., 2009, and references there-in) and based on regional assessments concluded New Zealand has more than adequate underground storage space. Any ranking of locations would however, require detailed site-specific studies. A lack of funding has precluded much work on this next step, but it is recognised that the most likely place to start CCS is in the apron of a depleted/empty onshore oil or gas field in Taranaki. (GNS Science, sub. DR390, p. 5)

Economic considerations – in particular the level of emissions prices – will be key in deciding whether to invest in CCS. The estimated level of emissions price needed for CCS projects to break even varies considerably, depending on the industry, the type of facility (ie, new or retrofitted) and the policy settings of the Emissions Trading Scheme (ETS).

Transfield Worley (2011) developed two case studies to assess the relative costs of installing CCS technologies. The first looked at retrofitting an existing natural gas, combined-cycle power station; the second considered adding a carbon dioxide compression system to a hypothetical new lignite processing plant. The retrofit required a much higher emissions price to break even (Table 14.3), although Transfield Worley noted that retrofitting may be economic at current emission prices “for existing process plants with carbon dioxide separation processing” (2011, p. 11). The higher emissions prices envisaged by Transfield Worley (Table 14.3) are also well within the range of those identified in the Commission’s modelling scenarios (Chapter 3).

Table 14.3 Potential CCS break-even emissions prices

Discount rate	Retrofit carbon price to break even (by tonne of CO ₂ equivalent)	New plant carbon price to break even
5% (social discount rate)	\$NZ 83 per t CO ₂ e	\$NZ 20 per t CO ₂ e
10% (then-Treasury discount rate)	\$NZ 103 per t CO ₂ e	\$NZ 32 per t CO ₂ e
15% (industry/commercial discount rate)	\$NZ 128 per t CO ₂ e	\$NZ 45 per t CO ₂ e

Source: Transfield Worley (2011).

Notes:

1. Discount rates are a tool used for putting the costs and benefits of a potential investment or policy proposal that occur at different points in time onto a comparable footing. Higher discount rates put more weight on short-term benefits and costs. The current Treasury default discount rate is 6%, not 10%.

New Zealand Oil & Gas agreed that CCS could be viable at current prices, especially if this took place at oil or gas fields and if the CCS activity took place as part of oil or gas production.

Our preliminary estimates indicate that carbon could be sequestered in certain realistic New Zealand cases for a net cost of \$18/tonne. A field with the right production qualities potentially could be economic at today’s NZU [New Zealand Unit] values if emissions credits were available for CO₂ sequestration to a producing oil and gas field. With no oil and gas production, we estimate that carbon sequestration could be economically viable at \$68.90/tonne. (sub. 56, p. 9)

The lower viability price of \$18 per tonne when CCS took place alongside oil and gas production reflected the “enhanced recovery” that would result from the captured gas being “re-injected to boost performance of the well” (sub. 56, p. 10). Under the price of \$68.90 per tonne, captured gas would be injected into an end-of-life field and there would not be any improvements to gas and oil production to offset the additional expense.

The Transfield Worley (2011) study identified a number of suitable locations for CCS, including Marsden Point Oil Refinery, Huntly Power Station and Kapuni Gas Treatment Plant. Plants such as Marsden Point already separate CO₂ as part of their existing operation. So CCS is likely to be more cost-effective for these locations. Barton, Jordan and Severinsen (2013) note that some New Zealand industries have experience working with similar sorts of technology.

Due to the large costs and economies of scale associated with undertaking CCS, both studies suggest that CCS is viable for coal-fired power stations with carbon dioxide emissions above 0.8–1 million metric tonnes a year, and above 0.4–0.5 million metric tonnes a year for other operations.

The role of the NZ ETS in CCS

CCS is currently treated as a “removal activity” under the NZ ETS, and ETS participants conducting CCS could therefore claim credits for CO₂ removed from the atmosphere. However, credits can only be claimed for emissions from activities that must surrender units under the NZ ETS. This means that CCS activities not directly linked to NZ ETS participants or that sought to remove general carbon from the atmosphere would not qualify for NZ ETS credits. This disadvantages CCS against other carbon removal activities such as forestry. The Commission concurs with Barton, Jordan and Severinsen (2013) that the NZ ETS should be amended, so that CCS is “a removal activity whether or not the CO₂ is from an activity that is required to surrender units” (p. xi). Such amendments would also need to be accompanied by other policy changes to ensure that CCS operators were required to surrender any credits where captured carbon leaked, including after a CCS site had closed (Barton et al., 2013).

Existing legislation does not adequately govern CCS activities

Existing legislation is not set up to deal with the complexities of CCS, and acts as a barrier to the uptake of these technologies. Barton et al. (2013)²⁰¹ assessed the current legislative frameworks applicable to CCS and concluded:

A close analysis of the RMA [Resource Management Act 1991], the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (EEZ Act), and the Crown Minerals Act 1991 produces the conclusion that none of those Acts is capable, either in its detail or its general architecture, of delivering the legal framework that is required for CCS. (p. vii)

Key problems identified with existing legislation include:

- the limited ability of the RMA to provide “close ongoing regulatory supervision that CCS requires over very long time frames” (p. vi);
- inadequate procedures for allocating permits, especially the ‘first in, first served’ rule when there are competing resource consent applications;
- the lack of mechanisms in the RMA for dealing with “long-term liability for CCS operations after closure” (p. vii);
- potentially unbalanced assessment criteria — resource consent authorities are limited in their ability to consider the positive impacts of CCS activities on climate change when considering applications, but can consider negative impacts;
- inconsistent rules between regions, with some local rules effectively prohibiting some CCS activities; and
- slow rule-making processes and variable “institutional capacity of councils to regulate technically complex activities” (p. 36).

Because of the significant weaknesses of the existing legislative frameworks, Barton et al. concluded that the best response was not to amend existing laws but to establish a new “CCS Act”. That Act would be specifically designed to facilitate and regulate geological sequestration of carbon dioxide.

Having a suitable regulatory framework for CCS activities will be important, given the technology’s potential significance for climate change management. The Commission concurs with the analysis of Barton, Jordan and Severinsen (2013, p. vi) that an entirely new Act is the best response and that any new legislation should focus on the “regulation of CCS, not for CCS”. In essence, the law should provide for appropriate cost–benefit assessments of new activities, rather than promote CCS.

GNS agreed that a new Act is required and noted that this should proceed with urgency given that companies and regulators will require the Act to be in an advanced state before making final investment decisions – “a lead-in time of 10 years or more would not be desirable” (GNS Science, sub. DR390, p. 6).

²⁰¹ Transfield Worley (2011) and RSNZ (2016) have also emphasised the need for legislative reform if CCS is to become viable.

R14.6

New legislation should be prepared to regulate carbon capture and storage activities (CCS). Regulation should address issues including the long-term regulatory supervision of CCS, including after an operation's closure, and procedures and assessment criteria for permits.

R14.7

Once new CCS legislation is in place, the New Zealand Emissions Trading Scheme should be amended to make CCS a recognised removal activity, no matter the source of emissions being captured and stored.

14.7 Conclusion

Industrial sources make up a significant and rising share of New Zealand's total greenhouse gas emissions. Mitigation through improved efficiency, demand management and co-firing are possible for most heat users. Switching to lower-emission fuels (such as biomass and electricity) offers greater emissions reductions, particularly for low and intermediate process heat uses. The technical and commercial viability of abatement opportunities depends on the nature and location of the production process and the scale of heat required. Higher emissions prices will be needed to encourage changes to production process and investment. Even then, the process of decarbonisation may take some time since any capital plant (such as a boiler) has a long life. Barring significant technological advances, opportunities to reduce emissions from industrial processes (such as iron, steel and aluminium production) remain limited, at least in the short term.

Large, single-point sources of significant emissions such as steel, aluminium and cement could be suitable candidates for carbon capture and storage (CCS) processes. As CCS technologies are still developing, the scale and price at which they will become viable remains very uncertain. Even so, it will be important that New Zealand's regulatory system is appropriately set up to accommodate these changes and manage risks. New legislation should be introduced to appropriately regulate CCS.

15 Waste

Key points

- Waste represents about 5% of New Zealand's greenhouse gas (GHG) emissions. Most emissions (90%) are methane (CH₄) from organic solid waste disposed to landfill, with the rest from wastewater treatment and discharge (mostly CH₄, but some nitrous oxide, N₂O). Just over two-thirds of total waste emissions are from waste disposed to what are known as unmanaged landfills.
- New Zealand has the highest waste emissions per person of all members in the Organisation for Economic Co-operation and Development. However, waste emissions data is highly uncertain, particularly for emissions from unmanaged waste disposal (including on-farm disposals known as farm dumps).
- CH₄ emissions occur as organic waste decomposes. As nearly 40% of total waste to municipal landfills is organic, solid waste emissions reductions rely on reducing organic waste volumes to landfill in the first place, and better CH₄ management once organic waste reaches landfill.
- Better CH₄ management does not require the development of new technology. While technological improvements can make mitigation more efficient, emissions can be effectively avoided by existing technologies, such as landfill gas recovery or anaerobic digestion systems.
- New Zealand takes a predominantly market-based approach to waste, via the emissions price under the New Zealand Emissions Trading Scheme (NZ ETS, incentivising emissions reductions) and the waste disposal levy (incentivising reduced waste to landfill). However, neither currently operates at a level adequate to incentivise emissions reductions. Nor are they adequate in their coverage across waste disposal sites.
- Improved waste data is urgently needed to transition to a low-emissions waste sector. Much existing data is out of date, inconsistent or incomplete. As a result, the ability to clearly identify or quantify opportunities to reduce emissions is limited. Any projects to improve waste data should include specific information on waste emissions. Work should also begin to improve measurement methodologies for wastewater treatment plants.
- Given what current data illustrates about sources of waste emissions, it is clear that higher prices (eg, under the waste disposal levy) will be the priority mitigation driver. Higher prices will help to reduce emissions in the current, landfill-dominant framework, as well as catalysing the uptake of a more transformative and innovative circular economy approach in New Zealand.
- Pricing in the waste sector should recognise the atmospheric properties of CH₄ as a short-lived gas. This means that waste CH₄ is suitable for inclusion in an emissions pricing scheme (Chapter 9). But, until such a scheme is established, landfill sites subject to the NZ ETS (as currently structured) should remain so, where higher prices will occur as a result of scheme reforms (Chapter 5).
- To make the waste disposal levy more effective, it must be extended to all unmanaged, yet known and consented, facilities for disposing of solid waste, and the rate (especially for active waste) increased over time. Consenting processes, bylaw processes or both must be changed to cover remaining unmanaged solid waste sites. Any inclusion of wastewater treatment plants into emissions pricing schemes should occur after relevant recommendations from the Department of Internal Affairs' review of the three waters (drinking, storm and wastewaters) have been enacted.

Waste is the smallest of New Zealand's greenhouse gas (GHG) emissions sources, producing about 5% of gross emissions in 2016. But, according to current data, and in carbon dioxide equivalent (CO₂e) terms, this is only slightly less than emissions from electricity. Waste also represents a major mitigation opportunity. At

present, New Zealand has the highest waste emissions per person in the Organisation for Economic Co-operation and Development (OECD), suggesting significant scope to further reduce emissions.

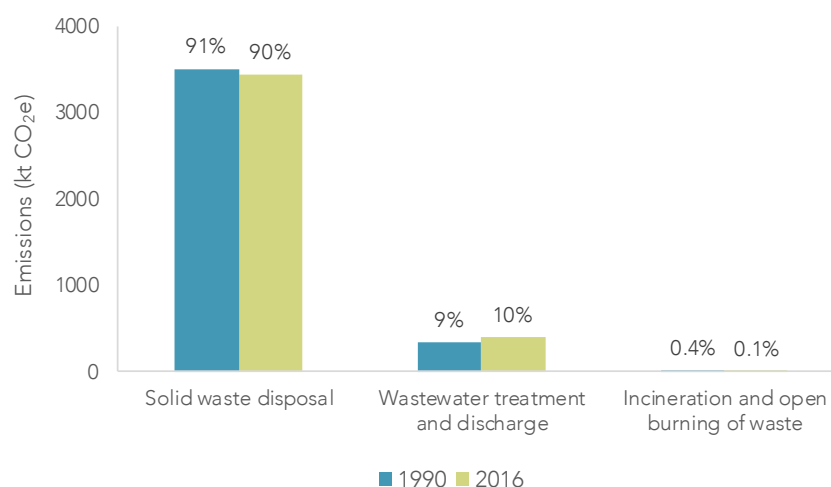
This chapter will:

- explain the main sources of, and associated policy framework for, waste emissions in New Zealand;
- show how New Zealand's policy framework compares to leading international comparators;
- describe Māori perspectives on waste management;
- identify opportunities to reduce emissions from New Zealand's main sources of waste emissions, focusing in particular on matching policy responses (such as the waste disposal levy) to key emission sources; and
- consider the future of waste emissions, including the potential for embedding a circular economy approach to the New Zealand economy.

15.1 Waste emissions in New Zealand

Data from the national emissions inventory shows that methane (CH₄) comprises the majority of waste emissions (97%), followed by nitrous oxide (N₂O) at 3% (solely from wastewater treatment) and carbon dioxide (CO₂) at 0.03% (solely from incineration) (MfE, 2018d). The vast majority of emissions are from solid waste disposal (ie, waste to landfill), followed by wastewater (Figure 15-1). CH₄ emissions occur when organic material decomposes without the presence of oxygen (ie, anaerobically). The process by which this occurs is called methanogenesis, which is the formation of CH₄ by microbes known as methanogens.

Figure 15-1 New Zealand's GHG emissions from waste by source category



Source: MfE (2018e).

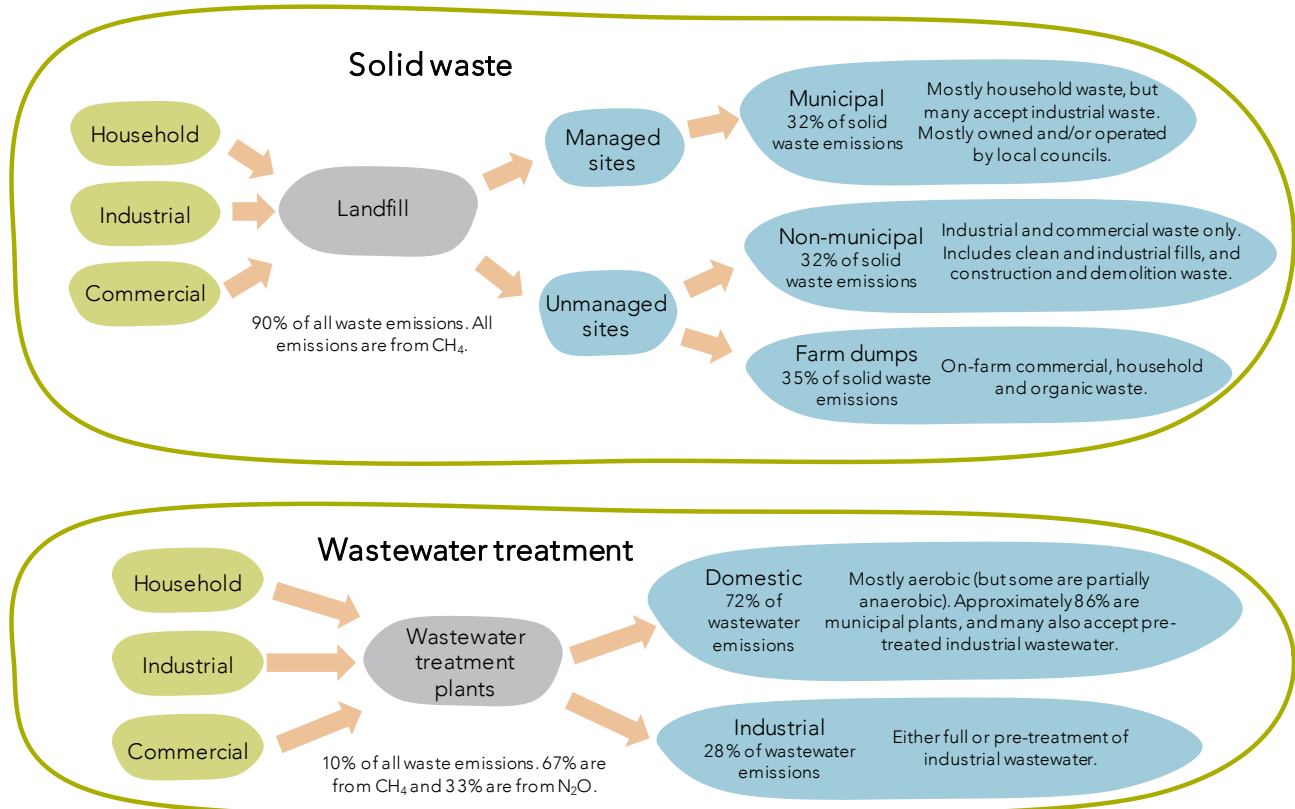
Between 1990 and 2015, total waste emissions decreased slightly from 4 118 kilotonnes (kt) of carbon dioxide equivalent (CO₂e) to 4 001 kt CO₂e. Emissions reductions from better landfill management practices such as improved CH₄ recovery have been offset by increased emissions from income and population growth. The correlation between economic growth and the amount of waste generated is well-known, despite attempts internationally to “decouple” this relationship (Bogner et al., 2008; Sjöström & Östblom, 2010).

The relationship between total waste volumes and waste emissions is also strong. Much effort both in New Zealand and internationally to reduce emissions from waste has focused on overall waste minimisation efforts. However, even though actions to reduce waste volumes may also reduce emissions, actions to reduce waste emissions (such as CH₄ recovery) may not necessarily reduce waste volumes.

Waste types and facilities

Figure 15-2 shows the sources and processing of the two main waste types in New Zealand: solid waste, and wastewater treatment. All emissions from solid waste and 67% of emissions from wastewater treatment are CH₄ emissions. Wastewater treatment also results in N₂O emissions during biological nitrogen removal, and incineration results in CO₂ emissions (not shown in Figure 15-2 due to its small scale).

Figure 15-2 Main waste types in New Zealand



Source: MfE (2018d, 2018e); Water New Zealand, pers. comm. 20 February 2018.

Notes:

1. A managed solid waste disposal site has controlled placement of waste, and includes at least one of the following: cover material, mechanical compacting, or levelling of waste. Sites that fail to meet this definition are considered to be unmanaged (UNFCCC, 2015a). All currently operational municipal landfill sites in New Zealand are managed sites.
2. Not shown are 1% of solid waste emissions from uncategorised municipal landfill sites operating before 2010 (MfE, 2018d).
3. Clean fills are sites disposing of largely inert waste (eg, concrete or sand) that does not decompose to cause emissions.

Solid waste

Virtually all solid waste in New Zealand is disposed of at landfill (either managed or unmanaged).²⁰² Since 1971, there has been a significant reduction in the number of municipal waste sites (by over 90% according to data from the national GHG inventory). Many smaller sites have closed in favour of larger, regional facilities with better management practices (MfE, 2018d). There are now 39 significant municipal landfill sites, compared with 563 in 1971 (MfE, 2018d). Key drivers include requirements to meet resource consent conditions, the National Environmental Standards for Air Quality (Air Quality NES), and the development of the New Zealand Waste Strategy (section 15.2).

However, the total number of landfill sites in New Zealand is unknown. A 2014 survey identified 1 048 landfills, of which 264 were open to waste disposal, 460 were closed (ie, no longer accepting waste), and 324 were of unknown status (MWH, 2017). Another survey identified 426 known, consented waste disposal facilities as of mid-2016. Of these, 45 are managed sites and are subject to the waste disposal levy (MfE, 2017m). Within this group, 34 also participate in the NZ ETS (MfE, 2010b) (section 15.2). The remaining 381 known, consented waste disposal facilities fall under the category of unmanaged non-municipal sites as

²⁰² Acknowledging that some solid waste may be disposed of illegally, or processed at other sites such as recycling centres (Auckland Council, sub. DR273).

shown in Figure 15-2. The limited number of facilities subject to either of these two instruments has implications for the volume of emissions reductions expected to occur under present arrangements.

A substantial number of small, unmanaged waste sites also exist over and above the 426 consented waste disposal facilities, including on-farm waste disposal known as farm fills or farm dumps. These farm dumps are estimated to comprise 35% of all solid waste emissions (MfE, 2018d; MfE, pers. comm. 7 May 2018). However, this figure must be treated with extreme caution as the inventory identifies significant uncertainty for data from unmanaged waste sites (MfE, 2018d).²⁰³ This is mostly because limited information is available on farm dumps and their management practices. Existing data is based on surveys conducted in the Canterbury, Waikato and Bay of Plenty regions, and which have been extrapolated to the rest of the country. Another reason for the lack of concrete data is that, while unmanaged waste disposal is regulated under the Resource Management Act 1991, the construction of a farm dump may be regarded as a permitted activity by regional councils and, if so, does not need to be notified.

Wastewater

Wastewater emissions rose 18% between 1990 and 2016 due to an increased volume of wastewater handled during this period. The majority of emissions are CH₄, but N₂O emissions occur both directly at wastewater treatment plants (WWTPs) and indirectly after effluent disposal into waterways or the ocean.²⁰⁴

Water New Zealand (sub. DR186) estimates that approximately 317 municipal WWTPs are sited in New Zealand. It holds data on 262 of these sites (including 258 where data on water volume is available (Water New Zealand, 2018). Table 15.1 shows that 66% of all wastewater is treated at 11 large plants, with a substantial number of treatment plants treating a very small share of total wastewater.

Table 15.1 Overview of New Zealand WWTPs (2016/17)

Cubic metres (m ³) treated	Number of plants	Volume of water treated (m ³)	Share of total treated wastewater
10 million +	11	342 355 256	66%
1 million to 10 million	38	133 306 686	26%
100 000 to 1 million	99	40 075 972	8%
Less than 100 000	110	41 198 30	1%
Total	258	519 857 744	100%

Source: Water New Zealand (2018).

Notes:

1. Data for some WWTPs for the 2016/17 year was not available. In these cases, the most recent available data was used. Figures do not add up to 100% due to rounding.

WWTPs are not subject to the NZ ETS or any other emissions mitigation instrument. Most WWTPs treat domestic wastewater; but across sites where data is available, on average 7% of wastewater treated is trade waste (Water New Zealand, 2018). Of the 262 WWTPs, 19% only conduct primary treatment (also known as physical treatment), where wastewater is held in a basin so that heavy solids sink and other material rises to the surface. The remaining 81% conduct either secondary or tertiary treatment. Secondary treatment is where microbes consume biodegradable organic materials. Tertiary treatment enables wastewater to be discharged to sea or other waterways. Most wastewater treatment processes are aerobic (ie, use oxygen to break down waste), but a significant number of WWTPs use partially anaerobic processing such as oxidation ponds or septic tanks. Water New Zealand (sub. DR186) notes that over 600 000 New Zealanders (excluding holiday homes) rely on onsite wastewater systems.

²⁰³ The uncertainty range is identified as plus or minus 140% in activity data (eg, types and volumes of waste) and plus or minus 40% in emission factors.

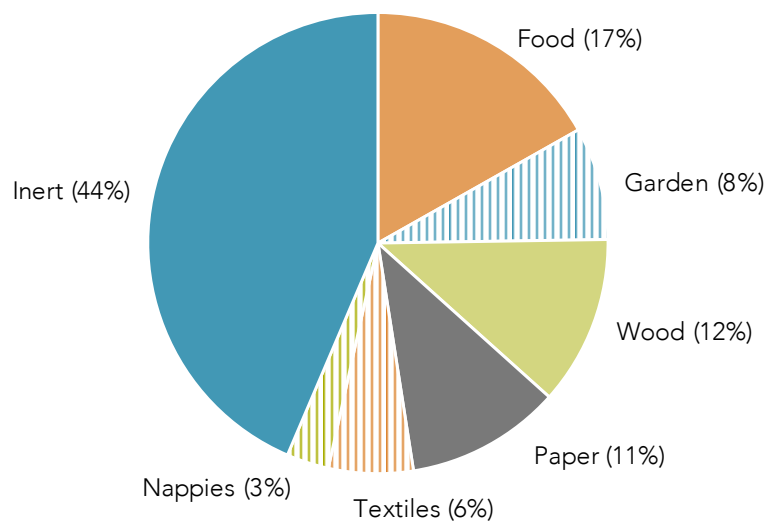
²⁰⁴ WWTPs also produce CO₂ emissions when wastewater decomposes under aerobic conditions (eg, in the soil). However, these form part of the natural carbon cycle and so represent no net change to the system (Coster, n.d.) and are not counted in the national emissions inventory (Chapter 9).

The meat industry and pulp and paper industries comprise the two main sources of industrial wastewater in New Zealand. Most industrial wastewater treatment is aerobic, with most CH₄ arising from anaerobic treatment flared (MfE, 2018d).²⁰⁵ Meat industry wastewaters are nitrogen-rich, which is the reason for the relatively high level of industrial N₂O emissions from wastewater in New Zealand.

Waste composition

A key mechanism to reduce landfill CH₄ emissions is to reduce organic waste volumes because this is the dominant source material for methanogenesis to occur. Food, wood and garden waste are considered to be organic waste (Hoorweg & Bhada-Tata, 2015). Paper is only classified as organic waste if it is contaminated by food residue. Some textiles can be considered as organic waste (eg, cotton or woollen fabrics), but many other textiles are made from synthetic sources (eg, nylon or polyester). As such, in general, textiles are not classified as organic waste. Figure 15-3 shows the waste composition to municipal landfills in New Zealand between 2013 and 2016. It shows that a substantial proportion of waste to landfill comprises organic material (37% of total waste, excluding paper and textiles).

Figure 15-3 Estimated composition of waste to municipal landfills, 2013–2016



Source: MfE (2018d).

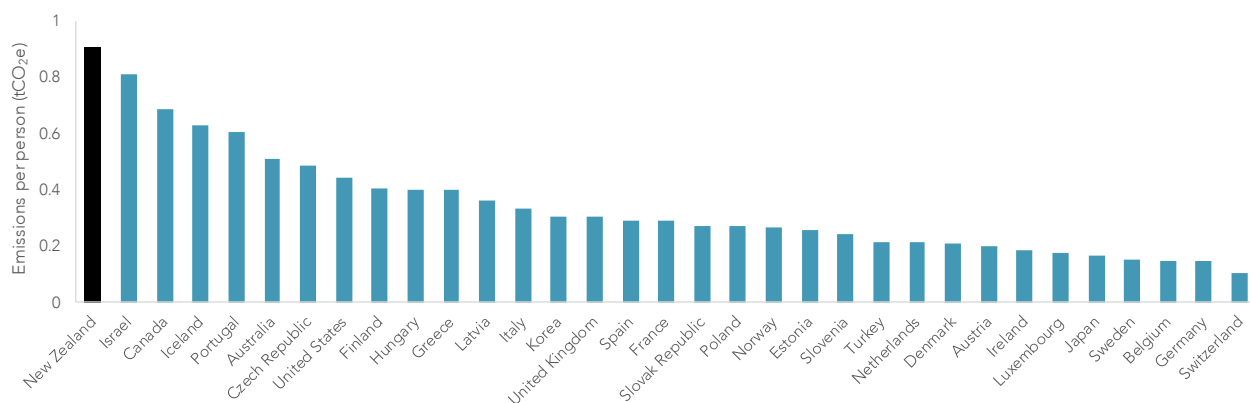
Another way to categorise waste is to distinguish between “active” and “inert” waste. Active waste is any substance that can either decay or contaminate land (and so includes household and organic waste). Inert waste basically refers to construction and demolition waste that does not biodegrade (eg, rocks, sand or concrete). Inert waste is often disposed of at what are known as clean fills (Figure 15-2).

Waste composition to municipal landfills has stayed largely static since the 1950s, with slight decreases in the proportion of garden, paper and inert waste, and increases in wood, textiles and nappies. While overall waste composition is known, information available on the proportion of waste disposed to managed municipal sites from industrial sources is limited (MfE, 2018d). Further, no recent or comprehensive data is available on waste generated by economic activity (ie, by sector), either in total volume, or in terms of emissions produced. A sample of six landfill sites occurring over 2007 and 2008 showed widely varying waste volumes by sector (eg, industrial waste ranged from 10% to 80% of total waste volume, and landscaping and earthworks waste ranged from less than 5% to approximately 40%) (MfE, 2008).

New Zealand compares unfavourably on waste emissions internationally

While highly uncertain, the substantial emissions attributed to unmanaged waste sites may explain why New Zealand’s waste emissions per person are the highest in the OECD (Figure 15-4).

²⁰⁵ Flaring CH₄ produces CO₂ emissions. However, as with the CO₂ produced by decomposing wastewater, this is considered to be part of the natural carbon cycle and so is not counted as an emission. It is however a potential fuel source.

Figure 15-4 Waste emissions per person, OECD countries, 2014

Source: OECD (2018a); UN DESA (2018).

Emissions reductions do not require the development of new technology

Emissions mitigation in the waste sector does not require the development of new technology. As experts in the field clearly stated a decade ago, “GHG emissions from waste can be effectively mitigated by current technologies” (Bogner et al., 2008, p. 27). Installing a landfill gas recovery or extraction system is “the single most important measure to reduce emissions” (Bogner et al., 2008, p. 19). These systems recover CH₄ via a system of extraction wells and industrial processes, with the recovered gas available as a renewable energy source (eg, to replace fossil fuels in industrial processes such as boilers or steel production) (US EPA, 2018a). Estimated CH₄ recovery rates range considerably from approximately 20% to 90–95% (Waste Not Consulting, 2009; Waste Management New Zealand, sub. DR332).²⁰⁶ These systems can be profitable, particularly if they offset emission charges borne by waste facility operators.

Of the total solid waste deposited to municipal landfills in 2016, only 12% was disposed of at sites without landfill gas recovery (MfE, 2018d). An estimated 23 of New Zealand municipal landfill sites have landfill gas recovery systems, with an average efficiency of 68% (MfE, 2018d).

Other emissions reductions technologies include anaerobic digestion, which is where bacteria break down organic waste (including food waste, manures or crops) inside an anaerobic digester to produce biogas (which can then be converted into electricity) (section 15.10). The remaining solid waste (known as digestate) can also be used as a fertiliser replacement (Anthony, 2015). This is not to say that technological improvements could not reduce emissions more effectively or efficiently (ie, at lower cost). For example, improving landfill gas recovery systems, particularly in terms of achieving greater volumes of recovered gas, could make these systems more profitable at smaller landfill sites.

F15.1

Mitigation of emissions from the disposal of waste at solid waste disposal facilities, and at wastewater treatment plants, does not require the development of new technology. Waste emissions can be effectively mitigated by current technologies such as landfill gas recovery systems or anaerobic digestion.

15.2 The policy framework for waste and emissions in New Zealand

The New Zealand Waste Strategy

The policy framework for waste and emissions in New Zealand is comprised of several legislative elements sitting underneath the overarching context of the New Zealand Waste Strategy (MfE, 2010a). In general, waste policy takes a market-based approach in New Zealand, particularly when compared to many other

²⁰⁶ The emissions inventory allows for a maximum CH₄ capture rate of 90%. However, this is disputed, with Waste Management New Zealand arguing that “less than 5% of the methane produced at a well operated Class 1 landfill is released to the atmosphere as a GHG” (sub. DR332, p. 5).

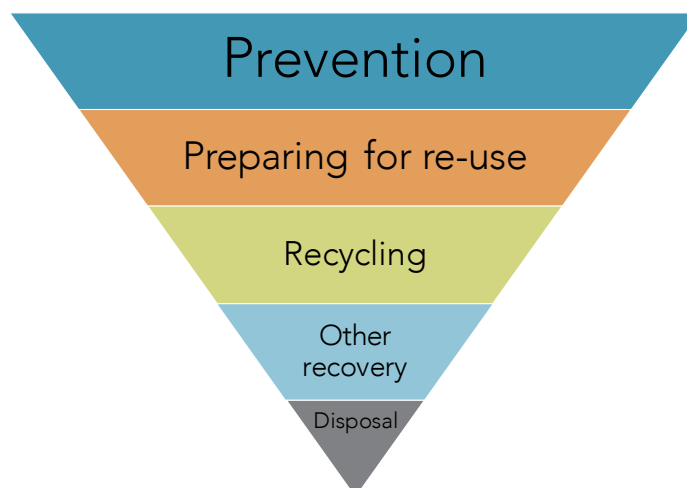
countries that take a more regulatory approach (eg, by banning particular types of waste from landfill, section 15.4).

Particularly relevant pieces of legislation to emissions reductions are the:

- Waste Minimisation Act 2008 (WMA), which focuses on reducing overall waste volumes;
- Resource Management Act 1991 (RMA) and Local Government Act 2002 (LGA), which regulate waste disposal and management via consenting and bylaw processes. The Air Quality NES are also set under the RMA, and require landfills with over 1 million tonnes of refuse to collect GHG emissions; and the
- Climate Change Response Act 2002 (CCRA), which, via the Climate Change Response (Emissions Trading) Amendment Act (2008), requires disposal facility operators to participate in the NZ ETS.

The New Zealand Waste Strategy, published in 2010, has two key goals: 1) to reduce the harmful effects of waste; and 2) to improve the efficiency of resource use. As such, it aims to cover the entire waste hierarchy (Figure 15-5), where prevention (eg, via a circular economy approach, section 15.11) is prioritised, and disposal is a mechanism of last resort. These high-level goals replace the vision of a “zero waste” New Zealand that was supported by numerous specific and quantitative targets in the first New Zealand Waste Strategy published in 2002.

Figure 15-5 The waste hierarchy



Several of the specific waste targets within the 2002 Strategy directly related to mitigating GHG emissions. One example was the target for the diversion of garden wastes from landfill to beneficial use to have exceeded 95% by the end of 2010. Yet, there was a lack of data and implementation capacity, and insufficient or uncertain means to actually achieve many of the specific waste targets became apparent. These challenges meant that the specificity of the 2002 version was replaced with the more flexible and high-level 2010 approach (MfE, 2004).

The 2010 version contains less precise direction about mitigating waste emissions. For example, it no longer specifies quantity targets for specific types of waste reduction, and does not focus on reducing organic waste as a priority. Even so, the Strategy does retain two main avenues for linking waste and emissions: via the waste management and minimisation plan (WMMP) process, and by territorial authorities spending the waste disposal levy. Both WMMPs and the levy are required under the WMA.

The Waste Minimisation Act 2008

The purpose of the WMA is to encourage waste minimisation and a decrease in waste disposal so as to protect the environment from harm, and to provide environmental, social, economic, and cultural benefits. The WMA clearly focuses on the prevention aspect of the waste hierarchy. Five particularly relevant parts relating to reducing emissions by avoided waste creation are noted below.

- **Product stewardship** encourages responsible management of the environmental impact of products. Under the WMA, the Minister for the Environment can declare a product to be a priority product. Once so declared, a product stewardship scheme must be developed and accredited. Such schemes involve any party involved in the life of a product accepting responsibility for reducing the product's environmental impacts. While several voluntary schemes exist, no mandated product stewardship schemes have been established to date (MfE, 2017c).
- The **waste disposal levy** raises revenue for waste minimisation activities, and increases the cost of waste disposal to recognise that disposal imposes costs on the environment, society and the economy.
- The **responsibilities of each territorial authority** are to prepare and review WMMPs, and, if it provides a service that collects waste (either directly, or via a contractor), to do so promptly, efficiently, and at regular intervals. This section also deals with the ability of each territorial authority to make bylaws about waste, such as prohibiting or regulating the deposit of waste.
- **Reporting and audits** enable the Governor-General, on the recommendation of the Minister for the Environment, to make regulations for reporting and audits about waste management and minimisation.
- The **Waste Advisory Board** provides advice to the Minister for the Environment on topics including product stewardship schemes, the effectiveness of the waste disposal levy, and regulations as regards records. No information is publicly available about the work of the Board (eg, Board minutes).

Waste minimisation and management plans

As noted above, waste emissions may be addressed via the requirement for territorial authorities to consider the Strategy when creating WMMPs. The Strategy identifies GHG emissions as an example of a harmful property of waste. Therefore, when aiming to reduce the harmful effects of waste, territorial authorities can prioritise mitigating GHG emissions as a driver for local investment and policy decisions.

Some examples of this approach exist. For example, the Auckland, Christchurch City and Eastern Waikato²⁰⁷ WMMPs discuss climate change, while in Wellington Region's WMMP (2017), Hutt City Council identifies a number of goals in the explicit context of reducing emissions. Those goals include reducing and reporting on the Council's own emissions, supporting household composting to reduce emissions, and reducing waste to landfill relative to Gross Domestic Product. Territorial authorities must also use their WMMPs to guide their spending of the waste disposal levy.²⁰⁸

The waste disposal levy

The waste disposal levy is a type of landfill tax and is set at \$10 a tonne (excluding GST) on waste disposed of at a disposal facility. Landfill operators pay the levy. Yet operators may choose to pass this cost on to the person or company disposing of the waste. Under Section 7 of the WMA, a disposal facility is defined as

a facility, including a landfill, — (i) at which waste is disposed of; and (ii) at which the waste disposed of includes household waste [waste from a household that is not entirely from construction, renovation, or demolition of the house]; and (iii) that operates, at least in part, as a business to dispose of waste.

A conservative levy rate was chosen so as to avoid unintended consequences, such as increased illegal dumping, and to reduce the impact on businesses and households (MfE, 2017a). The funds collected by the levy are divided equally across two sources:

- to territorial authorities for waste minimisation activities set out in their WMMPs; and
- to the Waste Minimisation Fund, to support waste minimisation projects.

Over the 2015 to 2016 year, the total levy collected was \$33.5 million (MfE, 2017m). At present, 45 waste disposal facility operators are subject to the levy. As required under the WMA, the levy is regularly reviewed, with reviews occurring in 2014 and 2017 (and another scheduled for 2020).

²⁰⁷ Comprising Hauraki, Matamata Piako, and Thames Coromandel District Councils.

²⁰⁸ As set out in Section 31 of the WMA, each territorial authority's share of the levy is calculated according to a formula based on population.

The Resource Management Act 1991 and the Local Government Act 2002

The RMA provides three main avenues for reducing emissions from waste. First, via section 418 (1A), it regulates waste disposed at managed facilities, such as by proscribing the discharge of contaminants into the air or land from the storage, transfer, treatment or disposal of waste. Second, it provides for local governments to determine whether waste disposal sites require consents or permits, ranging from larger facilities through to waste disposed as unmanaged waste sites such as farm dumps (Knowles & Wilson, n.d.). Third, via the Air Quality NES, it requires large landfills to collect GHG emissions. Modelling commissioned by the Ministry for the Environment (MfE) estimates that the Air Quality NES will play a substantial role in reducing New Zealand's emissions from solid waste sites into the future (MfE, 2017j) and so is an important cornerstone of emissions-reduction policy in this sector.

Part 8 of the LGA is also pertinent as it enables local authorities to make bylaws about onsite wastewater disposal systems, waste management, trade wastes and solid wastes. Bylaws can be made to protect the public from nuisance and to protect, promote and maintain public health and safety.

The Climate Change Response Act 2002

The CCRA, amended by the Climate Change Response (Emissions Trading) Amendment Act 2008, requires disposal facility operators to report their CH₄ emissions and, in response, to surrender New Zealand Units (NZUs) under the NZ ETS. Disposal facilities are defined the same as for the WMA, with the additional exclusion that the definition "does not include a facility, or any part of a facility, at which waste is combusted for the purpose of generating electricity or industrial heat" (Section 6 of the CCRA (Emissions Trading) Amendment Act 2008). Wastewater treatment facilities are not subject to the NZ ETS, and other exemptions about the size, location and age of solid waste disposal facilities also apply.

Box 15.1 outlines the different goals of the waste levy and the emissions price under the NZ ETS, the two main market-based mechanisms to minimise waste in New Zealand.

Box 15.1 The difference between the NZ ETS emissions price and the waste disposal levy

At present, the two key pricing mechanisms to reduce waste are the NZ ETS emissions price and the waste disposal levy. Each has a different aim. The NZ ETS price aims to reduce waste emissions at least cost across the economy (and is agnostic about how that happens). In contrast, the waste disposal levy aims specifically to reduce the volume of waste disposed of at landfill (including for purposes other than emission reductions, such as amenity or cultural values, or to reduce soil contamination). The levy will have some effect on emissions, because it aims to reduce total waste volumes, of which organic waste is a substantial component (D. Wilson et al., 2017).

These different aims mean that it is not possible to solely rely on the levy to reduce emissions for two main reasons. First, the levy does not specifically target a reduction in organic waste volumes, which is the main driver of CH₄ emissions from waste. A differentiated levy rate for active waste could achieve a more effective emissions reduction result (section 15.8), but this is not the case at present.

Second, and perhaps most importantly, only an effective emissions price can encourage the adoption of better CH₄ reduction or capture technologies at landfill sites, as any emissions effect arising from the levy ends at the point of waste disposal. This is particularly relevant as emissions still occur from closed landfills. So, for example, while local government (as primary landfill operators) may attempt to induce behaviour change related to waste minimisation, some degree of post-disposal emissions management is vital.

At present, 34 disposal facility operators are registered participants under the NZ ETS (EPA, 2018a). Of these, 24 are district or city councils. Councils can also operate landfills as part of public-private partnerships, such as between Whangarei District Council and Northland Waste Limited.

Waste is one of the sectors affected by the phased removal of the one-for-two transitional measure. As of 2018, the surrender obligation is at 83%, and will rise to 100% in 2019 (MfE, 2016f). There is no case for free allocations because waste is not an emissions-intensive, trade-exposed sector. However, an effective emissions price may not necessarily be very high. Studies suggest that, even at a cost of US\$10 a tonne of CO₂e, 86% of landfill CH₄ emissions in the OECD could be mitigated for the year 2030 (Monni et al., 2006).

Landfills may either use a default emissions factor for their emissions, or, if they believe their emissions factor should be lower, they may apply to the Environmental Protection Authority for a unique emissions factor (UEF) that reflects the actual emissions from their facility (either in terms of waste composition, or proportion of landfill gas captured). For example, this means that if disposal facilities have a landfill gas recovery system which allows them to either flare or use the captured CH₄ for fuel, they can claim a UEF of up to 90% (D. Wilson et al., 2017). This can substantially lower surrender obligations under the NZ ETS.

The public liability under the NZ ETS, particularly as prices rise, is considered by some councils as “a really strong economic driver to fix the way we [councils] do our waste, because it’s going to cost us significant amounts of money if we don’t resolve the issue” (Wellington City Councillor Iona Pannett in Cann, 2017). As well as efforts to reduce waste disposed of at landfills, councils are considering various mechanisms to cover liabilities, including higher gate fees at landfills, higher council rates, and restrictions on organic waste able to be disposed of at landfills (Cann, 2017).

15.3 Māori perspectives on waste management

How waste is managed is an important consideration when understanding the Māori relationship with the environment. Improper waste management is considered to be a threat to the mauri (life force) of the environment, and has a significant impact on the social, cultural and economic wellbeing of tangata whenua. The mauri of the environment can be impacted in ecosystems, its life-giving properties, and associated mahinga mataitai (customary food gathering) (Te Ātiawa o Te Waka-a-Māui, 2014).

The cultural norms around waste, including the tikanga associated with the disposal and management of waste, are of particular importance to Māori. These are complex and connected to cultural principles including whakapapa, tapu, mauri and mana (Tina Porou, pers. comm. 19 April 2018). One example of these norms is the concern of tangata whenua for the disposal of human waste. This is seen in how some hapū and iwi oppose the use of water as a receiving environment for human waste, and see the clear need to separate food production from human waste (Mahaanui Kurataiao Ltd, 2013; Morgan, 2004). Indeed, when developing wastewater treatment facilities,

the universal driver for many of the technological solutions and associated resource consent conditions is the abhorrence to Maori of direct discharge of human waste (domestic wastewater) to natural water almost regardless of the degree of treatment. (Bradley, n.d., p. 1)

Māori cultural considerations are also important when considering mitigation technologies. For example, anaerobic digestion of wastewater can create, as a by-product, biosolids that can be used as a fertiliser replacement. Yet this violates the separation between food and human waste. Therefore, “while tāngata whenua may support the disposal of biosolids onto forestry plantations, the use of biosolids on food crops would be culturally unacceptable” (Mahaanui Kurataiao Ltd, 2013, p. 113).

As well as proper waste management, reducing waste volumes is considered to be a priority action in many iwi management plans (Mahaanui Kurataiao Ltd, 2013; Te Ātiawa o Te Waka-a-Māui, 2014). While the emissions consequences of waste minimisation are not the immediate focus in management plans (as compared to the emphasis on immediate degradation to soils or waterways), it is recognised in general that “reducing the volume of solid waste and wastewater produced in the takiwā (district) will reduce pressure on existing infrastructure, and on the environment and cultural values” (Mahaanui Kurataiao Ltd, 2013, p. 113).

Tangata whenua are also at the forefront of zero waste initiatives, with a focus on managing waste in environmentally sustainable ways based on mātauranga Māori. An example is the Para Kore Movement that is designed to support Māori to reduce waste, and is leading work to extend this kaupapa to all aspects of collective Māori spaces (Para Kore, 2018). Other examples are being seen in some Māori trusts and

incorporations focusing on reintegrating waste into their operational costs as a core expression of *kaitiakitanga* (Tina Porou, pers. comm. 19 April 2018).

15.4 International approaches to reducing waste emissions

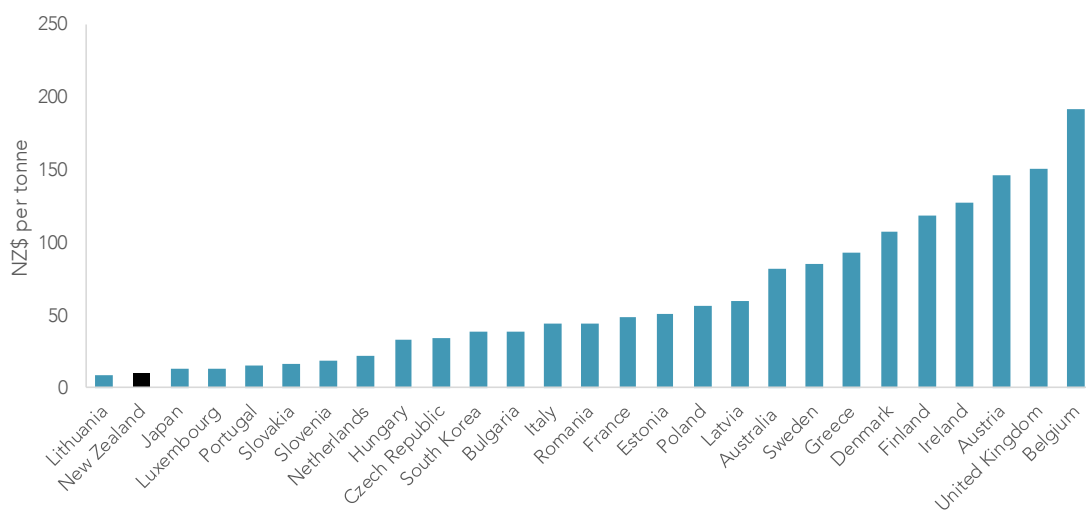
In comparison to other developed countries, New Zealand is unusual in not reducing its waste emissions over recent decades. For example, between 1990 and 2016, UK waste emissions decreased by 70% (BEIS, 2018a), and in Germany, waste emissions reduced by 72% over the same period (Umwelt Bundesamt, 2017). Waste emissions also fell by 46% in Australia between 1990 and 2015 (Government of Australia, 2017b).

Much of this reduction can be attributed to policy intervention. In the European Union (EU), waste emissions are not included in the European Union Emissions Trading System (EU ETS), but are instead managed through the Waste Framework Directive. This framework establishes a waste-management hierarchy where prevention is the preferred option, followed by re-use, recycling and other forms of recovery, with disposal such as landfill being the last resort.

Underneath the overarching framework, Directive 1999/31/EC on the landfill of waste (the Landfill Directive) specifically targets solid waste disposal (European Commission, 2010). It required EU member states to reduce the amount of biodegradable waste they sent to landfill to 35% of 1995 levels by 2016. It also requires CH₄ capture at landfill sites and, if possible, use of the recovered gas to produce energy (Council of the European Union, 1999).

In the United Kingdom, the main drivers of emissions reductions are identified as including improvements in landfill standards, changes to the type of waste to landfill, and an increase in the amount of landfill gas used for energy (BEIS, 2018a). The United Kingdom also has a much higher landfill tax rate. The rate has increased from £7 a tonne in 1996, when the tax was first introduced, to a current level of £88.95 (approximately \$151) a tonne (HMRC, 2017). Indeed, most countries have a substantially higher landfill tax rate (for active waste) compared to New Zealand (Figure 15-6).

Figure 15-6 Landfill tax rates for municipal solid waste in New Zealand and comparator countries



Source: CEWEP (2017); The Korea Bizwire (2017).

In addition to landfill taxes, many countries also have landfill bans. Of relevance to emissions reductions, these include banning waste to landfill that could either be recycled or incinerated to produce energy (eg, Denmark), or banning biodegradable or organic waste to landfill (eg, Finland, Luxembourg, Netherlands, Norway, and Poland) (CEWEP, 2017).

While waste emissions are not included in the EU ETS, they are included in California's cap-and-trade programme (under the Global Warming Solutions Act 2006). In Québec and Ontario's cap-and-trade systems, waste emissions are also included as a result of participants being able to purchase offset credits to cover up to 8% of their emissions. An offset credit represents

a quantity of GHG emissions that was never emitted or that was permanently and irreversibly removed from the atmosphere by a project voluntarily implemented by an individual, organization or business, above and beyond usual practices. (Government of Québec, 2018a, p. 9)

Both systems contain specific protocols for the creation of offset credits through the treatment or destruction of CH₄ at landfill sites. This is in comparison to the NZ ETS which requires disposal facility operators to surrender units for any emitted CH₄ (and therefore are incentivised to reduce emissions to avoid the financial liability, rather than to receive credit for avoided emissions). In Québec, as of March 2018, offset credits have been issued for six landfills, which are estimated to generate a total reduction of 76 kt CO_{2e} a year (Government of Québec, 2018b).

Other policy instruments are noted below.

- In the UK's Waste and Emissions Trading Act 2003, yearly allowances are set for local authorities. These allowances limit how much biodegradable municipal waste a local authority can landfill in any particular year. Authorities can buy and sell allowances from other authorities if they expect to landfill more, or less than their allocations.
- In Australia, a landfill tax is complemented by the Australian Government Emissions Reduction Fund, enabling businesses, local councils, state governments and land managers to earn Australian carbon credit units through activities that reduce emissions. These units can be sold to the Government through a carbon abatement contract, or to other businesses seeking to offset their emissions (Government of Australia, 2017a). Activities specific to waste include burning landfill gas, processing organic waste through alternative technologies, or diverting organic material for composting or energy generation.
- In California, the Air Resource Board Landfill Measure imposes landfill gas collection and control system rules to reduce CH₄ emissions. Larger landfills are also subject to federal New Source Performance Standards and Emission Guidelines (implemented by local air districts) to reduce CH₄ emissions.

New Zealand has a substantial policy deficit regarding emissions and waste. In particular, specific, quantitative waste reduction targets were removed without an effective pricing regime to drive emissions reductions (either under the waste disposal levy or the NZ ETS emissions price). This has seen New Zealand make minimal progress in reducing emissions, especially in contrast to other developed countries.

15.5 Framework principles for making decisions about minimising waste emissions

When identifying opportunities to reduce waste emissions, it is useful to highlight several key decision-making considerations. These considerations (some shown as questions below) can help to clarify the reasons why particular policy instruments may be more or less suitable to certain contexts than others:

- What harm is being avoided, or behaviour being incentivised, through the policy instrument?
- How can unnecessary overlap between instruments be avoided (eg, to reduce the risk of departing from the effectiveness of a single emissions price)?
- What is the scientific integrity of the policy instrument?
- How are co-harms and co-benefits dealt with, and are supplementary mechanisms required?
- What transaction costs are associated with the instrument, and are they proportionate?

Numerous policy strategies are available to reduce waste emissions. Considering the above considerations, this section outlines five opportunities to reduce emissions from waste in New Zealand. The first addresses the substantial uncertainty regarding waste-related emissions data in New Zealand. The following three opportunities relate directly to specific types of waste disposal facilities, while the final represents a cross-cutting opportunity across multiple types of waste.

The ordering of these opportunities is based on New Zealand being unlikely to radically move away from landfill as a waste disposal method in the near future. As a result, it is important, and pragmatic, to prioritise mechanisms to reduce landfill emissions within existing, path-dependent, disposal frameworks. However, this should not preclude recognition of the potential to transform the approach to waste in the future (section 15.11).

15.6 Better waste data

New Zealand has poor waste data. Much of the data collected on the waste sector is out of date, inconsistent or incomplete, indicating that the reporting and audit provisions of the WMA are under-used. The majority of New Zealand's environmental indicator reports, Solid Waste Analysis Protocol data, and landfill surveys are over five years old (with many over 10 years old). Data coverage is also poor, as

the only reliable data about waste that the Ministry [for the Environment] has access to, comes from the 45 levied waste disposal facilities. These facilities receive an estimated 30% of New Zealand's total waste disposed to the land. The Ministry does not have access to data from the remaining estimated 70% of waste disposed at 381 known, consented landfills or at uncontrolled environments like farm dumps. (MfE, 2017m, p. 54)

In its 2017 Environmental Performance Review of New Zealand, the OECD concluded that "New Zealand lacks comprehensive, timely and internationally comparable data on waste generation, treatment and disposal" (OECD, 2017e, p. 23). One of the key recommendations from the MfE's 2017 review of the waste levy (MfE, 2017m) was the need to invest in developing a national waste data collection and evaluation framework.

This lack of data is concerning from an emissions perspective, particularly due to the limited information available about emissions management practices in the unmanaged landfill sector (non-municipal landfills and farm dumps). This is evidenced by the very large uncertainty for emissions data about these sites in the national GHG inventory (MfE, 2018d). Lack of data also has implications for the ability of local and national government to identify opportunities for further reducing emissions (and means that it is not possible to quantify in this report the likely emissions reductions from these opportunities). Better data is critical to direct mitigation action.

Many submitters on the draft report agreed with this assessment (including Queenstown Lakes District Council, sub. DR240; WasteMINZ TAO Forum Steering Committee, sub. DR261; and Scion, sub. DR366). A notable exception is Taranaki District Council, which stated that it has good data on both "solid waste sources, recycling of waste and waste disposal to landfill", and on rural waste (sub. DR188, p. 9).

MfE is currently developing a project to collect better waste data (MfE, pers. comm. 27 February 2018). Key topics will include:

- waste infrastructure available nationwide (eg, transfer stations, resource recovery parks, landfills, rural recycling facilities, and materials recycling facilities);
- services available nationwide (eg, council kerbside services, and commercial recycling);
- major processing facilities (eg, plastics processing, cardboard manufacturing, concrete waste re-use, and wood waste processing); and
- recycling collection volumes (glass, metals, paper, cardboard, and plastics).

Ensuring that data also meets the requirements of the Environmental Reporting Act 2015 (that aims to create a national-level environmental reporting system) has been identified as relevant. Using technology and innovative survey techniques to improve waste data may also be possible, and help to identify unknown waste disposal sites (Glanville & Chang, 2015; Silvestri & Omri, 2008). These technologies (such as remote sensing, GIS and optical satellite images) have a long history in detecting and monitoring land-use change.

F15.2

Good quality data on waste in New Zealand is lacking. This has major implications for understanding emissions management practices related to waste in New Zealand, and identifying subsequent opportunities to further reduce emissions. In response to these issues, the Ministry for the Environment (MfE) is developing a project to collect better waste data in New Zealand.

R15.1

The Ministry for the Environment (MfE) should ensure that its project to collect better waste data allows for the direct measurement or estimation of emissions-related data. This is to reduce the very large uncertainty about waste emissions, and to identify opportunities to reduce emissions in the future.

15.7 Reducing emissions from unmanaged solid waste sites

If emissions from unmanaged solid waste sites do, indeed, represent anything close to the estimated 64% of all waste emissions (2 561 kt CO₂e), then close attention to this source is warranted. To reduce emissions, organic waste disposed of at these sites must either be reduced in volume or diverted to managed disposal facilities where CH₄ emissions can be more effectively mitigated.

It is important to reiterate that the category of unmanaged solid waste sites covers two very different types of disposal facilities:

- 381 known, consented waste disposal facilities that are not subject to either the NZ ETS or the waste disposal levy; and
- an unknown number of small, unmanaged waste sites, mostly farm dumps.

Reducing emissions from known, consented facilities

At present, no driver exists to reduce emissions from known, consented but unmanaged facilities. In other words, a problem of coverage exists in terms of suitable policy instruments. To reduce emissions, the most likely effective measure will be to extend some form of volume or emissions price to these sites (D. Wilson et al., 2017). Either measure could achieve emissions reductions because site operators could pass on their price liability to site users, which would result in reduced volumes of waste to landfill. This would be particularly effective if operators applied higher charges for active waste²⁰⁹ (see Box 15.2 for a discussion on the appropriate rate for the waste disposal levy in particular).

Box 15.2 What rate should the waste disposal levy be?

Many submitters thought the waste disposal levy rate of \$10 a tonne is too low. They argued that it should be increased significantly (eg, up to \$150 a tonne) to drive further emissions reductions.²¹⁰ The 2017 review of the levy found that, given the quantity of waste to landfill continues to increase, the levy is not meeting its objective. The review concluded that “gradually increasing the levy will drive the message that waste disposal is unviable and will provide the necessary signals to industry to prepare for this change well in advance” (MfE, 2017m, p. 73). The 2017 review also suggested investigating a differential levy rating system (where a differential rate adjusted for harm caused by each waste stream). This is particularly relevant for the issue of active (including organic) waste and its emissions

²⁰⁹ While, from an emissions perspective, the goal is to reduce organic waste decomposition, the key distinguishing categories from a practical collection and processing perspective are between active (including organic) and inert waste.

²¹⁰ Christchurch City Council, sub. 13; Hitachi Zosen Inova Australia Pty Ltd, sub. 68 and DR181; Sustainable Business Network Circular Economy Accelerator, sub. 75; Deidre Kent, sub. 87; Auckland City Council, sub. 97; The Morgan Foundation, sub. 127; Waimakariri District Council, sub. DR192; Sustainable Business Network, sub. DR254; Wellington City Council, sub. DR276; Low Carbon Kapiti, DR299; and Bioenergy Association, sub. DR352.

consequences, as opposed to other types of waste such as inert waste (WasteMINZ TAO Forum Steering Committee, sub. DR261).

Another review specifically focusing on the potential impacts of adjustments to the current levy rate and structure was commissioned by a consortium of organisations, including seven local government bodies (D. Wilson et al., 2017). That review found that applying a gradually increasing levy rate to the level of \$140 a tonne by 2024 would increase recycling rates from 35% (current baseline) to 60%. This represents a nearly 40% reduction in overall waste volume to landfill. It also showed a substantial increase in gross value added (outweighing additional overall costs to the economy). Due to limited data availability, the Wilson et al. review did not quantify expected rates of emission reductions, but expected these to occur as a co-benefit of higher diversion away from landfill. Even so, it is clear that a higher waste disposal levy, and particularly one that encourages reductions in organic waste disposed of at landfill, will be more effective at reducing emissions than its current rate.

Either a volume or emissions price would also encourage better waste stream management on the part of unmanaged site operators. Waste stream management, in its broadest definition, comprises separate collection, management and processing of different types of wastes. An example is paper which, if contaminated, cannot be recycled and instead decomposes in landfill causing CH₄ emissions. At non-municipal sites, this would focus on separate management and processing of waste at the disposal facility rather than separate collection, which is more relevant to managed municipal sites (discussed below). Better waste stream management was a notable theme of submissions (Tony Banks, sub. 3; Canterbury District Health Board, sub. 16; Bioenergy Association, sub. 37 and DR352; Hitachi Zosen Inova Australia Pty Ltd, sub. 68 and DR181; OI NZ, sub. 85 and DR296; and Auckland Council, sub. 97 and DR276).

As noted above, many other jurisdictions have instituted bans on biodegradable or organic waste to landfill. However, such an approach may not be needed in New Zealand in light of an effective emissions price. Passing the emissions price onto users could serve to discourage such waste to landfill as effectively as a ban. This would be especially so if disposal facility operators charged an adequately differentiated price for waste according to harm in terms of their contribution to CH₄ emissions. However, this should not preclude Government considering bans if the emissions price does not achieve desired results.

Extending an emissions price to known, consented facilities could also reduce emissions by providing an incentive to invest in landfill gas recovery systems. However, as many of these sites are small, it may not be economically viable to install these systems, and site operators may either choose to pay the emissions price or close. Closing some sites would also achieve emissions reductions by diverting waste to sites with better management practices, even given the potential emissions increase from requiring more transport services to dispose of waste at locations more removed from the waste source (Lundie & Peters, 2005).²¹¹ Yet, the administrative complexity and transaction costs of extending an emissions price means that broadening the coverage of the simpler volume-based levy is likely to be the most appropriate option. At present, many of these sites have no ability to manage or even monitor emissions. Therefore, an effective levy, particularly one that charged a higher rate for active waste, would be successful at reducing emissions by providing an incentive to minimise the overall volume of waste.

In response to the 2017 review of the levy, MfE is planning to extend the levy to cover all known, consented waste disposal sites (an additional 381 sites) (MfE, pers. comm. 27 February 2018). This will also achieve the valuable co-benefit of achieving a better understanding of the waste disposed of at these facilities, such that more accurate emissions estimates are possible. It will also mean that the higher revenue gathered by the levy will result in a larger quantity of funds going directly to territorial authorities, or via the Waste Minimisation Fund, for waste minimisation activities, leading to further emissions reductions. A proportion of this higher levy rate could be usefully directed to education or behavioural campaigns to discourage illegal waste dumping. MfE is considering the levy rate as part of its work to extend its coverage.

²¹¹ Note that these emissions could be avoided with a switch to low-emissions vehicles (Chapter 12).

F15.3

A large number of solid waste sites are known and consented, yet technically considered “unmanaged”. Reducing emissions from these sites is vital because current data estimates that they comprise nearly two-thirds of all waste emissions. The most effective solution to achieving emissions reductions at these sites is to apply an effective waste disposal levy. MfE plans to take a staged approach to extending the levy to unlevied solid waste disposal sites to encourage waste reduction and support New Zealand’s transition to a circular economy.

R15.2

The Government should, under the Waste Minimisation Act 2008, apply the waste disposal levy to all known, consented waste disposal facilities. The rate of the levy should be steadily increased over time, and a differentiated levy rate introduced where active waste is charged at a higher rate than inert waste.

Reducing emissions from farm dumps and other unknown waste disposal sites

Achieving emissions reductions from farm dumps, and other, unknown, waste disposal sites is especially challenging, predominantly due to significant gaps in data and uncertainty about their management practices, number and emissions. The key goal is to ensure these sites are better managed so that emissions are mitigated, or to divert waste from these sites to disposal facilities where CH₄ emissions are either avoided (eg, through better waste stream management) or mitigated (eg, through landfill gas recovery).

It is extremely unlikely that a pricing mechanism would achieve either of these outcomes. This is predominantly because such sites are not commercial operations and are therefore unsuitable for such an approach. Instead, a regulatory avenue, either via the bylaw process under section 56 of the WMA and Part 8 of the LGA, or changes to the resource consenting process via the RMA, is considered to be the most effective option. This could result, for example, in local government bodies no longer allowing farm dumps as permitted activities for sites. Instead, they would need such sites to obtain resource consent (eg, they would become a controlled, discretionary or non-complying activity under the RMA).

Pursuing this strategy would likely require better support for local government bodies to develop more effective consenting requirements through an overarching regulatory framework. One mechanism could be a national environmental standard, issued under section 43 of the RMA. Indeed, the OECD (2017e, p. 73) noted that “New Zealand has no national regulation for disposal of agricultural waste, despite the large size of the sector”. Councils could also enact rules to require waste disposal methods that had lower emissions consequences, which would incentivise better uptake of technologies such as anaerobic digestion.

Restrictions via bylaws or the resource consent process may encourage waste diversion to managed sites, or reduced waste production. Yet it may also encourage illegal waste dumping, or, without uptake of low-emissions vehicles, have negative transport emissions consequences (when waste is diverted to other sites). These implications will need to be managed by local governments. A case could be made that a proportion of the additional funds gathered from the waste disposal levy should be directed towards providing incentives for uptake of technologies such as on-farm anaerobic digesters, or directed at behavioural interventions with affected parties. It will be important for councils to work alongside rural communities to support better waste management practices, with a regulatory approach as an important backstop.

Other relevant actions include work by MfE on a proposed National Environmental Standard for the outdoor storage of tyres (MfE, 2018f), and Government accreditation for two voluntary product stewardship schemes focusing on agricultural waste which may otherwise be burned on farm. *Agrecovery*, the first scheme, recycles and collects containers and unwanted or expired chemicals. *Plasback*, the second scheme, collects agricultural plastics (eg, silage wrap) and recycles it into a plywood replacement product (MfE, 2018b).

F15.4

Emissions reductions at farm dumps and other, unknown, waste disposal sites, could be encouraged by the creation of bylaws as allowed under the Waste Minimisation Act 2008 (and Part 8 of the Local Government Act 2002), or resource consenting processes under the Resource Management Act 1991.

R15.3

Local government should be better supported, as needed, to develop effective bylaws or consenting requirements for farm dumps and other, unknown, waste disposal sites, through an overarching regulatory framework for wastes such as agricultural waste. MfE should investigate whether a national environmental standard about waste is an appropriate mechanism to deliver this framework.

15.8 Reducing emissions at managed solid waste sites

As with unmanaged sites, two actions will have the most impact at reducing emissions from managed solid waste sites: reducing organic waste volumes to landfill, and better management of CH₄ once organic waste reaches landfill. The key driver for reducing emissions at these sites is most likely to be a higher emissions price. While a higher waste disposal levy would work to reduce overall waste volumes to landfill (and therefore emissions), a higher emissions price would more specifically target emissions reductions.

Data shows that 34 managed solid waste sites are registered participants under the NZ ETS (section 15.1). The NZ ETS has been largely ineffectual to date at driving emissions mitigation, and it is clear that a higher emissions price is needed to incentivise mitigation (Chapter 5). If proposed reforms of the NZ ETS are implemented, it is very likely that the emissions prices faced by landfill operators in New Zealand would increase, helping to incentivise the uptake of technologies such as better landfill gas capture systems.

As noted in Chapter 9, CH₄ – caused by the decomposition of organic waste at landfill – is a short-lived gas. This means that it has a different atmospheric effect and so should be treated differently in terms of mitigation instrument. In Chapter 9, the Commission recommends that biogenic CH₄ from both agriculture and waste should be subject to an emissions pricing scheme that recognises this different atmospheric effect. This would mean changing the way sites currently subject to the NZ ETS (as it is presently structured) are incentivised to reduce their emissions.

At present, most managed solid waste sites are currently covered by the waste disposal levy and the NZ ETS. Yet, the question remains, whether to exclude such sites from the levy if those sites are also covered by another emissions pricing scheme (Box 15.3).

Box 15.3 Should managed landfills be covered by a volume price and an emissions price?

Value exists in avoiding unnecessary overlap between instruments (section 15.5). If the only aim when considering whether landfills should face both a volume and emissions price is to reduce emissions, then an exclusion may be justified. However, given that the levy targets other waste minimisation goals, it may be viable to run in tandem with an emissions price. However, making waste emissions subject to two policy instruments may be inefficient because it departs from the effectiveness of a single emissions price (Waste Management New Zealand, sub. DR332). Work to include biogenic CH₄ in a new emissions pricing scheme should consider this issue in more detail.

Two further issues are also relevant and relate to the ability of landfill operators to apply for a unique emissions factor (UEF) as opposed to a default emissions factor (DEF) in the NZ ETS. This can apply to two areas: waste composition and landfill gas capture (section 15.2). If the UEF is lower than the DEF, the emissions liability is reduced. A higher waste disposal levy for active waste should reduce the organic component of waste. So, operators could apply for a UEF (based on waste composition) to limit a dual financial penalty for the same waste (Greater Wellington Regional Council, sub. DR195). But, the UEF system can also have perverse consequences when it comes to landfill gas. In the current system,

the more organic materials sent to landfill the more gas is generated and so the better the landfill gas capture rate appears against the default emissions factor. Because there is no requirement to use a unique emissions factor based on waste composition when claiming gas capture the current system incentivises more organic waste to landfill. (WasteMINZ TAO Forum, sub. DR261, p. 2)

In response, the WasteMINZ Territorial Authorities' Officers (TAO) Forum recommends that "landfills which claim a gas capture rate above a base level (for example 50%) need to use a unique emission factor based on their waste composition" (p. 2). This should also be considered in work to include biogenic CH₄ in an emissions pricing scheme (Chapter 9).

In response to the mitigation incentive arising from an emissions price, councils (as the majority holder of the emissions liability for these sites) can make individual decisions about which activities may be the most effective in their local area. For example, higher prices could incentivise councils to enact measures to specifically reduce organic waste to landfill. These could include information or behaviour campaigns about waste reduction (such as "Love Food Hate Waste"), or higher landfill gate fees or rubbish charges for active waste (Covec, 2012; Love Food Hate Waste New Zealand, 2018). Evidence shows that higher NZ ETS prices are already being passed through as higher landfill gate fees. At Dunedin City Council's landfills, the cost to dispose of a carload of rubbish will increase by 25% from \$36 to \$45 on 1 July 2018 in direct response to higher emissions prices under the NZ ETS (ODT, 2017).

A higher emissions price could also make waste stream management, either at a household or transfer station level, more cost-effective. This could entail moving away from comingled kerbside rubbish collection to separate collection and composting of food waste.²¹² Councils could also charge by quantity or by volume²¹³ for standard household waste disposal, and subsidise (and collect more often) separate organic waste collection (as is currently the case with recyclable materials, such as glass, plastics or paper). Finally, an effective emissions price could also encourage better landfill gas recovery systems. Most managed sites have recovery systems, but a higher emissions price could incentivise further uptake or to upgrade less-efficient systems to achieve greater recovery efficiencies (D. Wilson et al., 2017).

F15.5

The most effective actions to reduce emissions at managed municipal solid waste sites are a reduction in organic waste volumes to landfill and better management of CH₄ at landfill. An effective emissions price will help to achieve both, while giving facility operators (particularly local authorities) the flexibility to determine which strategy is likely to be the most cost-effective at reducing emissions in their own jurisdiction.

R15.4

All managed solid waste sites subject to the NZ ETS should be included in an emissions pricing scheme that recognises the nature of biogenic CH₄ as a short-lived gas.

R15.5

When determining the rate of the waste disposal levy, the Government should consider whether a partial levy offset is required to avoid unnecessary overlap with the emissions price. This work should consider the role of default and unique emissions factors in properly incentivising emissions reductions.

²¹² Yet any schemes encouraging separate collection of domestic food waste must also consider the potential to create nuisance and the potential public health aspects (eg, from *Legionella* infections) of such schemes (Auckland Regional Public Health Service, sub. 105).

²¹³ While charging by quantity or volume occurs in some places in New Zealand (such as Auckland and Wellington), other places such as Hamilton include a rubbish disposal charge as part of residential rates. Yet not separating the charge reduces the incentive to minimise waste by volume. In its environmental performance review of New Zealand, the OECD (2017e) recommended encouraging local authorities to introduce this type of charge. If such a charge is more widely introduced, it will also be important to mitigate any unintended consequences (such as increased illegal waste dumping) and effects on lower-income households (Chapter 9) (Te Rūnanga o Ngāi Tahu, pers. comm., 26 March 2018).

15.9 Better wastewater treatment

Reducing emissions at WWTPs represents a relatively small emissions reduction opportunity (0.45% of New Zealand's total emissions across more than 250 WWTPs). These emissions are equivalent to just under one third of the emissions generated from New Zealand's heavy-duty trucks and buses (Chapter 12).

Technical options to reduce emissions by better control of the operational conditions of WWTPs exist. For example, the scope to reduce emissions at WWTPs is considerable through the use of anaerobic digestion systems (see the next section on waste-to-energy). Operators can also:

- operate WWTPs at “high solid retention times to maintain low ammonia and nitrite concentrations”, to reduce N₂O emissions; and
- cover “thickening sludge tanks and sludge disposal tanks...to avoid gas leakages” and achieve subsequent capture of CH₄ emissions (Campos et al., 2016, p. 3).

Scope may also exist to reduce emissions from WWTPs by reducing the amount of wastewater that needs to be treated (section 15.1). The Commission has previously found a strong case for the use of volumetric charges for water given that it provides an incentive to change consumer behaviour, helps to identify leaky pipes, and can extend the life of existing infrastructure assets by reducing water use (NZPC, 2015). Cities such as Auckland and Tauranga that have introduced volumetric charges for water have seen reductions in demand of 33% and 25% respectively. Because most water provided to residential dwellings becomes wastewater, this demand reduction also translates to reduced wastewater volumes (although not on a one-for-one basis, as some water is used outdoors and does not become wastewater).

At present, because WWTPs are not covered by the NZ ETS or any other emissions reductions policy, no mechanism directly encourages uptake of emissions mitigation options (MfE, pers. comm., 16 March 2018). However, some incentives do apply to WWTP operators that encourage emissions reductions as a co-benefit. For example, capturing CH₄ for biogas is a cost-saving mechanism (as it can substitute for fossil fuels), and is currently occurring in New Zealand. At the sole dairy processing facility in New Zealand that uses anaerobic wastewater treatment, the subsequent emissions are recovered and the captured biogas is mostly used for process heat in boilers (with the remainder flared) (MfE, 2018d). Even so, it is unlikely that relying on these co-benefits is adequate to encourage desired emissions reductions.

Extending the coverage of an emissions pricing instrument could further incentivise better emissions management at WWTPs. The Commission asked submitters for their views on the merit of bringing WWTPs into the NZ ETS and received a range of views.

Submitters in favour noted the presence of mitigation options and importance of GHG reductions even though they make up a relatively small share of New Zealand's total emissions:

In our view, the NZ ETS should be extended to cover wastewater treatment plants. This is fair, and will provide incentive for the sector to reduce emissions, along with other parts of our economy. Whilst the sector arguably makes a small contribution to NZ's GHG emissions, each area needs to take responsibility for its particular contribution. (Scion, sub. DR366, p. 99)

QLDC is generally supportive of an introduction of wastewater emissions to the ETS. We agree with the Productivity Commission that, even with technology available today, there are investment options available to some wastewater treatment schemes that would reduce emissions while still meeting effluent discharge requirements. (Queenstown Lakes District Council, sub. DR240, p. 2)

Yes [inclusion of WWTPs in the NZ ETS] is consistent with the 'polluter pays' principle. Although some consideration should be given to administration costs relative to the scale of emissions, there is no reason to exclude waste water treatment plants from the Emissions Trading Scheme. (Greater Wellington Regional Council, sub. DR195, p. 7)

Water New Zealand (sub. DR186) acknowledged that the opportunities for emission reductions in the wastewater sector are not insignificant, but argued that WWTPs should not be included in the NZ ETS. Water New Zealand put forward three main reasons, each discussed in detail in the following sections.

Methodological issues

Wastewater treatment emissions are poorly understood, with methods for GHG estimation from wastewater treatment not included in MfE's GHG reporting guidance. Councils that do calculate fugitive wastewater emissions have used methodologies outlined in the Intergovernmental Panel on Climate Change, 2006, Guidelines for National Greenhouse Gas Inventories (Water New Zealand, sub. DR186). However, these methodologies are not always relevant to the types of treatment used in New Zealand. Several other submitters raised similar concerns:

We do not support the inclusion of wastewater treatment plants in the ETS at this point in time. This is because the emission profile of wastewater treatment plants in New Zealand is currently not well understood, there are no measurement or reporting standards relevant for New Zealand wastewater treatment plants, nor does there appear to be any co-ordinated response on how such emissions could be minimised. (Fonterra, sub. DR355, pp. 10–11)

What is needed is a clearer understanding of what greenhouse gas emissions result from the different treatment processes and discharges to both water and land, so that all wastewater treatment plants work from the same reporting basis. Guidance in this assessment is needed before the inclusion of wastewater treatment plants into the ETS could be supported. (Christchurch City Council, sub. DR284, pp. 6–7)

DCANZ [Dairy Companies Association of New Zealand] opposes the inclusion of wastewater plants in the ETS at this time due to the need for further work to improve the measurement frameworks for these emissions. (DCANZ, sub. 380, p. 4)

While Queenstown Lakes District Council was generally supportive of introducing wastewater emissions into the NZ ETS, they also acknowledged that “measuring GHG emissions from wastewater treatment is much more complex than other sources (such as energy), and depends significantly on the type of treatment process being used” (sub. DR240, p. 2). Queenstown Lakes District Council commissioned research into different approaches to measuring emissions at two of their WWTPs (Project Shotover in Queenstown and Project Pure Wanaka). The results (Table 15.2) illustrate that a significant estimation error is involved.

Table 15.2 Estimated GHG emissions from WWTPs in Queenstown and Wanaka

			Plant	Ponds	Total
Project Shotover	Total CO _{2e} t yr ⁻¹	Mean	562	2 120	2 682
		Range	16 – 2 158	663 – 3 289	679 – 5 447
Project Pure (Wanaka)	Total CO _{2e} t yr ⁻¹	Mean	268	-	268
		Range	12 – 1 081	-	12 – 1 081

Source: Bloomberg et al. (2018).

Notes:

1. CO_{2e} t yr⁻¹ refers to carbon dioxide equivalent, and includes CO₂, N₂O and CH₄ emissions.

Watercare developed an emissions accounting tool in early 2018 (sub. DR275) and shared it with MfE. The tool has the potential to help develop methodologies for inclusion in the New Zealand emissions inventory. The tool covers emissions from various emissions sources and covers scopes (see Figure 7.6 in Chapter 7 for more on scope 1, 2 and 3 emissions).

Scale and capability

Wastewater operators vary significantly in scale and capability. As Table 15.1 showed, 209 WWTPs (or 81% of all plants) process only 9% of total treated wastewater in New Zealand.

Water New Zealand (sub. DR186, p. 6) notes that wastewater management teams within territorial authorities are often small and staff generally lack the capacity and resources for actions “beyond business as usual”. As such, Water New Zealand suggests that most small councils currently lack the capacity to act on any of the emissions reduction opportunities that exist. Rangitikei District Council also raised these concerns.

The Rangitikei District has 6 wastewater treatment plants to service. These costs already include resource consents, upgrades and ongoing maintenance, and are posing a significant affordability issue for the District. Council acknowledges the need to address climate change and recognises that even small contributions can assist in reducing carbon emissions and accepts that we should show leadership where we can contribute to lower emissions; however, because of the relatively low impact, we request the Commission considers whether the emissions benefits which could be gained are proportional to the likely costs. (Rangitikei District Council, sub. DR200, p. 3)

Potential for emissions mitigation efforts to compromise water treatment

Several inquiry participants noted that in some instances councils are already struggling to operate WWTPs to an acceptable standard within budget constraints. Given existing constraints, concerns were raised that including WWTPs in the NZ ETS could be detrimental to treatment standards.

Councils are having difficulties treating wastes to acceptable standards at an affordable price for the contributing users. We are unsure whether additional costs from bringing particularly municipal wastewater treatment into the ETS would further exacerbate costs and treatment standards might be compromised. (Environment Institute of Australia and New Zealand, sub. DR260, p. 4)

Local governments are already struggling to fund waters infrastructure, especially given the upgrades that will likely be required in order to replace resource consents in the near future. (Whakatāne District Council, sub. DR317, p. 2)

Regarding wastewater treatment plants, a primary focus for Te Rūnanga is investment in plant that reduces risks to water quality, human health and the environment generally... we would be concerned if small plants faced costs when we know there is [an] urgent need to address basic performance in some areas. This is especially true in small rural or remote communities. There are many such communities within the Ngāi Tahu takiwā that are already struggling to find the resources necessary to upgrade their systems. (Te Rūnanga o Ngāi Tahu, sub. DR362, p. 13)

The Department of Internal Affairs has been leading a cross-agency review of three waters infrastructure²¹⁴ to explore whether current system settings and practices are fit for purpose. The findings of this review also raised concerns about the existing performance of water services.

- There are risks to human health and the environment in some parts of the country.
- There is evidence of low levels of compliance, monitoring and enforcement against a range of standards, rules and requirements.
- There is evidence of capability and capacity challenges, particularly for smaller councils. A consistent theme that emerged is the role that scale plays in relation to asset management and governance capability, levels of compliance, and service quality.
- There is evidence of affordability issues in some places, driven by a range of factors and funding pressures. These include population growth, renewals, meeting increased expectations around drinking water and freshwater, and adapting to the impacts of climate change.
- Variable asset management practices, and a lack of good asset information, are affecting the efficiency and effectiveness of three waters infrastructure and services. (DIA, 2018a, p. 4)

A process to encourage emissions mitigation at WWTPs

Emissions pricing is a key pillar in New Zealand's transition to a low-emissions economy. To be effective, emissions prices should be pervasive through the whole economy – shaping resource and investment decisions across all emitting sectors and sources. As such, the threshold for excluding any emitting sectors should be high. Although the concerns raised about including WWTPs in an emissions pricing mechanism are unlikely to be insurmountable, they do indicate the need for additional analysis to be undertaken before the costs and benefits of bringing WWTPs into a pricing scheme can be assessed.

The most important element of this analysis is to develop appropriate measurement methodologies. Water New Zealand notes that improved understanding of wastewater fugitive emissions is an important first step in managing wastewater emissions. It suggests that methodologies covering the range of treatment

²¹⁴ The "three waters" are drinking water, stormwater and wastewater. See DIA (2018b) for more information on the review.

processes could usefully be included in MfE's Voluntary Greenhouse Gas Reporting Guidance and that doing so would facilitate the assessment of fugitive emissions.

Scion (sub. DR366, p. 100) notes that methodological improvements are also needed to more accurately capture N₂O emissions:

The methodological approach used must incentivise the reduction of N₂O emissions. The method used in the NZ GHG Inventory... is incapable of achieving this, since it is based on per capita protein consumption. A method of direct measurement of N₂O from secondary wastewater treatment is therefore necessary. Operators would then have a choice as to how to better operate plants to reduce N₂O emissions.

However, this is not straightforward:

Correct determination of nitrogen emissions requires the various stages of the nitrogen cycle to be addressed. This is a complex process, which varies depending on wastewater treatment plant configuration and effluent quality. There are international guidelines for such determinations. Tailoring these to a New Zealand context is beyond the job scope of most water treatment operators, who in general lack either the time or expertise for such determinations. The development of appropriate fugitive emission factors for the New Zealand would require third party support, either from central government or academia. (Water New Zealand, sub. DR186, p. 7)

The complexities of measuring wastewater emissions, and the potential for extremely wide variation in reported emissions depending on the measurement technique employed (Table 15.2) points toward the need to establish new measurement methodologies. As the agency with responsibility for New Zealand's GHG inventory, MfE should lead this work, in conjunction with Local Government New Zealand, and any other agencies with particular expertise in wastewater management. This project could be undertaken in tandem with MfE's existing project to collect better waste data (Finding 15.2).²¹⁵

Until further work has been undertaken to develop measurement techniques, it is difficult to assess the case for with bringing WWTPs into the NZ ETS. However, given the large number of small treatment plants (currently), and the technical challenges in measuring emissions from WWTPs, transaction and ongoing compliance costs could be significant.

Concerns around the capability of councils to adapt to inclusion in an emissions pricing scheme without compromising treatment standards is also a concern. As noted above, a review of three waters infrastructure is already being undertaken, and it has identified numerous concerns about three waters management. That review is expected to recommend regulatory changes later this year. Depending on the final findings and recommendations from that review, there may be a good case to delay introduction until after any relevant recommendations have been acted on. This may include consolidating the large number of three waters suppliers (Table 15.1), which would reduce concerns around the administrative or technical competency required for smaller WWTPs being included in the scheme.

Finally, there is need to consider exactly how emissions from WWTPs could or should be priced. As shown in Figure 15-2, two-thirds of emissions from WWTPs are CH₄, and the remaining one-third is N₂O. In the discussion in Chapter 9 and in the preceding section, the logic is strong for including CH₄ in an emissions pricing scheme that recognises its shorter atmospheric lifetime. But because N₂O is long-lived, it is more suitable to being included in an NZ ETS in which a steadily decreasing cap helps to push emissions to net-zero (or lower). Even though two different types of GHGs occur during one process, WWTPs could, in theory, still be included in two schemes.

The Commission considers that WWTPs should be incentivised to reduce emissions. Inclusion into emissions pricing schemes that recognise the atmospheric effects of the GHGs in question is likely to be the most effective mechanism to encourage mitigation. Yet it will be important to first establish an agreed measurement approach and to assess the transaction costs of its use in any relevant scheme. Consideration should also be given to the outcomes of the three waters review (particularly in terms of consolidation of

²¹⁵ As well as emissions from large WWTPs, CH₄ emissions also occur from the use of septic tanks (domestic and commercial). A proposed National Environmental Standard for onsite wastewater systems (ie, including septic tanks) was discussed in 2008, but withdrawn in 2009. How much septic tanks contribute to overall levels of CH₄ emissions from waste in New Zealand is uncertain due to data limitations (MfE pers. comm. 2 July 2018). Depending on its scope, work to improving waste data should help to address these limitations.

water operators, and ability to measure emissions) in future work to determine appropriate policy instruments for emissions reductions.

R15.6

In principle, wastewater treatment plants (WWTPs) should be incentivised to reduce emissions. To enable the case to be assessed for including WWTPs into emissions pricing schemes, MfE and Local Government New Zealand should begin a project to improve measurement methodologies for WWTPs. Any inclusion of WWTPs into emissions pricing schemes should occur after relevant recommendations from the Department of Internal Affairs' three waters review have been enacted.

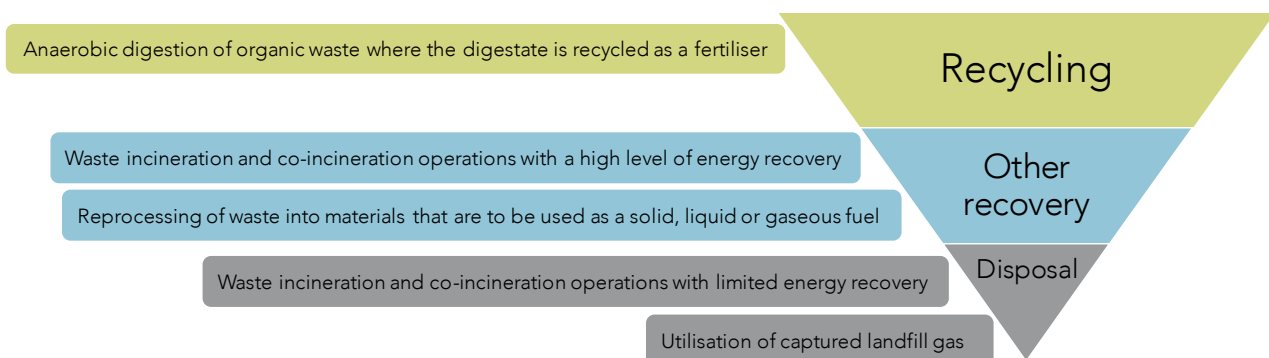
15.10 Waste-to-energy

Rather than landfilling or otherwise disposing of waste, it is instead possible to reconsider waste as a source material. As the Wise Response Society notes, "a major barrier is that we have come to view certain materials as waste rather than material resource" (sub. 102, p. 34). One key avenue is waste-to-energy (WtE). This comprises transforming organic waste (eg, via incineration of municipal waste or wood wastes, or anaerobic digestion of farm wastes) into a renewable energy source (such as biogas).²¹⁶

WtE fits into the waste hierarchy at various scales (Figure 15-7). In New Zealand, Nana et al. (2011) estimated that waste in New Zealand could produce up to 630 000 megawatt hours (MWh) of renewable electricity each year. This included using effluent from the meat and dairy sectors, with the subsequent 1 petajoule²¹⁷ of methane biofuel sufficient to replace 2% of the current national power production from natural gas. The Bioenergy Association (sub. 37, p. 8) also notes:

Adoption of waste-to-energy programmes around use of solid and liquid municipal waste and food processing waste could result in emission reductions of 90 kt CO_{2e} per annum by 2030 and 150 kt CO_{2e} per annum by 2040. Many of the waste-to-energy opportunities are financially attractive today with around 4-6 year financial payback periods.

Figure 15-7 Waste-to-energy within the waste hierarchy



Source: Adapted from European Commission (2017).

The economics of incinerating waste to produce energy are unclear...

WtE from the incineration of waste is a common method for waste processing, and to achieve emissions reductions, in other countries, particularly in Europe. However, at present, no WtE plants incinerate waste in New Zealand (excluding the use of wood wastes as a fuel source for industrial boilers, Chapter 14). Key factors working against such WtE plants include public acceptance and consenting processes under the RMA, particularly in terms of managing particulate emissions to air (EFI, 2008), although technologies exist for managing such emissions, as Scion notes (sub. DR366). The type of GHGs produced from waste incineration is also important to consider, as incineration predominantly results in long-lived GHGs like CO₂ and N₂O (Astrup et al., 2009). A proposed \$250 million household WtE plant in Westport to encourage

²¹⁶ See also Chapter 12 for liquid transport biofuels, Chapter 13 for biogas for electricity supply, and Chapter 14 for biomass for industrial processes.

²¹⁷ A petajoule is a unit of energy. One petajoule equals one quadrillion (10¹⁵) joules, or approximately 163 400 barrels of oil.

employment and reduce GHG emissions (Buller District Council, 2016) was due to receive financial support for a feasibility study from the Provincial Growth Fund. However, funding is presently on hold.

In general, WtE is costlier in the short term as compared to landfilling waste. However, in the longer term, and depending on system characteristics (such as the distance between the WtE plant and the waste source), the potential emissions reductions benefits and co-benefits can make WtE plants an attractive economic proposition (Assamoi & Lawryshyn, 2012; Hitachi Zosen Inova Australia Pty Ltd, sub. DR181). This is particularly likely if a higher emissions price or waste disposal levy is applied. In an analysis of the levy, a rate of \$100 a tonne was identified as necessary to incentivise WtE. However, if a separate levy on incineration (introduced to discourage incineration due to air pollution concerns) of \$40 a tonne is also included, scenario modelling showed that WtE via incineration would no longer be viable (D. Wilson et al., 2017). The National Energy Research Institute (sub. 53, p. 6) also notes that for “the foreseeable future we are not facing constraints on the availability of low cost renewable electricity so it is unlikely that waste will be a significant contributor outside some specific niches”.

The level of emissions price necessary to make WtE using the incineration of waste, especially household waste, cost-effective in New Zealand is unclear. Even so, the Commission considers that the emissions price should remain a key driver when analysing whether or not WtE plants are cost-effective. The need to reduce long-lived GHGs to net-zero or negative (Chapter 9) will also be a relevant factor in any analysis.

...but anaerobic digestion can offer a cost-effective opportunity to re-use organic waste

Many examples of anaerobic digestion exist in New Zealand, with the bioenergy produced able to either be used onsite (eg, to create a fully self-sufficient WWTP), or on-sold to an external user (eg, power companies purchasing excess energy). For example, Palmerston North City Council successfully operates large-scale anaerobic digesters at its WWTP (including sourcing additional external biomass including food waste) (Palmerston North City Council, 2017).

At present, 53% of the current effective New Zealand population is connected to 15 WWTPs that have anaerobic digesters to help provide onsite energy. Additional drivers, such as an increased emissions price, could lead to WWTPs with co-located anaerobic digesters covering an estimated 78% of New Zealand’s population. This would help to divert solid waste away from landfill sites without effective gas recovery systems (Calibre Consulting, 2017). Increasing the capacity of existing anaerobic digestion systems also appears to be a particularly suitable avenue to pursue (Calibre Consulting, sub. DR327). Recent research shows that processing residual industrial waste from WWTPs in anaerobic digestion plants could reduce emissions by up to 151 kt CO₂e a year by 2050. This represents 150% of projected GHG emissions from industrial wastewater, suggesting that industrial wastewater treatment has the ability to become emissions neutral by 2030, and emissions negative by 2050 (Boušková, 2018).

At present, anaerobic digestion of farm waste (eg, dairy effluent) is less cost-effective. Research suggests that in New Zealand a herd of approximately 1 000 cows is required to consider installation of an anaerobic digestion system, and even then “the net benefit is modest and is sensitive to assumptions about capital and operating costs and the value of energy” (Milet et al., 2015, p. 75). However, WtE (once agriculture is included in the NZ ETS) may be a more financially viable proposition for farmers to offset on-farm energy costs.

Policy guidance regarding waste-to-energy in New Zealand

Some submitters identified a lack of policy guidance about WtE in New Zealand. This includes that the New Zealand Waste Strategy does not adequately consider how to better use the amount of inevitable waste, as well as a lack of direction for specific sectors and technological applications (Bioenergy Association, sub. 37; Hitachi Zosen Inova Australia Pty Ltd, sub. 68). Other jurisdictions provide specific guidance about WtE (such as the New South Wales Energy from Waste Policy Statement). It appears doubtful whether such a policy statement is needed, given existing anaerobic digestion projects in New Zealand, and the uncertainty regarding the financial viability of WtE using incineration.

F15.6

Waste-to-energy provides an opportunity to reduce emissions by diverting waste from landfill and substituting for fossil fuels. Anaerobic digestion (eg, at wastewater treatment plants) is a current cost-effective approach to reduce emissions, but the potential to incinerate waste (especially household waste) is less clear.

15.11 The future of waste: A circular economy approach

The above sections have focused on priority areas where waste emissions reductions need to occur if New Zealand is to achieve its low-emissions goals. However, this more urgent focus (particularly on reducing landfill emissions) should not preclude more transformative ideas or perspectives on how waste could contribute to emissions reductions, or even be conceived of.

One well-known concept is the circular economy: an economy where “the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised” (EC, 2015, p. 2). The three key principles of the circular economy are to design out waste and pollution, keep products and materials in use, and regenerate natural systems (Ellen MacArthur Foundation, 2018). Incorporating circular economy principles means ensuring disposal is a measure of last resort on the waste hierarchy, with a primary focus on waste prevention, such as by designing products so that they stay in circulation for longer. Where waste is inevitable, a circular economy does encourage better waste use, such as via WtE (European Commission, 2017).

The circular economy is therefore important to consider beyond the confines of waste. An increasing emphasis in New Zealand and internationally is to engage with businesses about how incorporating such principles can be directly economically beneficial, such as by acting as a platform for innovation, as well as reducing emissions. For example, recent research shows that Auckland could achieve up to an additional \$8.8 billion in additional economic activity, and reduce emissions by 2 700 kt CO₂e in 2030 by adopting a circular economy approach (Blick & Comendant, 2018; Sustainable Business Network, 2018). This is similar to research conducted elsewhere: in Scotland, for example, applying circular economy principles is estimated to reduce emissions by 11 Mt CO₂e a year by 2050 compared to ‘business as usual’ practices (Pratt & Lenaghan, 2015). A more embedded circular economy approach may also help to reduce the impacts on vulnerable groups from higher waste charges (Local Government New Zealand, sub. DR248).

Policy change required to shift towards a circular economy

Ensuring the circular economy can be implemented requires an examination of policy frameworks so that regulatory barriers can be removed. An analysis of European policy in relation to a circular economy framework identified numerous regulatory barriers hindering an effective uptake of its principles. These barriers included legislative gaps, incomplete implementation or enforcement of legislation, and conflicting legislation (such as hygiene issues in relation to food waste) (Technopolis Group, 2016).

At present, some avenues exist within the New Zealand policy framework to encourage circular economy principles (eg, via the current funding round for the Waste Minimisation Fund which is focusing on circular economy projects). Encouraging better waste stream management or WtE can also assist activities further down the waste hierarchy. However, it is clear that changes are needed to fully harness the ability of a circular economy approach to drive the transition to a low-emissions economy. Two key policy mechanisms will be to increase the rate of the waste levy for active waste so that reducing waste becomes a better financial decision from the outset, and to make better use of waste streams (Sustainable Business Network, 2018). Fully harnessing the benefits of a higher levy (particularly in terms of changing the behaviour of product manufacturers), will require complementary policy approaches, such as better use of the product stewardship provisions of the WMA (including requiring mandatory product stewardship).

It is also possible that other policy measures may need to change to fully capture the benefits of a circular economy. For example, the Sustainable Business Network (2018) suggests that changing the Goods and Services Tax (GST) structure for circular products may act as a powerful driver encouraging this approach. A similar model is currently being considered by the European Commission (2018b).

A lack of knowledge of circular economy business models has been identified as a barrier to their development, specifically in terms of access to finance (Neumann & Achimescu, 2018). Establishing a stable climate policy regime will help to overcome this market failure (Chapters 7 and 8). Taking a sectoral approach is also likely to provide a useful avenue towards accelerating the uptake of the circular economy. For example, the food, transport and logistics, and built environment sectors are particularly targeted in Auckland’s work on shifting to a circular economy. Sharing success stories will help to raise awareness of the viability of different types of business models. Finally, it is possible that shifts to account for consumption-based emissions (as opposed to production-based emissions), as is discussed in Chapter 10, could more deeply embed the potential for a circular economy approach to drive the transition to a low-emissions economy (Sustainable Business Council, sub. DR254).

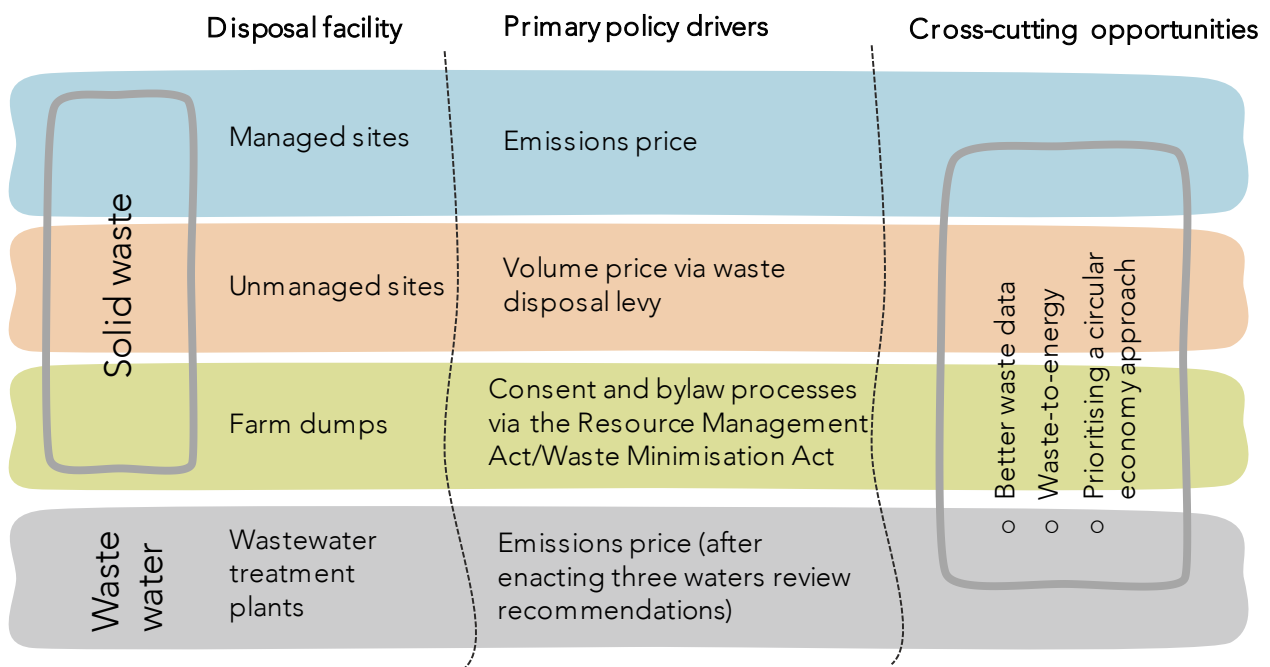
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A circular economy approach has significant potential to reduce waste emissions in New Zealand and drive the transition to a low-emissions economy by acting as a platform for innovation.

15.12 Conclusion

Opportunities exist to reduce waste emissions in New Zealand (summarised in Figure 15-8). Primary policy drivers are available that relate directly to particular types of disposal facilities, but so too are cross-cutting opportunities, including better waste data, and reducing organic waste at source.

Figure 15-8 Opportunities for reducing waste emissions



Based on its analysis, the Commission does not consider it necessary to recommend specific waste emission reduction targets, or even specific volume reduction targets of particular types of waste (ie, reverting to the approach of the 2002 Waste Strategy). This is because, compared with other jurisdictions that have adopted a more regulatory approach with integrated targets (such as the European Union), waste in New Zealand is covered by two other approaches that, given recommended reforms, have substantial potential to effectively reduce emissions: an emissions price and the waste disposal levy.

Instead of a target, price will continue to be the key mechanism that drives emissions reductions. If the coverage of the levy and emissions pricing mechanisms are extended as recommended above, then the only remaining gap is farm dumps. If more reliable data continues to show that unmanaged waste sites represent a substantial emissions source, farm dumps are likely to require a separate regulatory approach because they are not suitable to either the levy or an emissions price.

16 The built environment

Key points

- Emissions are generated throughout the life-cycle of buildings and infrastructure. This includes emissions embodied in the production of building materials and building processes; and emissions generated through the operation, maintenance and disposal of buildings and infrastructure.
- The emissions embodied in buildings can vary significantly depending on the materials used and the construction technique. Advances in building materials, such as laminated timber structural elements, have created opportunities to safely reduce the use of emissions-intensive materials such as steel and concrete. A new mandate for the Energy Efficiency and Conservation Authority to promote the use of low-emissions materials, along with an improved emissions pricing regime, will both help to incentivise the uptake of low-emission materials.
- It is important that the Building Code does not present barriers to building technologies and materials with lower embodied emissions. Forthcoming reviews of the Building Code should examine whether the Code is sufficiently flexible to enable practitioners to adopt building materials and techniques with low embodied emissions, including the re-use of buildings and materials.
- Commercial and residential buildings consume more than half of New Zealand's operational electricity. Improving the energy efficiency of buildings provides a valuable avenue for tempering electricity demand, particularly as transport and other parts of the economy electrify.
- Electricity generation still makes up about 5% of New Zealand's emissions, due largely to the use of coal and gas-fired stations to meet peak demand – much of which is generated by domestic electricity use on winter mornings and evenings. As such, in the short term, efficiency measures that reduce electricity demand during periods of peak demand will provide the greatest emissions reduction benefits.
- A range of policy measures are already in place to improve the energy efficiency of buildings. The Ministry of Business, Innovation and Employment should review the costs and benefits of additional programmes (including the alignment of New Zealand's lighting standards with Australia) to deliver energy savings in housing and buildings.
- Increasing the density of urban areas, combined with good public transport and accessibility, can reduce vehicular travel and emissions. Higher-density housing often requires lower operational energy, and lower embodied emissions on a per capita basis.
- Councils should review, and if justified remove, barriers to higher-density development, particularly in inner suburbs and in areas close to public transport routes. Councils should also ensure that infrastructure charges reflect the full costs of dispersed development.
- When deciding whether to invest in infrastructure, decision makers should be aware of the life-cycle emissions associated with infrastructure assets. Effective asset management can help to reduce demand for new investment.
- Where government investment in additional infrastructure is required, an effective emissions price, along with stable and credible climate policy, will incentivise decision makers to factor in current and likely future emissions prices in their assessment of different options. As a transitional measure until these conditions are met, government agencies should use a shadow emissions price when assessing options for new infrastructure investment.

This chapter examines the potential for reducing emissions within the built environment, specifically buildings, urban areas, and infrastructure. For buildings and infrastructure, the focus is primarily on emissions embodied in the production of building materials and building processes; and emissions generated through the operation, maintenance and disposal of buildings and infrastructure. For urban areas, the chapter also considers emissions not directly related to the construction or operation of buildings, but affected by the nature of the built environment. For example, the way some cities have developed has made residents less reliant on private vehicle travel, producing lower transport emissions.

Most parts of the built environment have a long lifetime. This has two important implications from the perspective of emissions mitigation strategies:

- the initial design and construction of built environments can lock in certain behaviours and emissions for a long time; and
- changes in the built environment are usually very gradual, and are therefore unlikely to make a material contribution to emission reduction targets in the short term.

Co-benefits are another important consideration when examining emissions-reduction strategies relating to the built environment. Many inquiry participants who proposed mitigation strategies relating to the built environment noted that they had important co-benefits – for example health and emissions co-benefits from the improved thermal performance of residential buildings (Auckland Regional Public Health Service, sub. 105).

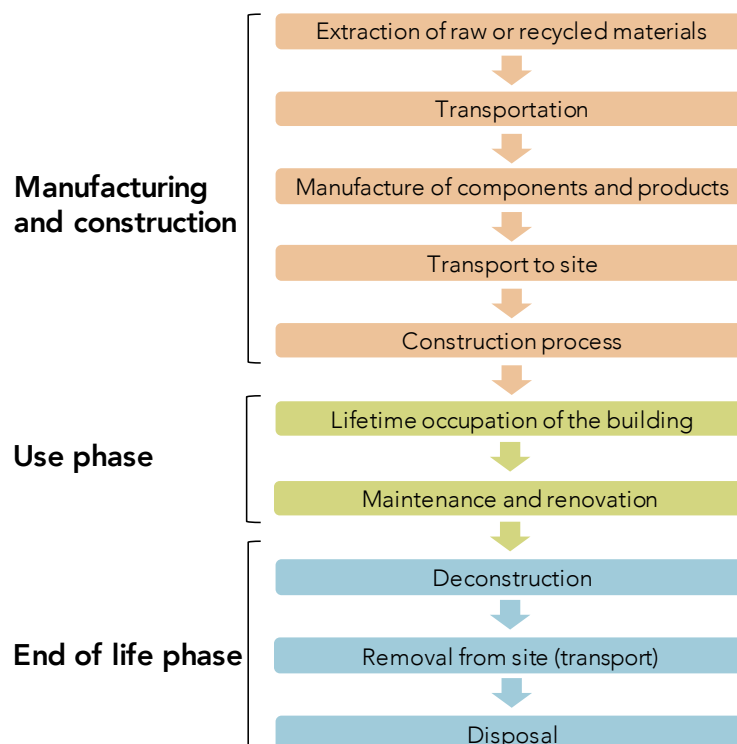
16.1 Emissions through the life-cycle of a building

Emissions are generated throughout the life-cycle of a building.

Greenhouse gas emissions from buildings are generated throughout the buildings full life cycle from the production of building materials, to the operational energy consumption of a building (heating, cooling, hot water heating, lighting, appliances and electrical equipment), building maintenance and end-of-life disposal. (Scion, sub. 67, p. 6)

Figure 16-1 shows some important emissions sources, split across three stages of a building's life.

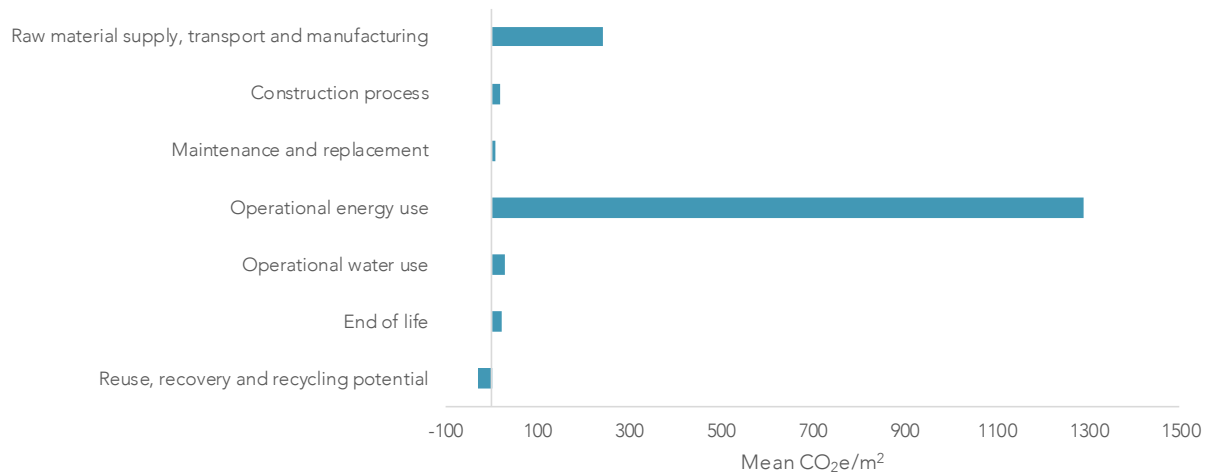
Figure 16-1 Emissions sources in the life-cycle of a building



Source: Adapted from Monahan and Powell (2011).

The vast majority of emissions generated across the life-cycle of a building are generated from its use. For example, Berg et al. (2016) assessed emissions from 30 commercial office buildings over a 60-year service life (Figure 16-2). Their analysis showed operational energy use at 80% of life-cycle emissions, and the manufacture of materials (foundations, structure and enclosure only) at 15%. Other stages of the building life-cycle (including the construction process, maintenance and end-of-life) collectively contributed the remaining 5%.

Figure 16-2 Mean life-cycle emissions for commercial office buildings



Source: Berg et al. (2016).

While energy use is the dominant driver of emissions from buildings, numerous submitters noted the importance of assessing emissions from a life-cycle perspective (for example Scion, sub. DR366; Fletcher Building, sub. DR349; and Thinkstep, sub. DR344).

To support more widespread use of Life Cycle Assessment (LCA), BRANZ²¹⁸ has developed *LCAQuick – Office*. This tool, which is free to use, provides a resource to help stakeholders involved in the early stages of building design to better understand LCA. In particular, the tool details:

- what building LCA is and how to use it
- how to incorporate LCA into existing workflows
- what outputs of LCA look like and how to use and interpret them
- how decisions taken at early design can contribute to potential environmental impacts during the building life, where these occur and how to reduce them
- how the environmental impacts of early designs compare to environmental impacts calculated for reference New Zealand office buildings. (Berg et al., 2016, p. 17)

BRANZ have recently released a similar package, *LCAQuick – Residential*, which provides a means for designers to calculate how house design impacts GHG emissions.

F16.1

Greenhouse gas emissions are generated across the life of a building. Calculation of life-cycle emissions when a building is being designed, for example using BRANZ's *LCAQuick* tools, presents an opportunity to identify low-emissions building designs.

Emissions embodied in construction

Although the majority of New Zealand's building stock that will exist in 2050 is already in place, using building materials with lower embodied emissions, and using lower-emissions building practices to further reduce emissions is possible.

²¹⁸ BRANZ is an independent research, testing and consulting organisation for the building and construction industry. BRANZ is funded via the Building Research Levy and revenue generated through commercially contracted research projects (BRANZ, 2018a).

When a building is constructed – before it starts operating and generating operating emissions – it is already responsible for tons of GHG emissions. (Strain, 2017 cited in Strategic Lift Inc. sub. 60, p. 2)

Giesekam et al. (2014) note that over half of the embodied carbon in construction is associated with the production of materials, and that a range of embodied carbon mitigation strategies exist.

These include strategies that seek to minimize extraneous material usage through ‘lightweighting’, structural optimization or site waste reduction; strategies that focus upon maximizing the useful life of materials by extending the life of existing structures and designing new structures to be adaptable and easy to deconstruct (allowing reuse of materials and components); or substitution of materials and construction products for alternatives with lower carbon supply chains. A variety of alternative materials are available, including materials derived from naturally occurring substances; materials that incorporate waste or recycled content; materials that have been repurposed or sourced for reuse from other sites; and construction products that have been optimized through novel production techniques. (p. 425)

Numerous studies have examined the potential of different design and construction strategies to reduce embodied emissions. The International Energy Agency (IEA) reviewed 80 studies that assessed mitigation strategies, including substitution of materials, reduction of resource use, and design changes to reduce the total volume of construction. Overall, the IEA analysis found that the substitution to bio-based materials will reduce emissions, due to low-energy production methods. Studies evaluating strategies to reduce the use of materials – for example through the use of lightweight construction and re-use of old building structures – also generally found that these approaches were effective in reducing emissions. However, studies examining substitution to recycled materials produced mixed results. (IEA, 2016b).

While emissions embodied in materials are the primary source of emissions during the manufacturing and construction phase, different construction methods can affect emissions. For example, Burgess et al. (2013) show that when constructing a 120m² house, pre-fabricated construction approaches can reduce emissions by around 15% during the construction phase. This is primarily due to lower material wastage from errors, greater ability to store and re-use waste materials, and lower transport emissions.

MacGregor et al. (2018) have calculated the total volume of materials used in the construction of standalone residential dwellings in New Zealand in 2016, along with their associated embodied emissions (Table 16.1). Concrete foundations, steel framing and sheet metal roofing were the most significant sources of embodied emissions.

Table 16.1 Materials used in new standalone dwellings with estimated embodied emissions (2016)

Material	Volume used	Embodied emissions (tonnes CO _{2e})
Concrete framing and foundations	620 000m ³	198 152
Timber framing and foundations	382 600m ³	-263 037
Steel framing	3 500m ³	71 526
Timber walls	933 000m ²	-12 187
Fibre cement walls	505 400m ²	6 736
Clay (brick, tile) roofing and wall claddings	1 128 900m ²	28 305
Concrete roofing and wall claddings	776 100m ²	9 832
Sheet metal roofing and wall claddings	4 607 600m ²	73 236
Total		112 563

Source: MacGregor et al. (2018).

Based on these estimates, MacGregor et al. (2018) find that the emissions embodied in building materials are equivalent to the emissions that arise from a little over three years of occupation. However, the authors

note that this is likely to be a significant underestimation because the figures set out in Table 16.1 do not capture the full embodied emissions associated with standalone dwellings. The figures exclude material wastage, transport of materials from manufacturer to construction site, and other building materials (such as ceiling linings, insulation, floors, paint, plumbing and electrical), and fixtures and fittings.

The findings of MacGregor et al. (2018) are consistent with similar analysis in other jurisdictions and with other New Zealand research examining multi-storey buildings.

- Monahan and Powell (2011) calculated the embodied emissions for an 83m² detached three-bedroom home in the United Kingdom based on three different construction techniques. Their results showed that the emissions embodied in a masonry house (with block internal walls and an outer brick cladding) were 51% greater than a house built with timber framing and cladding (Monahan & Powell, 2011).
- John et al. (2009) examined the emissions associated with four different designs for a multi-storey building in New Zealand and found that the initial emissions embodied in materials for timber designs were significantly lower than concrete and steel designs.

A consistent finding across studies that examine emissions embodied in materials is that incorporating more wood products sourced from sustainably managed forests reduces embodied emissions, particularly when used as a substitute for materials such as brick, aluminium, steel and concrete (Buchanan & Levine, 1999). Several inquiry participants also noted the benefits of wood in construction.

High-technology wooden construction for structural elements instead of steel not only reduces emissions from material manufacture but provides a carbon sink for the life of the building. (Waikato Regional Council, sub. 48, p. 6)

Wood has lower embodied energy compared with alternative structural construction materials, and in addition to this provides carbon sequestration and storage benefits. (Scion, sub. 67, p. 7)

Recent advances in technology have widened the range of opportunities for the use of wood in construction. For example, researchers at the University of Canterbury have developed *Pres-Lam* – a pre-stressed, laminated, timber building system that is designed to be a sustainable alternative to heavier, non-renewable, concrete and steel framing (University of Canterbury, 2017). This technology was used to construct a three-storey arts building at the Nelson Marlborough Institute of Technology. The construction project was supported by the Ministry of Agriculture and Forestry (now the Ministry for Primary Industries) which, at the time, provided funding support toward buildings that promoted the use of timber in low-rise construction (Philip, 2011). Similar technology will be used in a planned office block in Wellington’s CBD, which, at 52 metres tall, will be the world’s tallest wooden office building (Winter, 2017).

Reflecting wood’s relative emissions profile and advances in wood construction, several inquiry participants recommended policies to encourage greater use of wood. In particular, some saw benefits in the wider adoption of ‘Wood First’ policies.

Substitution of steel and concrete for engineered timber (laminated structural lumber or LVL) in mid-rise commercial buildings and road bridges is an opportunity to reduce emissions, and could increase economic activity by producing higher value-added wood products... An example of more active policy in this area is Rotorua District Council’s adoption of a ‘Wood First Policy’ to encourage government agencies to use natural, timber-based construction. (EECA, sub. DR326, p. 14)

Government can add to the confidence in the future of the forestry industry by endorsing the “Wood First” movement... It is not difficult to promote the use of wood for commercial as well as domestic use. This attitudinal change is matched by the developments in wood technology. With the use of glue-laminated and engineered wood products New Zealand should be at the forefront of use of its timber for buildings. (Geoff Thompson, sub. DR304, p. 3)

[New Zealand Forest Owners Association] considers that encouraging the use of timber in the built environment is an important contribution to a low-emissions economy. Policies such as Rotorua Lakes and Gisborne District Councils’ Wood First policy are good examples of this approach but do not go far enough. A policy that is mandated by both central and local government should require buildings up to two storeys high to be designed and costed based on timber construction. (New Zealand Forest Owners Association, sub. DR246, p. 5)

Policies to encourage the use of wood have been adopted by local authorities internationally (British Columbia and Ontario in Canada, France, Japan, Australia, Finland, and the Netherlands) and in New Zealand (eg, Rotorua Lakes Council Wood First Policy; and the proposed Gisborne City Council Wood First Policy) (Scion, sub. DR366). Such policies generally require that sustainably sourced wood should be considered as the primary construction material where feasible, for public sector buildings, along with policies to encourage greater uptake of wood in private construction projects (Make it Wood, 2018).

Rotorua Lakes Council's Wood First Policy sets out a set of actions that the council will take to encourage the uptake of wood including:

- Developing an assessment toolkit for all council led building projects to see how wood might be incorporated as a component in the design.
- Encouraging contractors to include wood options in their proposals to council...
- Acting as a facilitator to encourage growth and investment in the local forestry and wood products industry, including the service industries that support it...
- Acting as a leader in encouraging councils to link together to support the forestry industry.
- Taking a lead role in working with central government and its agencies to support and grow the forestry sector. (Rotorua Lakes Council, 2015)

In Chapter 14, the Commission discusses the mandate of the Energy Efficiency and Conservation Authority (EECA) and recommends that EECA's mandate is extended to include the promotion of low-emission materials. If this recommendation is accepted, EECA would be in a position to develop specific policies to encourage the uptake of wood and other low-emissions materials. However, it is important that the emission profiles of different building materials are considered in the context of their full life-cycle use. As discussed earlier, emissions generated through the use of a building across its life are typically much greater than emissions embodied in materials. There may be scenarios where building designs with relatively high up-front embodied emissions perform better over their life-cycle as a result of superior efficiency during their use.

For example, Vale (2017) compared the thermal performance of different dwellings and identified that dwellings with a greater volume of thermal mass (primarily concrete) out-performed lighter-weight structures. Vale (2017) concludes by cautioning against considering the choice of materials in isolation:

[It] can be demonstrated that very high-mass houses can show substantial savings in lifecycle energy compared with conventional forms of construction. These findings suggest that the choice of materials may need to be a lot more subtle than simply having a list of materials that are "unsustainable." Sustainability depends much less on the choice of materials and much more on how they are used. (Vale, 2017, pp. 318-319)

As such, any programmes to support the use of low-emissions materials should be aware of how the choice of materials will affect the total life-cycle emissions of a building.

As noted earlier, BRANZ has already developed tools to measure the life-cycle emissions associated with buildings. They are also currently developing a *Transition to a Low Carbon Built Environment* research programme. This will place BRANZ in a good position to provide technical expertise to support EECA's role in disseminating information about low-emission materials.

R16.1

The Energy Efficiency and Conservation Authority should, where cost-effective, develop programmes to support the use of low-emissions building materials in a way that lowers the overall emissions of a building across its full life-cycle, including the operational phase and end-of-life.

Some inquiry participants suggested changes to the Building Code provide scope to transition to materials with lower embodied emissions.

... [A]mendments to the resource and building consent frameworks [are] needed to enable and incentivise low emitting building materials and methods. (Greater Christchurch Partnership, sub. 57, p. 7)

In particular, some submitters suggested amending the Building Code to encourage greater use of wood.

The Building Code should be reviewed to ensure the correct balance between climate change issues and other requirements. In particular, consideration of the benefits of wood and wood-related products in any review of the building code is encouraged, both in construction and for insulation... Timber and other carbon-neutral building products should be preferred over carbon-intensive products. (Oji Fibre Solutions, sub. 71, p. 8)

Consideration of the benefits of wood and wood-related products in any review of the Building Code is ... encouraged... It is a low-embodied energy building material and a store of GHG for the life of the building. (New Zealand Institute of Forestry, sub. 73, p. 7)

While mitigation opportunities exist in the choice of materials and building techniques, several inquiry participants questioned the merit of using the building code to encourage low-emissions materials.

While it is understandable that use of the Building Code as a mechanism for encouraging resort to products and materials offering low emissions mitigation has appeal, there are inherent dangers in seeking to use a process designed to ensure as much as possible the construction of safe, durable and well-built structures for purposes other than those for which it was originally intended. (New Zealand Building Federation, sub. DR371, p. 2)

Regulation should enable, not restrict, alternative building materials and techniques when possible. The 'performance-based' philosophy that is the foundation of New Zealand's current Building Code provides sufficient flexibility for designers and developers to make choices about how to meet the required performance standards. We do not support changes to the Building Code that would prescribe particular building material or practices. (Property Council New Zealand, sub. DR283, p. 2)

The focus and purpose of the Building Code should remain on the production of good quality, safe and durable buildings. Any move to assess the embodied emissions of building materials as part of the Building Code would undermine its purpose and potentially raise concerns with safety, stability and durability. (New Zealand Steel, sub. DR309, p. 16)

Additionally, the compliance costs of establishing and enforcing appropriate thresholds across different building types may be relatively high. Instead, using building materials with low-embodied materials can be encouraged through EECA's expanded role in promoting low-emissions materials. Increasing the price and coverage of the New Zealand Emissions Trading Scheme (NZ ETS) as set out in Chapter 5 can also induce a search for low-emissions materials. However, in the absence of a uniform global emissions price the effect of the NZ ETS is likely to be limited to building materials that are predominantly produced domestically.

While no strong case exists for introducing a limit (in the Building Code) on allowable embodied emissions, building regulations must be sufficiently flexible to enable the adoption of low-emission building materials and processes (without compromising on other regulatory objectives, such as fire safety). The Building Code sets out the minimum structural and safety standards for building work (such as protection from fire, durability and moisture control), but not how the building should meet them. Building practitioners can comply with the Code by using prescriptive guidelines ("Acceptable Solutions") prepared by the Ministry of Business, Innovation and Employment (MBIE). Alternatively, building practitioners can propose other ways ("Alternative Solutions") to meet the requirements of the Code. Where an Alternative Solution is used, the burden is on the practitioner to demonstrate how their solution complies with the Code (NZPC, 2014b).

The Productivity Commission has previously found that this approach to regulation (known as a deemed-to-comply model) can help to enable innovation.

Deemed-to-comply models can help shift regulatory regimes from prescriptive/input-based approaches to more enabling approaches where desired: the existing input-based guidance becomes the detailed rules, but firms are allowed to seek other options. Deemed-to-comply models can also allow regulatory systems to adapt to changes in technology or shocks. Rather than having to change the underlying statute and regulatory framework, the detailed rules can be updated to reflect new developments. (NZPC, 2014b, p. 196)

The Government has recently stated that they intend to review the Building Code (Swannix, 2017). In addition, the *New Zealand Energy Efficiency and Conservation Strategy 2017–2022*, prepared by MBIE, included a commitment for MBIE and EECA to support improvements in the energy performance of commercial and residential buildings "through reviews of the energy efficiency provisions in the building

code and increasing minimum energy performance over time, where cost-effective on a lifecycle cost basis" (MBIE, 2017d, p. 17).

The main driver underlying both these commitments to review the Building Code appears to be a desire to lift the operational performance of buildings. However, given the potential for significant reductions in embodied emissions, it would be beneficial if future reviews of the Building Code included an exploration of whether the Code (in practice) presents any undue barriers to adopting materials and building techniques with low embodied emissions. As part of this process, the review should also consider any Code-related barriers to reducing emissions that are generated at the end of a building's life. For example Resilienz (sub. DR206, p. 34) suggests "making clearer and less onerous the code provisions for the reuse of buildings or building components to fulfil code-controlled functions in new building work."

R16.2

Future reviews of the New Zealand Building Code should examine whether the Code is sufficiently flexible to enable practitioners to adopt building materials and techniques with low embodied emissions, including the re-use of buildings and materials.

Emissions generated from using buildings

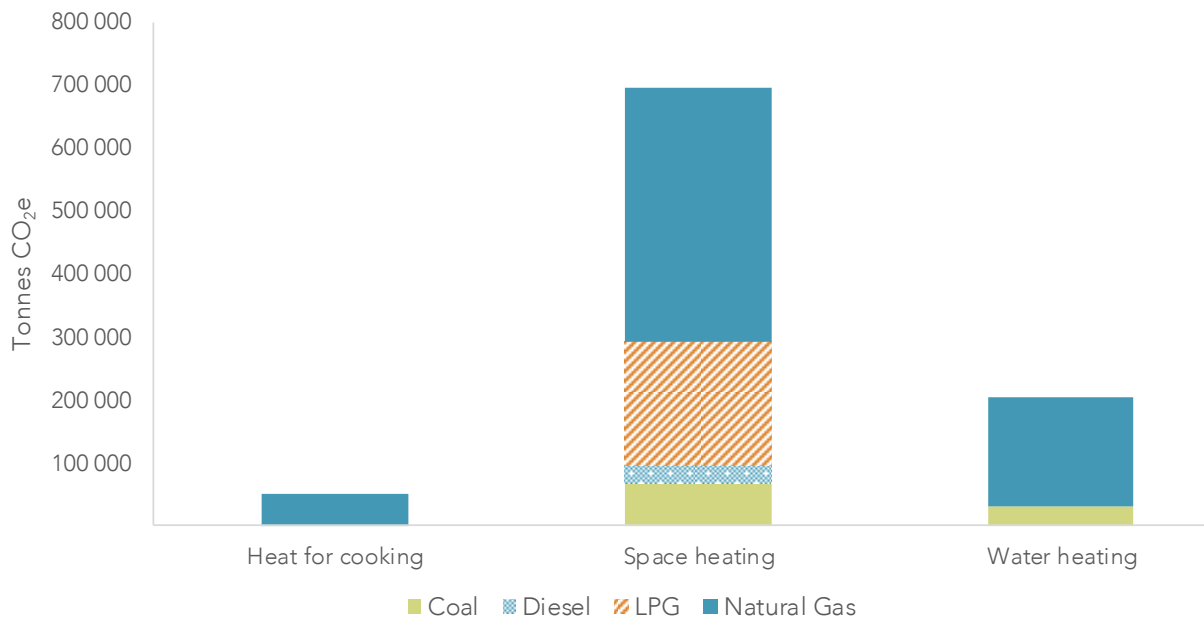
Emissions from the use of commercial and residential buildings (excluding any emissions from electricity generation) make up 2% of New Zealand's emissions (MfE, 2017f). Table 16.2 sets out a breakdown of these emissions, and shows that most emissions are carbon dioxide (CO₂) produced through the combustion of fossil fuels.

Table 16.2 Emissions from domestic and commercial and institutional buildings (2016)

Emissions source in each building type	Fuel consumption (TJ)	Total emissions (kt CO ₂ equivalent)
Commercial and institutional		
Liquid fuels	6 794	462
Solid fuels	1 081	101
Gaseous fuels	8 164	441
Residential		
Liquid fuels	3 392	207
Solid fuels	344	34
Gaseous fuels	6 360	344

Source: MfE (2018d).

The New Zealand emissions inventory does not distinguish what these fossil fuels are used for. However, EECA's *Energy end use database* shows that the majority of emissions from the combustion of fossil fuels in homes and public-sector buildings are generated from liquefied petroleum gas (LPG) and natural gas, primarily for space and water heating (Figure 16-3).

Figure 16-3 Emissions from the combustion of fossil fuels in homes and public-sector buildings

Source: EECA (2018b).

Notes:

1. Public sector buildings include those from the following sectors: central government administration, defence, education and training, healthcare and social assistance, local government administration, and public administration and safety.
2. Not all of the buildings included in the inventory are included in this figure due to different classifications.

Mitigation options for space and water heating are discussed in Chapter 14. That chapter finds that emissions pricing has an important role to play in encouraging the uptake of low-emission heating systems. It also recommends that government should take the lead in phasing out the use of coal and other fossil fuels for heating by limiting any future installation of fossil fuel-powered heating systems in government buildings.

F16.2

The main direct emissions from buildings arise from the combustion of fossil fuels for space and water heating. Higher emissions prices, greater clarity about future emissions prices, and limits on the use of fossil-fuel powered heating systems in government buildings will be important in transitioning to the use of low-emission fuels for heating buildings.

Electricity use in New Zealand buildings

Although the majority of New Zealand's electricity is generated from renewable sources, electricity generation has accounted for between 4% and 8% of New Zealand's total yearly emissions over the past five years (MfE, 2018e). Based on a production accounting model, these emissions are all attributable to the electricity generation industry because the GHGs enter the atmosphere at the point that the electricity is generated (as such, electricity is not included as an emissions source in Table 16.2). If emissions are attributed based on the point at which electricity is consumed, around half of emissions associated with electricity generation can be attributed to use in residential and commercial buildings. In 2016, 31% of electricity was consumed by residential customers, and 25% was consumed by commercial users (MBIE, 2017b).

Most emissions from electricity generation occur as a result of the use of fossil-fuelled generation to meet periods of peak demand on winter mornings and evenings (Chapter 13). Accordingly, from the perspective of reducing emissions in the short term, measures to reduce electricity use during peak times are of central importance (Concept Consulting, 2018a).

Much of the peak generation of electricity in New Zealand is met with fossil fuel (thermal) plant and therefore efforts to increase the share of renewables on the New Zealand grid need to include measures to flatten energy demand and make buildings more responsive to the more intermittent availability of renewables. (NZGBC, sub. 82, p. 1)

Several submitters agreed that periods of peak demand are the primary cause of emissions from electricity generation, but cautioned that electricity demand could rise steeply in future. This would make the continued or greater emissions from electricity generation more likely.

- The Building Excellence Group (sub. DR217, p. 5) noted the risk of additional gas turbine generation being used to meet “the compounded impacts of simultaneous peak demand loads from increased evening electric vehicle charging and evening energy use in residential dwellings”.
- Scion (sub. DR366) noted that several studies (BRANZ, 2015; EHINZ, 2018) have identified that many New Zealand homes are inadequately heated, and that if heating behaviour changed to address this, the overall energy demand from the New Zealand housing stock would increase.
- The New Zealand Green Building Council (NZGBC) noted that Statistics New Zealand’s median population projection indicates that by 2050 the population will have grown by around 1.4 million people, which at current occupancy rates translates to around 500 000 dwellings and a significant increase in workplace buildings. NZGBC (sub. DR263, p. 7) estimated “that at current average energy efficiency the additional homes and workplaces would add up to 7.5 TWh of grid demand. Much of this demand will happen in the early evening in winter contributing to peak capacity constraints”.

The following sections examine options to reduce emissions from electricity generation by lowering electricity demand in new and existing buildings.

Raising energy efficiency standards in the Building Code

As with emissions embodied in construction, several inquiry participants argued that energy efficiency standards in the Building Code should be strengthened as a way to reduce electricity use and associated emissions (eg, Guardians of New Zealand Super, sub. 32; The Morgan Foundation, sub. 127; and Molly Melhuish, sub. DR264). Several submitters noted that New Zealand’s Building Code is weaker than in other developed countries. For example, Jonathan Holmes notes that other “countries have incrementally improved or increased the level of their building codes to enforce higher building standards with respect to airtightness, moisture management, health & comfort, energy consumption... Currently the NZ Building Code... is now very much behind these standards set for buildings overseas” (Jonathan Holmes, sub. DR148, pp. 1–2).

As noted above, both the Government and EECA/MBIE have already committed to reviewing New Zealand’s Building Code. These reviews present an opportunity to fully assess whether raising energy efficiency standards delivers net benefits. From the perspective of reducing emissions, these reviews should establish how higher standards will affect demand for electricity, and how, in turn, this affects emissions from the generation of electricity. Several submitters supported a review of the Building Code.

We support the recommendations ... for the Government to commit to setting a timeline for reviewing and updating the New Zealand Building Code particularly on insulation, ventilation and lighting requirements. (New Zealand Super Fund, sub. DR334, p. 8)

Building Code energy performance requirements for large buildings (H1) have not been updated since they were introduced in 2000 (except for lighting). In EECA’s view, the scope of H1 is limited (e.g. heating, ventilation, and air conditioning (HVAC), a significant energy end use, is excluded) and the stringency for some criteria is low (e.g. minimal thermal envelope requirements and lighting). (EECA, sub. DR326, p. 20)

Auckland Council submitted that any review of efficiency standards in the Building Code should not be limited to assessment of emissions reduction potential and should include wider co-benefits.

Forthcoming reviews of New Zealand’s Building Code should not only assess whether there is scope to materially reduce peak demand for electricity through the introduction of more stringent energy efficiency standards... but also consider the wider co-benefits that more stringent energy efficiency standards can deliver. (Auckland Council, sub. DR273, p. 9)

One recent examination of the costs and benefits of building to standards that exceed the current Building Code showed that this has a small benefit in terms of emissions reductions, and relatively much larger benefits in terms of energy savings (Eaqub & de Raad, 2018).

Fletcher Building supported initiatives to improve the construction standard of new dwellings, but noted the importance of avoiding driving up construction costs.

The New Zealand Building Code could be used to reference green rating tools as a means of compliance and working towards zero carbon buildings. Likewise, Government could change procurement standards for infrastructure or KiwiBuild projects, to encourage further uptake of rating tools such as Green Star, Home Star, the Infrastructure Sustainability rating or Greenroads.

However, this must be considered in tandem with the broader policy objectives of reducing the cost of residential construction. Any changes made to carbon emissions with respect to the built environment must be achieved pragmatically, over the long term, so as not to push up the price of residential and commercial construction. (Fletcher Building, sub. DR349, p. 5)

Additionally, as discussed earlier, efficiency improvements need to be considered in the context of the full life-cycle of the building, including emissions embodied in materials. For example, EECA (2018e) notes that the correct use of thermal mass, such as masonry walls and concrete slab floors, can help to moderate internal temperatures, making houses more comfortable and energy efficient. But while thermal mass can help to reduce electricity consumption, materials such as concrete have relatively high embodied emissions. This point was raised by the New Zealand Building Federation, who noted that balance may need to be struck “between those products and materials which are manufactured to perform well as an ... energy saver but which require a significant input of electricity in the manufacturing process” (sub. DR371, p. 2). Similarly, BRANZ (sub. DR398, pp. 3–4) noted that

operational energy use (and its associated carbon burden) should not be divorced from the carbon burden of materials selected in building design. We suggest that the timing of carbon emissions is also potentially important in helping us plan our response to climate change. Front-loading carbon emissions now to achieve carbon savings decades into the future may not be the best strategy. This is particularly pertinent for New Zealand’s low carbon grid electricity. Instead we argue that any policy and market approach should be aware of all other potential impacts to reduce the risk of detrimental consequences.

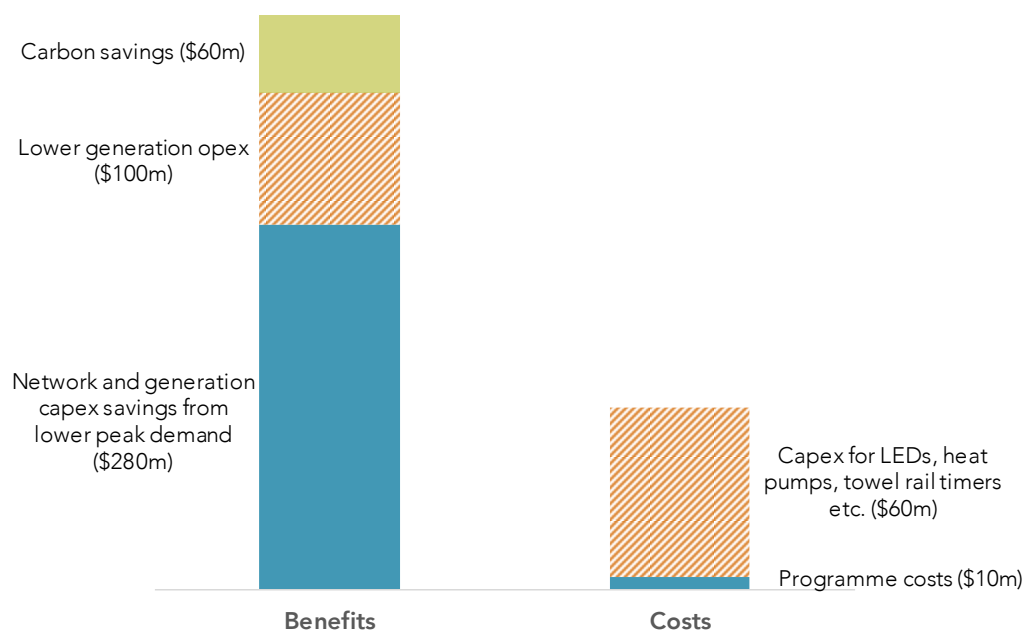
R16.3

Forthcoming reviews of New Zealand’s Building Code should assess whether there is scope to materially reduce peak demand for electricity through the introduction of more stringent energy efficiency standards.

Improving energy efficiency in existing buildings

Any changes to energy efficiency standards in the Building Code would only affect new builds or renovations of existing dwellings. Many older buildings, that will remain in use for decades, offer significant potential for efficiency improvements (Burgess, 2011).

Concept Consulting (2018b) has examined the emissions reduction potential associated with improving energy efficiency in residential dwellings. It determined that energy efficiency measures (mostly relating to space heating and lighting) had technical potential to reduce residential peak demand by around 0.8kW for each dwelling. Concept Consulting assumes that only 10% of the original technical potential is realisable (which it suggests is a conservative estimate). This equates to emissions reductions of about 170 kilotonnes (kt) of carbon dioxide equivalent (CO₂e) a year (around 5.6% of all emissions from electricity generation). Overall, Concept Consulting estimates the net present value of realisable net benefits over the next ten years to be around \$300 million (Figure 16-4).

Figure 16-4 Estimated realisable net benefits from energy efficiency in residential homes (10 years)

Source: Concept Consulting (2018b).

Notes:

1. Emissions savings were valued at \$60 a tonne of CO₂e.

In examining the uptake of energy conserving technologies, numerous studies have identified what is referred to as the “energy efficiency gap”. This is the difference between the actual level of investment in energy efficiency and the higher level that appears rationally justified from the consumer’s perspective (Barton, 2014; Marilyn Brown, 2001).

Studies examining the energy efficiency gap identify a number of potential market failures that may delay the adoption of energy conserving technologies. One example is the presence of split incentives where the landlord is responsible for the fabric of the building, but the tenant is responsible for paying the energy bills, and is affected by the building’s heating and ventilation performance (Marilyn Brown, 2001). As a result, the landlord has a relatively low incentive to invest in energy-efficiency improvements. The NZGBC (sub. DR263, p. 5) suggests that “home owners lack the expertise to appraise the payback of energy efficiency measures and put a high discount rate on future energy savings.” EECA (sub. DR326, p. 19) suggests that barriers to the uptake of energy efficiency “include a lack of observable information about energy efficiency, a focus on minimising capital costs, rather than lifetime costs during construction and refurbishment, and inefficiencies getting locked-in at the design stage.”

Reflecting these barriers, a range of initiatives are already in place to encourage the application of energy-efficiency technologies to existing buildings (Table 16.3).

Table 16.3 Initiatives to encourage improvements in energy efficiency (selected examples)

Type of intervention	Examples
Information provision	<p>EECA is a government-funded Crown entity that provides information services about how to improve energy efficiency in New Zealand homes and businesses.</p> <p>Non-government organisations, such as the Sustainability Trust, also provide information and advice about energy efficiency.</p>
Subsidies	<p>The <i>Warm Up New Zealand</i> programme provided grants of 50% of the cost of insulation for low-income, owner-occupiers and landlords with low-income tenants. Grants for landlords came to an end in July 2018, however a new programme, <i>Warmer Kiwi Homes</i>, was launched</p>

Type of intervention	Examples
	in July 2018 which provides grants for insulation and efficient heating for low-income households (grants for heating will be available from July 2019).
Voluntary initiatives	<p>Homestar – a rating tool developed by NZGBC that measures the health, warmth and efficiency of New Zealand houses (NZGBC, 2017).</p> <p>NABERSNZ – a system for rating the energy efficiency of office buildings adapted from the National Australian Built Environment Rating System (NABERSNZ, 2017).</p>
Regulatory approaches	<p>Residential landlords must disclose the extent of insulation in their properties in a signed statement as part of any new tenancy agreement (since July 2016). From 2019, rental properties must be insulated up to the standard of the current Building Code (where retrofitting is practical).</p> <p>Minimum energy performance standards require that only products meeting a minimum standard for energy efficiency can be sold in New Zealand. Importers and manufacturers must ensure products are tested using the correct method, comply with the minimum standard, and are registered before being offered for sale. Certain products must also display an energy efficiency rating label (EECA, 2017d).</p>

Government should continue to implement energy-efficiency initiatives that seek to address barriers that delay the uptake of energy efficiency measures, provided that these initiatives are assessed based on their costs and benefits. Such analysis requires a good understanding of the relative costs and benefits involved in decarbonising the electricity generation system. Any cost–benefit analysis (CBA) should also consider co-benefits, which for some energy efficiency programmes have proved significant. For example, a CBA of the Warm Up New Zealand programme (which provided subsidies toward the costs of retrofitting insulation and/or clean heating for pre-2000 houses), identified that the benefits of the programme were around five times its resources costs, and nearly all of the benefits were from the improved health of occupants (Grimes et al., 2012b).

Energy efficiency policy should be reviewed frequently as changes in technology may change cost–benefit valuations. For example, improvements in technology may lower the cost of efficient products (as an example, LED lightbulbs have come down in cost significantly). Also, increases in electrification in other sectors of the economy (for example electrification of process heat or rapid uptake of electric vehicles (EVs)) might increase the imperative to reduce demand elsewhere on the electricity network.

Inquiry participants recommended further consideration of a range of energy efficiency policies – a selection is set out in Box 16.1.

Box 16.1 Policy measures to address the energy efficiency gap – views from submitters

Efficient lighting standards

Inquiry participants noted that New Zealand’s standards are falling out of step with those in other developed countries, including Australia, and that higher efficiency standards for lighting would help to reduce peak demand.

New Zealand should consider efficiency standards on lamps that will phase-out inefficient incandescent screw-in lightbulbs, in favor of LED, CFL [compact fluorescent lamp] or other more efficient types. Such standards are big energy savers and are now phasing in in Europe, China, the US and other countries. (American Council for an Energy Efficient Economy, sub. DR285, p. 6).

Generally speaking, New Zealand and Australia align standards to ensure consistency in our markets for trade benefits. However, since 2009, New Zealand’s lighting standards have not

synchronised with Australia's, who have phased out the importation of inefficient incandescent lightbulbs, [and] is in the process of phasing out halogen lamps. (EECA, sub. DR326, p. 13)

Building efficiency labelling

Several submitters suggested the introduction of mandatory energy efficiency labelling for buildings.

Energy rating tools and certification systems should be mandatorily implemented in NZ to robustly account for a building's primary energy demand and therefore for the operational carbon emission. (Scion, sub. DR366, p. 112)

Whilst we have efficiency labelling for appliances and fuel efficiency information about vehicles we have no such labelling ...of building performance. In the UK all properties put on sale have to provide a current and potential energy efficiency rating. (Jonathan Holmes, sub. DR148, p. 1)

Government should introduce mandatory energy labelling of all buildings at point of sale or rent to give consumers sufficient knowledge on which to base their decisions. (NZGBC, sub. DR263, p. 6)

In particular, submitters supported making NABERSNZ (a system for rating the energy efficiency of office buildings) mandatory for some or all office buildings.

It is recommended that the Government investigate and consult on having a mandatory requirement for New Zealand commercial facilities, of a certain size in square metres, to have, and display, a NABERSNZ rating for these facilities as is done in Australia. (Christchurch City Council, sub. DR284, p. 7)

The NABERS scheme is successful in the Australian market because it is mandatory for buildings above 1,000 sqm floor area. NABERSNZ exists in New Zealand but has experienced limited uptake. Making NABERSNZ mandatory in New Zealand will drive uptake, efficiency and emissions reductions. (Energy Management Association of New Zealand, sub. DR242, pp. 9–10)

A review of NABERS in Australia identified that it had been successful in inducing behavioural change to improve energy efficiency (ACIL Allen, 2015). The review projected a reduction in end-use energy consumption of 10 020 terajoules (TJ) and greenhouse gas (GHG) emissions of 2 051 kt of CO₂e over the period 2010 to 2023. Emissions reductions associated with greater uptake of NABERS in New Zealand would not be of a comparable magnitude, as electricity generation in New Zealand has a much lower emissions intensity than in Australia.

EECA (sub. DR326) reported that, given the success of NABERS at abating emissions in Australia, they are assessing options including voluntary uptake of NABERSNZ ratings (status quo), mandatory ratings for government offices only, and mandatory ratings for all offices (i.e. the current Australian position).

Building commissioning

EECA notes that, based on overseas evidence, greater uptake of building commissioning may provide significant scope for energy efficiency improvements.

Building commissioning (and re-commissioning) is the process of tuning the internal systems (most commonly HVAC systems) in a building for optimal energy performance. Over time, energy using systems deviate from optimal performance as, for example, temperatures are adjusted in response to ad hoc requests from tenants, building controls (e.g. louvres) begin to fail, and building management systems are not upgraded. For new buildings, commissioning should occur as part of the building handover process and, for an existing building, commissioning should be part of any maintenance regime. (EECA, sub. DR326, p. 21)

The Commission has not assessed the costs and benefits of specific interventions to improve energy efficiency. However, there does appear to be a particularly strong case to review standards relating to lighting.

- *Lighting makes a substantial contribution to peak demand* – Concept Consulting (2018b) estimates that the average peak electricity demand is about 2.2kW per residential dwelling and that lighting makes up about 18% of this demand (0.4kW).
- *Negative abatement costs* – EECA (sub. DR326) estimates that improving New Zealand’s lighting standards could reduce emissions by 1.4Mt of CO₂e through to 2030 at a negative net cost to New Zealand. For households, more efficient LED lightbulbs have a higher up-front cost, but use 85% less power to generate the same amount of light. Assuming that a light is used for three hours each day, replacing one incandescent 100W bulb with a 1400 lumen LED will save a household approximately \$25 each year²¹⁹ (Energywise, 2018).
- *Strong evidence base* – As noted above, Australia phased out the importation of inefficient incandescent lightbulbs in 2009 and is currently phasing out halogen lamps. Australia’s experience is likely to provide useful lessons for implementing a similar policy in New Zealand.

R16.4

The Ministry of Business, Innovation and Employment should review the costs and benefits of additional programmes (including those aligning New Zealand’s lighting standards with Australia) to deliver energy savings in existing housing and buildings.

Emissions in the disposal of buildings

Life-cycle analysis includes emissions resulting from the disposal of a building at the end of its life. These emissions can be reduced by extending the lifespan of buildings.

To reuse older building structures instead of constructing “virgin” buildings can be looked upon as a strategy to also reduce resource use and the associated EEG [embodied energy and greenhouse gas emissions] of the product and construction process stage. (IEA, 2016b, p. 71)

In addition, re-using or recycling many building materials is possible. For example, New Zealand Steel (sub. 64, p. 15) noted that “steel is infinitely recyclable” and that “the long-life nature of steel, complemented with adequate recovery mechanisms at product end-of-life, can effectively eliminate waste.” As noted earlier (Recommendation 16.3), forthcoming reviews of the Building Code should assess whether the Code presents any unnecessary barriers to the re-use of buildings, components or materials.

BRANZ estimates that up to 1.7 million tonnes of construction and demolition waste is sent to landfill every year (MacGregor et al., 2018). Disposing of these materials to landfill not only means that they are not being recovered for further use, but that they contribute to adverse environmental effects, including the generation of methane as waste breaks down and rots.

As discussed in Chapter 15, waste accounts for around 5% of New Zealand’s total emissions, most of which is methane generated at landfills. Chapter 15 sets out a range of measures to incentivise a reduction in the amount of waste that enters landfills, including a gradual rise in the waste disposal levy (and extending its coverage), and inclusion of emissions from landfills in a methane quota system or a dual-cap NZ ETS. If implemented, these pricing mechanisms would significantly strengthen the incentive to reduce waste from the demolition of buildings, along with construction waste more generally. In addition, BRANZ has established a work programme to improve resource efficiency in the building and related industries. The programme provides wide-ranging information about how to reduce construction waste, including information about designing for waste minimisation and planning for deconstruction (BRANZ, 2018b).

16.2 The relationship between urban form and emissions

Around 70% of New Zealanders live in an urban area with a population greater than 50 000. As a result, much of the country’s energy use and transport-generated emissions occur within urban areas. Differences in

²¹⁹ The savings assume the bulb is used three hours each day at 27 cents per kWh. The calculation does not include the higher purchase price for LED bulbs – however, the price difference between incandescent and LED bulbs has narrowed significantly. At August 2018, one major retailer was advertising 1400 lumen LED bulbs for between \$9 and \$12. These are estimated to have a lifespan of over 10 years, while incandescent bulbs will last around one year.

urban form (the physical characteristics that make up urban areas, including the shape, size, density and configuration of settlements) affect the magnitude of emissions.

Several submissions to this inquiry (for example, Tauranga City Council, sub. 126; and Canterbury District Health Board, sub. 16) suggested that higher-density urban forms are more efficient from an emissions perspective. They encouraged the Productivity Commission to consider urban design policies to encourage more compact development, and to prevent sprawl.

The following sections examine the potential magnitude of emissions reductions associated with different urban forms and consider whether urban planning tools should be used to pursue a certain urban form.

How does urban form affect emissions?

Research examining the relationship between different types of urban form and GHG emissions focuses on three main issues:

- transport-related emissions associated with different urban forms;
- emissions associated with how different types of building are operated; and
- emissions involved in how different types of neighborhoods are built.

The relationship between urban form and transport emissions

Many studies have examined the relationship between different urban form variables and transport emissions. While the results of these studies reveal some inconsistency (Robert & Jin, 2010), a growing body of literature shows that residents in more compact and transit-friendly urban areas drive less than those in more dispersed settings. As Ewing et al. (2010) note:

For decades, it has been known that compact areas have lower automobile use per capita and greater use of alternative modes of transport than do sprawling areas. They also tend to generate shorter trips. The combined effect is significantly less VMT [vehicle miles travelled] per capita in compact areas. (p. 20)

Robert and Jin (2010) examined 370 urban areas in the United States and found that areas with higher population density typically have lower VMT per capita. This result is primarily due to lower shares of the population auto-commuting, and shorter travel distances. The reduction in VMT in higher-density areas is partially offset because, on average, such areas have a greater concentration of road-infrastructure, which induces more travel.

Drawing on an extensive review of literature (primarily American) on the relationship between the built environment and household travel, the Transportation Research Board (2009), also concluded that developing more compactly lowers VMT.

Both logic and empirical evidence suggest that developing more compactly, that is, at higher population and employment densities, lowers VMT. Trip origins and destinations become closer, on average, and thus trip lengths become shorter, on average. Shorter trips can increase trip frequencies, but empirical evidence suggests that the increase is not enough to offset the reduction in VMT that comes from reduced trip lengths alone. Shorter trips also may lower VMT by making walking and bicycling more competitive alternatives to the automobile, while higher densities make it easier to support public transit. (p. 88)

The review raised some important issues about the relationship between density and VMT.

- Although a large number of studies examine urban form and vehicular travel, “capturing the nature and magnitude of the link between the two has proved elusive” (p. 89). Shortcomings of some studies have resulted in widely varying results regarding the importance of changes in land use and the magnitude of effects. For example, many studies identify statistically significant correlations between urban form and VMT, but few establish causal relationships using longitudinal data.
- Density is often used as a proxy for other urban form variables, but increasing density alone is insufficient to reduce the number of vehicles on roads. For this to occur, increases in residential density must

happen in conjunction with other changes such as mixing land uses to bring housing closer to jobs and shopping and increased accessibility of public transport.

The Transportation Research Board (2009) concluded that, drawing on the results of the studies that they deemed to have the most robust methodologies, the effects of increasing density are relatively modest. These studies indicate that doubling the density of a residential area is associated with a reduction in VMT of between 5% and 12% (Transportation Research Board, 2009).

Among the submissions to this inquiry that discussed urban form, most raised the potential for urban design, including higher-density development, to reduce transport emissions.

Good urban design encourages active and public transport and therefore emphasis should be placed on regulations and policies that facilitate good urban design planning. (CDHB, sub. 16, p. 6)

There needs to be strong coordination between land use and public transportation routes to reduce private vehicle use (e.g. the Auckland Unitary Plan's impetus on a quality compact urban form should help to facilitate improved and more effective public transport initiatives). (Auckland Regional Public Health Service, sub. 105, p. 11)

Sprawling, low-density development forces people to travel further and makes public and active transport costly or unviable, locking in dependence on private cars. Governments and councils should encourage compact urban form and allow more homes to be built near to where people work, study and play. This means loosening height and density restrictions, rezoning for mixed-use development, and removing detrimental regulations such as minimum parking requirements. (The Morgan Foundation, sub. 127, p. 7)

Substantive changes in density are likely to take several decades to eventuate. As noted above, most international studies suggest that density would need to double to achieve a reduction in VMT of 5% to 12%. From at least as early as the late 1990s, planners in Auckland have aspired to significantly increase the density of the city. But, between 2001 and 2013, Auckland's density (people per hectare) increased at an average yearly rate of just 0.8% or 1.2% (depending on how density is calculated) (Mead, 2013). At this rate, it will take several decades to achieve a meaningful reduction in VMT. Several submitters pointed out that the longer payoff period for emissions reductions associated with changes to urban form is not a reason to delay action. For example, Resilienz (sub. DR206, p. 11) suggests that this longer payoff period should be "taken as a compelling reason to "get on with" lowering such emissions profiles as soon as practicable, even if incrementally".

However, where payoffs occur over a longer time period there is a greater chance of technological developments altering the emissions payoff. In particular, the anticipated rise of EVs and other low-emissions vehicles may produce much of the emission reduction sought from reducing vehicle travel. (Even so, this does not affect other emissions that accrue in the shorter-term, such as lower emissions embodied in the materials needed to construct higher-density neighbourhoods – this is discussed in the following section.)

As the New Zealand Council for Infrastructure Development noted:

All available evidence today strongly indicates that electric vehicle prices are reducing, and will continue to reduce, as technology becomes cheaper. ...With the decline of conventional engines, the basis for urban planning to manage down private vehicle use is greatly reduced, yet we have seen very little evidence that shifting energy trends are reflected in planning provisions. (New Zealand Council for Infrastructure Development, 2016, p. 9)

Auckland Council argues that, even with a widespread adoption of EVs, there are good reasons to manage down private-vehicle use separate from reducing emissions.

A reliance on electric vehicles may reduce emissions but issues relating to traffic congestion and lost productivity will persist and potentially worsen as population increases. Traffic congestion is costing Auckland up to \$2 billion a year in lost productivity... Urban planning can promote viable alternatives such as rapid transit and reduce the need to travel through promoting a quality compact urban form that provides access to amenities within convenient walking and cycling distances. In addition the significant opportunities to improve wellbeing by reducing health issues such as stress, obesity, heart disease and cancer, through increasing active transport mode share will be lost if we do not manage down a reliance on private vehicle use through urban planning. (Auckland Council, sub. DR273, p. 11)

Stephan et al. (2013) note that, even with the widespread adoption of EVs, public transport is still more efficient from an emissions perspective, given the emissions embodied in the construction of roads, parking spaces and other infrastructure. Opportunities to reduce emissions embodied in infrastructure are discussed later in this chapter (section 16.3).

F16.3

Increasing the density of urban areas, combined with good public transport and accessibility, can generate small, but material reductions in vehicular travel. The associated reductions in emissions will be influenced heavily by the rate of uptake of electric vehicles and other low-emission vehicles.

Urban form and building operational efficiency

In addition to the relationship between urban form and VMT, studies have also examined the relationship between urban form and residential energy use. These studies typically find that dwellings in higher-density urban areas use less energy because dwellings in higher-density settings are typically smaller and so require less energy to heat and cool.

NZGBC raised the issue of building size.

New Zealand has the 3rd largest new-build dwellings in the world (as with car ownership second only to the USA and Australia). The average size of a newly built dwelling rose from 110m² in 1974 to 197m² in 2013 ... and this is despite a drop in the average occupancy of each home during the same time. The average space per person has risen dramatically. The BRANZ Heep report shows that floor space and energy use in dwellings is strongly correlated meaning that planning rules that encourage denser development and therefore smaller homes would (as with transport) have the effect of reducing carbon emissions. (NZGBC, sub. 82, pp. 2–3)

Table 16.4 shows that, on average, higher-density dwellings (townhouses and apartments) constructed in 2006 have a much smaller floor area than detached housing. This is only partially offset by detached housing having a greater average occupancy rate. As such, on a per capita basis, higher-density housing is smaller, and therefore may require less energy to operate.

Table 16.4 Size and occupancy rates for different types of dwelling, 2006

	Higher density	Detached housing
Average floor area of new-builds	107.9m ²	215.4m ²
Average occupancy rate	2.0	2.9
Average floor area per person	53.9m ²	74.3m ²

Source: Stats NZ (2008, 2018a).

Notes:

1. 2006 is the most recent year that Stats NZ collected occupancy data.

In addition to being smaller, it is often suggested that attached dwellings typically require less energy to heat and cool than a detached dwelling of a similar size because it has less exposed surface area (Ewing & Rong, 2008). Byrd and Matthewman (sub. DR202) present a different view:

Subsequent research reviewed in this paper has demonstrated that heat loss from building fabric is not a good indicator of whole-building energy use for compact buildings. When other factors are accounted for (common area energy use, occupancy, energy use for non-space heating) the correlation between built form and energy use is shown to be weak. Case studies in different climates using actual energy data have indicated that compact (tall) buildings perform worse than low-rise buildings. Furthermore, when energy generated on a building is taken into account, the net energy balance of a building strongly favours low-rise buildings rather than compact high-rise. (p.13)

However, the case studies referred to by Bryd and Matthewman were not conducted in New Zealand cities. Research that compares energy use in attached and detached housing using New Zealand data is scarce, but was examined in a dissertation by Polkinghorne (2011). That study found detached dwellings spend significantly more on residential energy than attached dwellings; yet it is not clear that the study controlled for the age of dwellings.

Urban form and emissions embodied in construction

Because the construction of different types of urban environments involves different types of materials and processes, the emissions embodied in construction can vary significantly.

Several overseas studies have examined the emissions embodied in the construction of different neighbourhoods. These typically find that higher-density neighbourhoods with multi-storey apartment buildings embody higher emissions due primarily to the need for greater concentrations of steel and concrete (Oldfield, 2012). However, these higher embodied emissions are usually more than offset by the fact that, on average, people living in high-density areas occupy smaller dwellings. For example, Norman et al. (2006) examined the GHGs emitted and energy used during the manufacture of construction materials used in low- and high-density developments in Toronto. On a square metre basis, the results show that high-density developments are 1.25 times more energy intensive and GHG emissions intensive, than low-density developments. However, when examined on a per capita basis, the relationship reverses, with low-density developments embodying approximately 1.5 times higher emissions. An examination of different neighbourhood types in Austin, Texas produced similar results, with higher-density areas embodying less energy per capita (Nichols & Kockelman, 2015).

Stephan et al. (2013) examined the embodied emissions for a typical low-density residential neighbourhood in Melbourne, and compared these with a range of alternative development scenarios, such as a 10% reduction in the floor area of all dwellings, or replacing half the dwellings with various forms of medium-density housing. They found that the emissions embodied in higher-density housing are significantly lower, owing to factors such as fewer materials being used (less floor space), shared walls, and greater use of shared infrastructure.

Submitters also noted that increasing the density of urban areas can reduce emissions embodied in infrastructure. For example, Auckland Council (sub. DR273, p. 10) notes that the promotion of compact urban form should be considered “in the context of ... avoiding the need to build infrastructure that would otherwise be required to service new outlying development and potentially lock-in additional carbon.”

F16.4

On a per square metre basis, high-density dwellings such as apartment buildings typically have higher embodied emissions when compared with standalone dwellings. However, because such high-density dwellings typically have much smaller floor areas, when examined on a per capita basis, the relationship with standalone dwellings reverses.

Urban planning as an emissions mitigation strategy

The previous section established that higher-density urban areas tend to be associated with lower emissions as a result of lower levels of private vehicle travel and lower embodied emissions (and potentially a lower requirement for operational energy) per capita in higher-density housing forms.

The Commission has previously made numerous recommendations that seek to enable density to develop in areas where people want to live. For example, in *Using land for housing*, the Commission identified a range of planning rules that limit the ability to develop higher-density housing. These included minimum apartment size requirements, apartment balcony requirements and minimum parking rules (NZPC, 2015). The same report also highlighted rules that could have net benefits, but which had been poorly designed in many cities. These included building height limits, density controls and overly broad heritage or “special character” protections.

The Commission has also found that much of the densification that has occurred in New Zealand cities has been concentrated near the urban fringe. Auckland in particular observed a subdued level of development in inner suburbs close to the city centre, while its largest contribution to intensification between 2001 and 2013 occurred between 10km and 20km from the city centre. Intensification of this nature is unlikely to capture the emissions-reduction benefits stemming from reduced private vehicle use and increased walkability and accessibility.

Submitters to this inquiry also noted the presence of barriers to higher-density development.

Our members note the minimum car parking requirements and the barrier they cause to intensification and new-build apartment living. Many buyers (and potential buyers) that live in the metropolitan area or near a key public transport route have no need for a car park... Urban planning rules are stringent and do not adapt to social changes quickly. We support flexible rules that account for the different living preferences of New Zealanders. (Property Council of New Zealand, sub. DR283, p. 3)

Higher density housing is severely restricted by the urban planning controls in place in most New Zealand cities... Built form in most New Zealand cities is controlled by site coverage limits, boundary setbacks, height limits and sunlight access planes (also known as recession planes). These cause few problems for single storey suburban houses on large sections, but they drastically constrain making efficient use of small sections where higher density is desirable... (James Carr, sub. DR318, p. 1)

The Commission's inquiries into *Better urban planning* and *Using land for housing* both identified the importance of efficient infrastructure pricing. In particular, the Commission has argued that where new developments require an extension of local infrastructure, new residents who benefit from the infrastructure should bear the costs of installation.

When those who benefit from new infrastructure pay installation costs, they automatically consider these costs when deciding where to locate... If developers and buyers of the newly developed property do not face these costs, they will find locating away from the existing network artificially cheap. This can bias development towards greenfield areas and away from land already serviced by network infrastructure. (NZPC, 2017a, p. 310)

Infrastructure costs for new development can vary significantly, depending on factors such as the type and density of dwellings/structures, whether the site is greenfield or infill, and the site's proximity to existing infrastructure. However, on average, costs tend to be lower for higher-density developments (NZPC, 2015).

R16.5

Councils should review and if justified remove, barriers to higher-density development, particularly in inner suburbs and in areas close to public transport routes. Councils should also ensure that infrastructure charges reflect the full costs of dispersed development.

While a strong case exists for local governments to take measures to free-up the capacity of urban areas to increase density in central locations, and along key public transport corridors, the Commission considers that land available for development should cater for a range of housing preferences. In high-growth areas, this will likely mean enabling capacity for cities to both grow up (through densification) and out (through greenfield development). Where councils use urban limits to constrain the outward expansion of cities, they should ensure that mechanisms are available to promptly review the placement and tightness of urban limits (NZPC, 2015).

The Commission has found that past policies that sought to limit urban expansion have involved significant costs. For example, the Commission's inquiry into *Better urban planning* (2017a) showed that urban limits used in Auckland to contain development within city limits have created an artificial constraint on land supply – leading to higher land prices and less affordable housing. Zheng (2013) showed that residential land inside Auckland's urban limit is almost 10 times more expensive than land outside the limit.

Urban planning systems should be flexible and responsive to changing technology

The Commission's *Better urban planning* report found that "the planning system is not well set-up to deal with the change and unpredictability inherent in growing cities" (NZPC, 2017a, p. 5). Because urban areas are complex systems that evolve in response to changes in technology and because of interactions between

millions of individual decisions, it is difficult to anticipate in advance the effects of higher emissions prices and other policies to reduce emissions. This reinforces the importance of planning systems being flexible and responsive, and having the ability to change land uses as required.

Flexibility and responsiveness in urban planning are particularly important in the context of climate change, as it is difficult to predict in advance the impact on cities of technological change, emissions prices and other mitigation strategies. For example, as set out above, current evidence points broadly toward higher-density urban forms exhibiting a lower emissions profile. However, changes in technology could significantly alter this. As an example, Bryd and Matthewman (sub. DR202) argue that dispersed urban form may be more energy efficient than compact urban form (Box 16.2).

Box 16.2 **The impact of disruptive technologies on future urban form in New Zealand cities**

Byrd and Matthewman (from Unitec and the University of Auckland respectively) suggest that the emergence of electric vehicles (EVs) and other disruptive technologies will fundamentally change the relationship between urban form and transportation energy use (sub. DR202). They argue that current policies to increase urban density have been influenced by research that has not taken account of technological change. They note that EVs are likely to dominate the market in years to come, and that “roof-mounted PVs [photovoltaics] in lower density urban areas can potentially generate more energy than is required for typical transport needs in urban areas” (p. 11). Due to the greater availability of roof area for placement of PVs in suburban areas, they argue that when disruptive technologies are implemented “suburbia becomes a net energy generator and that travel distance within an urban area has little impact on resource depletion or carbon production” (p. 13).

F16.5

Urban areas and technology will evolve in ways that are difficult to predict, and in ways that could significantly alter the emissions associated with different urban forms. It is important that urban planning systems are able to respond and adapt to these changes over time.

16.3 Construction of infrastructure

Section 16.1 describes the life-cycle emissions associated with the construction, maintenance, operation and disposal of buildings. In addition to the construction of residential and commercial buildings, each year a significant amount of construction activity is dedicated to putting in place and maintaining New Zealand’s infrastructure. Budget 2018 included plans for infrastructure spending of \$42 billion over a five-year period (New Zealand Government, 2018a). Over the same timeframe, forecast capital expenditure across all local governments was \$20 billion (Local Councils, 2018).

The emissions embodied in the construction of infrastructure can be significant. For example, the Swedish Transport Administration showed that an estimated 3.8 million tonnes of GHG emissions will be generated from construction (including material extraction, production, and transportation) of planned infrastructure investments for 2014–2025 in Sweden. This represents approximately 6% of Sweden’s total yearly GHG emissions (Miliutenko et al., 2014).

Assessing the underlying need to build infrastructure

An important first step in seeking to reduce emissions embodied in new infrastructure is to question the underlying need to build additional infrastructure in the first place.

Reducing carbon is not just about building new assets in a more intelligent way – it’s about demanding better performance from what we already have. Most of the UK’s infrastructure networks are already mature. Although new infrastructure is needed to meet new social and economic needs, getting more out of existing assets will play a significant part in increasing capacity and meeting customer demand.

Many of the carbon reduction opportunities available will be associated with upgrading, adapting and modernising infrastructure currently in operation. (UK Treasury, 2013)

The Commission's inquiry into *Using land for housing* found significant potential for local authorities to use existing infrastructure assets more intensively (NZPC, 2015). Additionally, the Commission recommended greater use of demand management techniques (such as volumetric charges for water and road tolls) to incentivise more efficient use of existing assets. Local Government New Zealand also advocated for greater use of demand management tools.

Thought should be given to ... increasing the use of incentives such as demand management tools, for example congestion pricing, as a means of driving behavioural change, and how the revenue from such tools could be utilised to support councils and their communities with climate adaptation and mitigation action. (LGNZ, sub. 36, p. 10)

Box 16.3 provides an example of how the construction of additional infrastructure can be avoided through efficient use of existing assets. Also described is an example from the United Kingdom where more effective use of existing assets reduced the scale of new investment.

Box 16.3 Reducing infrastructure emissions through effective use of existing assets

Wellington City Council

In 2015, Wellington City Council identified Victoria Street in Wellington's CBD as an area suited to a significant increase in residential and commercial activity. The council's preliminary estimates were that the infrastructure costs associated with accommodating this growth could be as much as \$20 million. However, more detailed analysis, making use of the council's asset management systems, showed that the planned level of development could be accommodated entirely with existing capacity. This finding prompted the council to undertake a major project looking at infrastructure use and demand across the city, with a view to optimising the use of previous investments (NZPC, 2015).

Anglian Water

As part of its 2010–2015 Asset Management Plan, Anglian Water identified the need for a 60km pipeline between the Covenham Water Treatment Works and Boston township. Detailed network modelling led to a solution in which 40% of the 15 megalitres of flow a day could be transferred through existing assets, reducing the size of pipeline required and eliminating an intermediate pumping station. Further gains were made by using standard products extensively. Relative to the original design, these improvements achieved a 12 000 tonne (57%) reduction in emissions during construction and an associated £13 million cost saving (Green Construction Board, 2013).

Infrastructure planning and procurement

Through their planning and procurement decisions, governments have the ability to influence the extent of emissions generated from the construction and use of infrastructure assets.

Life-cycle assessment of infrastructure emissions

As with buildings, emissions embodied in infrastructure accrue throughout the life-cycle of the asset. Life-cycle includes not only the materials and processes involved in the initial construction, but also operational emissions, maintenance and disposal at the end of the asset's life. Further, infrastructure design can also have a significant impact on emissions associated with the asset's use. For example, a smoother road surface reduces rolling resistance. In turn, this improves the fuel efficiency of vehicles travelling on that road. However, this needs to be balanced against the emissions embodied in the additional materials and construction processes required to build and maintain a smooth surface (T. Wang et al., 2014).

Manzo and Salling (2016) note that, for transport infrastructure projects, traditional evaluation frameworks commonly fail to provide a complete picture of environmental costs.

[W]hile the direct environmental costs, such as air pollution from vehicles operation, are normally included in the project evaluations, the indirect environmental costs, such as the energy and emissions associated with vehicle manufacturing, are usually not. (p. 274)

By contrast, a Life Cycle Assessment (LCA) considers the environmental impact of a given product or process throughout its lifespan. The Heavy Engineering Research Association (HERA) (sub. 96) recommended the use of LCAs:

When it comes to embodied energy and associated carbon footprint the application of Life Cycle Assessments (LCA) principles over the whole life of a product including its reuse, recycling or landfill option is in our view the appropriate pathway to describe environmental product performance. (HERA, sub. 96, p. 12)

Box 16.4 provides an overview of how LCAs are used in the planning stages of transport infrastructure in Norway.

Box 16.4 Life-cycle emissions analysis for Norwegian transport infrastructure

In Norway, life-cycle energy use and GHG emissions are always calculated as part of the CBA for transportation projects. GHG emissions are treated as an environmental cost in CBA, and GHG emissions caused by a project are calculated using the unit price for CO₂e. Life-cycle energy use and subsequent GHG emissions are quantified using a life-cycle methodology that assesses the direct energy use and GHG emissions from traffic, and the direct and indirect energy use and GHG emissions related to the construction, operation and maintenance.

Source: Miliutenko et al. (2014).

Sustainable procurement

Including environmental objectives in procurement decisions is often referred to as *sustainable public procurement*, although other terms such as *green purchasing*, *environmentally preferable purchasing*, or *socially responsible procurement* are sometimes used interchangeably (UNEP, 2017b).

Auckland Council (sub. 97) and Waikato Regional Council (sub. 48) noted the influence of public spending and the potential benefits associated with sustainable public procurement.

[M]any business-as-usual decisions have an emissions impact and reduction potential. In particular, public spending wields enormous purchasing power to influence supply chains and to achieve multiple benefits through sustainable public procurement (SPP). Positive social results from SPP include poverty reduction, improved equity and respect for core labour standards, while allowing governments to improve resource efficiency, support waste minimisation and achieve emissions reduction. (Auckland Council, sub. 97, pp. 16–17)

One area where the national transition to a low-emissions economy can occur is through the government procurement opportunities. Procurement that respects the prudential responsibilities with using public funding can be directed towards purchasing low-emission infrastructure and process related goods and services that take account of life-cycle greenhouse gas emissions. (Waikato Regional Council, sub. 48, p. 8)

Several other submitters to this inquiry also identified the influential role of public procurement in supporting lower-emissions products and services generally (Christchurch City Council, sub. 13; LGNZ, sub. 36; Contact Energy, sub. 29), in the uptake of EVs (Guardians of New Zealand Super, sub. 32; Motor Industry Association, sub. 51), and to stimulate the development of low-emissions technologies (Export New Zealand, sub. 91).

Box 16.5 sets out an example of how sustainable procurement is used in the Netherlands to reduce the carbon footprint of infrastructure investments.

Box 16.5 Sustainable public procurement in the Netherlands

The Department of Public Works of the Dutch Ministry of Infrastructure and the Environment (Rijkswaterstaat, or RWS) has developed an approach to encourage people to minimise environmental impacts related to infrastructure building. RWS tenders combine two sustainability criteria.

- Companies are rated on a scale of one to five on the basis of energy savings, efficient use of materials and use of renewable energy. Contractors that score favourably on this rating benefit from a discount applied to their tendering price (between 1% and 5%).
- The Sustainable Building Calculator (Dubocalc) is provided to tenderers to assess the environmental impacts of the use of materials specified in a contract. The costs are derived from an authoritative life-cycle analysis of materials (from extraction to demolition and recycling), including CO₂ emissions and ten other impacts. The aggregate environmental cost is translated into a monetary value that is combined with the tender price to award the contract.

Source: Baron (2016).

Effective emissions prices are essential for sustainable infrastructure procurement

Chapters 3 and 5 find that New Zealand's emissions prices will need to rise significantly over the next few decades if New Zealand is to significantly reduce its domestic emissions. Importantly, the NZ ETS needs to be accompanied by stable and credible climate policy (Chapter 8).

The NZ ETS should establish an emissions price at a level that reflects the harm from emissions. As part of investment decisions, Government agencies responsible for investment in long-lived infrastructure would be expected to factor this price into investment decisions and consider likely changes in the emissions price over the life of infrastructure assets.

The current emissions price in the NZ ETS is around NZ\$23 a tonne of CO₂e, which is well below the levels expected to be needed for New Zealand to meet its emission reduction targets. Even if prices rise rapidly, over the short term the use of the current emissions price in investment decisions will under-value the importance of emissions.

As noted in Chapter 5, in situations where emissions prices are absent or too low, governments should consider using a shadow price of emissions in their investment decisions. Examples of such decisions include investments in transport, water and energy infrastructure, buildings, and car fleets. These investments involve not only large resources but, once made, become sunk, irreversible and long-lived. Getting them wrong can lock in high emissions for a long time.

Several submitters supported the use of shadow prices, particularly in the context of government investment decisions.

I strongly recommend using shadow pricing for emissions in all cost-benefit analysis across [the] NZ state sector and influencing local government to do likewise – from 2018/19 onwards. (Liz Springford, sub. DR379, p. 8)

We support the use of shadow pricing for emissions – this should apply from 2018/19 across all NZ state sector and local government analysis. This should however be at least \$88 per tonne CO₂ equivalent (OraTaiao: New Zealand Climate & Health Council, sub. DR378, p. 10)

A shadow carbon price reflecting the required long term investment costs is absolutely necessary to avoid inefficient future investments in fossil fired solid fuel coal boilers. We recommend a shadow carbon price for use in government procurement policies that is not the ETS cap price, as this will defeat its purpose. (Pioneer Energy, sub. DR221, p. 1)

Venture [Southland] agrees with the idea of using a shadow carbon price in the absence of the emission pricing being too low or absent, such as currently being used by the European Investment Bank. (Venture Southland, sub. DR336, p. 6)

The Climate Commission could also recommend an appropriate shadow emission price to be used by government and businesses when making investment decisions in long-lived capital. (Catherine Leining, sub. DR279, p. 6)

The adoption of 'shadow pricing'... could provide an effective method for local governments to embed emissions-reduction into their decision-making regarding transport, energy, and water infrastructure. (Whakatane District Council, sub. DR317, p. 4)

The case for applying a shadow emissions price when assessing government investment decisions has merit from the perspective of avoiding emissions lock-in. As noted above, a significant capital investment in infrastructure is planned over the next five years. In addition, government leadership in adopting shadow pricing could have some positive spillovers, including raising the profile of shadow pricing and providing a practical approach to shadow pricing that businesses and other organisations could adopt. The potential for shadow pricing to have a broader influence was noted by Liz Springford (sub. DR379):

As well as avoiding locking in high-emissions from white elephant infrastructure and optimising tax and rates expenditure, other advantages of rapid introduction and uptake of up-to-date shadow pricing across the state sector and local government include: (i) learning by doing; and (ii) influence across NZ, as one-third of NZ's workforce are employed by state sector or local government. (p. 9)

Shadow pricing should be a transitional measure, that is used over the short-term until the recommended changes to the NZ ETS (Chapter 5) come into effect and the emissions price has responded to these changes. The proposed Climate Change Commission should, in conjunction with the Treasury and other government agencies responsible for major infrastructure investments (eg, the New Zealand Transport Agency), establish a shadow emissions price and guidelines for how to factor that price into decisions about government infrastructure investment.

R16.6

The proposed Climate Change Commission should work with the Treasury to develop guidelines on how to apply shadow prices for GHG emissions to decisions about government infrastructure investment. Shadow pricing should be used as a transitional measure until recommended changes to the NZ ETS come into effect and the emissions price has responded to these changes.

16.4 Conclusion

Emissions are generated throughout the life-cycle of buildings and infrastructure, including emissions embodied in the production of building materials and building processes; and emissions generated through operation, maintenance and end-of-life disposal. Options to reduce emissions from the built environment are limited by the fact that most buildings and infrastructure are already in place and have long lifespans. But on the contrary, any emissions in new buildings or infrastructure are locked in for a long time.

The introduction of an effective emissions price, coupled with stable and credible climate policy, is critical in encouraging the adoption of low-emissions materials in buildings and infrastructure. An effective emissions price will also strengthen the case for astute infrastructure asset management, including maximising the lifespan of existing assets, and factoring current and likely future carbon prices into any new investment decisions. As a transitional measure, government agencies should use a shadow emissions price when assessing options for new infrastructure investment.

While New Zealand has a relatively low-emissions electricity system, coal and gas-fired stations are still used to meet peak demand – much of which is generated by residential electricity use in winter mornings and evenings. Improving the energy efficiency of buildings provides a valuable avenue for tempering electricity demand, particularly as transport and other parts of the economy electrify. Energy efficiency policies that reduce electricity use during periods of peak demand will have the greatest benefit in terms of emissions reductions.

The nature of urban environments can also affect emissions – in particular, transport emissions are lower in cities that facilitate lower levels of private vehicle travel. Many inquiry participants advocated for the use of

urban planning policies to encourage more compact urban development, as this can reduce vehicular travel and emissions. But to make a meaningful emissions reduction, density needs to increase significantly, and occur in tandem with other changes such as improved public transport and accessibility to employment and other travel destinations. Councils should take measures to free up the capacity of urban areas to increase density in central locations and along key public transport corridors.

Part Five:

Achieving a low-emissions economy

Through Parts One to Four of this report, the Commission has explored the key opportunities and risks for New Zealand in making the shift to a low-emissions economy, and possible pathways for this transition. Additionally, it has recommended a comprehensive set of policies and institutions to drive emissions reductions while improving incomes and wellbeing.

Part Five brings together the Commission's main findings regarding the opportunities and challenges New Zealand faces in transitioning to a low-emissions economy, focussing on the essential actions that government must take in the short term to set the transition on the right footing.

17 Achieving a low-emissions economy

This inquiry focuses on how to maximise the opportunities and minimise the risks of transitioning to a low-emissions economy. The reforms recommended in this report cover a breadth of issues including emissions pricing, institutional settings, and regulatory change, all of which work together to achieve the behaviour shift required to transition to a low-emissions economy.

This chapter brings together the Commission's main findings regarding the opportunities and challenges New Zealand faces in transitioning to a low-emissions economy. While sustained action and change will be required for New Zealand to meet its targets for reducing emissions, this chapter focuses on the essential actions that government must take in the short term to set the transition on the right footing.

17.1 What is the challenge?

New Zealand is committed to be an active participant in the international response to the challenge of climate change (through the 2015 Paris Agreement), principally by making substantial reductions in its greenhouse gas (GHG) emissions. As explained in Chapter 9, New Zealand can play its part in achieving the Paris 2°C goal by reducing its emissions from long-lived GHGs (eg, carbon dioxide) to net-zero levels (or below) by around mid-century and reducing emissions from short-lived GHGs (eg, methane) to a lower level than at present.

The transition to a low-emissions economy will require significant changes that affect households, businesses, industries, cities, and regions. Among these changes, the Commission has identified three that must occur if New Zealand is to achieve its low-emissions goals:

- a transition from fossil fuels to electricity and other low-emissions fuels across the economy;
- substantial levels of afforestation; and
- changes to the structure and methods of agricultural production.

The transition from fossil fuels entails a rapid and comprehensive switch of the light vehicle fleet to electric vehicles (EVs) and other very low-emissions vehicles, and a switch away from fossil fuels in providing process heat for industry, particularly for low- and medium-temperature heat users.

Large-scale afforestation will be critical for offsetting New Zealand's remaining emissions. A planting rate similar to the highest ever recorded in New Zealand will likely need to be sustained over the next thirty years. Planting will mostly take place on land currently used for sheep and beef farming.

Other changes in the way land is used are also necessary, such as an expansion in horticultural and cropping land, and greater adoption of low-emissions practices on farms.

17.2 A strategic assessment

New Zealand is well positioned to respond to the challenge...

While the scale of the transition to a low-emissions economy is significant, New Zealand has several advantages that make it well positioned to respond to the challenge. New Zealand's large and sparsely populated land area provides scope for significant expansion in forest planting. Forestry already offsets a significant share of gross GHG emissions, and its contribution could increase. Afforestation presents other opportunities in addition to sequestration, including the potential for greater volumes of high-value wood products (which could potentially reduce the use of emissions-intensive materials in construction), feedstocks for bioenergy, and increased biodiversity.

New Zealand's existing electricity generation system is another comparative advantage. With a high proportion of electricity generation coming from low-emissions sources, the system is among the least emissions-intensive in the world. While a complete elimination of all fossil-fuelled generation with current technologies would likely result in a detrimental increase in electricity prices, there is significant scope to

increase the total volume of electricity generated, while also reducing the amount generated from fossil fuels. The ability to produce an abundant supply of low-emissions and inexpensive electricity will be particularly valuable as the light vehicle fleet and parts of industry transition from fossil fuels to electricity.

While substantial changes are needed to the New Zealand Emissions Trading Scheme (NZ ETS) to effectively incentivise behaviour change, the basic architecture is already in place. Recent changes are resulting in more effective prices, and the recommendations in this report (including the need to establish an emissions pricing scheme for biogenic methane, CH₄), are designed to be complementary, and build on these reforms.

Finally, the prominence of pastoral agriculture makes New Zealand's emissions profile distinctive from other developed countries. This presents a significant opportunity for New Zealand to provide leadership in developing an effective approach to tackling biogenic CH₄ while retaining strong environmental integrity.

... and addressing emissions will generate significant co-benefits...

Nearly every policy recommended in this report to support a reduction in emissions comes with some form of co-benefit. For example:

- a reduction in nitrous oxide (N₂O) emissions would improve water quality, while forest planting could reduce soil erosion and siltation of waterways;
- an uptake of EVs will reduce the emissions of particulates and other substances in exhaust fumes that are harmful to human health;
- a policy to improve energy efficiency of residential dwellings can have important health benefits; and
- application of a circular economy approach to waste has wider sustainability benefits, in addition to emissions-reduction benefits.

...but New Zealand must overcome some challenges and manage risks

While New Zealand is relatively well positioned to respond to the low-emissions transition, there are some areas that present a challenge. For example, New Zealand's vehicle fleet is old, and has a slow turnover rate. Even with a rapid uptake of low-emissions vehicles, the transition of the fleet will take decades.

Some of New Zealand's emitting sources are costly to decarbonise or have little potential for emissions reductions under current technologies without reducing production. For example, the scope to make large reductions in the emissions of livestock farms without reducing output is limited. Also, no commercially viable technologies are yet available for producing products such as steel and aluminium without generating emissions. Reducing output in these industries could lead to some emissions leakage, and therefore limit any benefit from New Zealand's mitigation efforts. The lack of cost-effective mitigation solutions for heavy road transport and aviation is also a risk to New Zealand, given its remote, low-density geography and reliance on freight and tourism.

Achieving the transition to a low-emissions economy relies heavily on significant future technological advances (eg, reductions in the cost and weight of EV batteries). Based on recent trends, this is not an unreasonable assumption. However, if technology develops slower than anticipated, the cost of the transition will be greater.

The impact of the transition will likely vary significantly across different households, businesses and communities. In particular, a rising emissions price could increase costs for low-income households and disproportionately affect communities with emissions-intensive industries. Targeted support will likely be required to help offset negative impacts of the transition and help to maintain support and momentum toward emissions reductions.

In the short to medium term, sequestration through significant afforestation will play a major role in meeting New Zealand's emissions-reduction targets. But, if handled poorly, this could create risks such as a loss of biodiversity and damaging disruption to rural communities. More broadly, slow rates of forest planting would place pressure (through higher emissions prices) on other emitting sectors. More planting of native species would contribute to biodiversity, build public support, and extend forestry's sequestration horizon.

It is also important to recognise the temporary nature of forest sequestration. Because there are limits to how much forestry the country can sustain, forestry will only buy time. In the longer term, new approaches to bring net emissions to zero will be required. It is critical that emissions reductions in other parts of the economy continue alongside afforestation.

... and address poor productivity that hinders the ability of the economy to handle change

A successful economy is one that is flexible in the face of change. In a flexible economy, resources move readily from less productive to more productive firms, and firms face few barriers to absorbing and benefiting from new technologies.

These economic characteristics are highly pertinent for the low-emissions transition. Many emissions-intensive industries will face disruptive change, while new employment and business opportunities will emerge in low-emissions industries. It will be important that workers can easily retrain and move to different industries, and firms can respond quickly to, and harness, promising low-emissions innovations developed in New Zealand or overseas.

Yet, in its previous inquiries and research, the Commission has found that, in general, New Zealand's economy is not as nimble and productive as it could be. Improving New Zealand's underlying productivity performance will play an important role in the transition, alongside the policy levers and decisions focused directly on mitigating emissions.

17.3 Immediate priorities

Achieving New Zealand's emissions reduction targets requires concerted effort and widespread change. Among the numerous policies recommended in this report, three areas hold particular priority in establishing the conditions needed for a successful transition. Change in these areas should be implemented within the next two years to set the strategy on the right trajectory and avoid New Zealand incurring unnecessary costs later in the transition.

Reform the New Zealand Emissions Trading Scheme and introduce biogenic methane into an emissions pricing system

Ensuring that emissions are appropriately priced is an essential component in New Zealand's mitigation strategy. Emissions pricing provides a strong incentive to reduce emissions at least cost. It decentralises decisions to invest, innovate and consume across the economy to people who have the best information about opportunities to lower their emissions. An emissions price is also pervasive through the whole economy – shaping resource and investment decisions across all emitting sectors and sources.

However, the current NZ ETS has a number of weaknesses. The reforms to the NZ ETS set out in Chapter 5 should be a high priority so that the scheme begins to drive behavioural change and changes in land use – particularly greater rates of afforestation. The emissions price in the NZ ETS will need to rise significantly, so the sooner this process begins, the more gradual the price increase can be. Also, a higher emissions price in the NZ ETS will help to identify those emissions sources where complementary policies are required to drive emissions reductions.

Further, while the NZ ETS should be the primary mechanism to drive reductions in long-lived gas emissions (such as from carbon dioxide and N₂O), a pricing system should also be established for biogenic CH₄. This system, either a dual-cap NZ ETS or an alternative methane quota system, will separately incentivise emissions reductions of biogenic CH₄ in recognition of its nature as a short-lived GHG.

Clear and stable climate-change policies

New Zealand lacks clear and stable climate-change policies. This lack of clarity and political agreement about longer-term goals has weakened incentives for change and undermined confidence in existing policies. The Government is currently developing a Zero Carbon Bill that will set a 2050 emissions target and aims to establish the foundations and institutions needed to meet that target. The Bill should establish:

- legislated and quantified long-term GHG emissions reduction targets;

- a system of successive “emissions budgets” that, separately for short- and long-lived gases, translate long-term targets into short- to medium-term reduction goals; and
- an independent Climate Change Commission to act as the custodian of New Zealand’s climate policy and long-term, climate-change objectives. The Climate Change Commission should provide objective analysis and advice to the Government on the scale of emissions reductions required over the short to medium term; progress towards meeting agreed budgets and targets; and barriers, opportunities and priorities, to reduce emissions.

Substantial investment in the innovation system

New Zealand’s strategy for its transition to a low-emissions economy should have a strong focus on innovation. Government should devote significantly more resources to low-emissions innovation than the modest and inadequate current allocation (Chapter 6). Yet, extra resources are unlikely to yield significant discoveries to assist in reducing emissions immediately. Rather, the investment will pay off more gradually throughout the transition. But given the long timeframes involved in bringing innovative ideas to fruition, it is important that the significant additional resources and infrastructure needed to boost New Zealand’s innovation system are established quickly.

Complementary policies

This report has also identified that a suite of complementary policies will be needed to support and accelerate the transition. These should be developed in parallel with work to establish the three foundations described above.

Prioritise policy that helps to avoid emissions lock-in

Chapters 11 to 16 set out numerous policies to reduce emissions across major emissions sources. Many of these recommendations may be able to be implemented in parallel. But to the extent that some prioritisation may be required, the Commission sees a good case to prioritise the following policies that seek to avoid investments that lock in emissions for an extended period:

- emissions standards for vehicle imports;
- a feebate scheme to accelerate the uptake of EVs;
- limits on the installation of new fossil-fuel powered heating systems; and
- the use of shadow pricing in government investment decisions.

Develop an abundant supply of low-emissions electricity

New Zealand already has a relatively low-emissions electricity system. However, maintaining a growing supply of abundant, low-cost, low-emissions electricity will be important as other parts of the economy switch from fossil fuels to electricity, particularly transport. Chapter 13 recommends regulatory changes to facilitate the expansion of both grid-scale and distributed renewable energy generation. It also recommends reducing barriers to innovative technologies that assist consumers to manage their demand during peaks.

Accelerate afforestation

Land use will need to change substantially if New Zealand is to transition to a low-emissions economy by 2050. In particular, land planted in forests will need to increase by between 1.3 million and 2.8 million hectares, mostly converted from marginally profitable beef and sheep land. In addition to their recent one billion trees programme, the Government should take other steps including making it easier and less risky for small foresters to participate in the NZ ETS and by providing recognition for carbon sequestered in harvested wood products.

17.4 Meeting the challenge

New Zealand can achieve a successful low-emissions economy, but there will be challenges. Stronger action in the immediate future is required, as delayed action will compound the transition challenge and risks New Zealand being left behind in technology and economic opportunities. Sixteen years ago, the

Government enacted New Zealand's current climate-change law. Yet, New Zealand has since made virtually no progress in reducing its emissions, in part due to the absence of political consensus around the fundamental need for action across the entire economy.

Shifting to a low-emissions trajectory will critically depend on political leadership and fortitude. Inertia and resistance to change can be expected. The challenge will be one of communication and conveying the advantages and opportunities of transformational change to the population at large. But, meeting this challenge will likely be futile without broad agreement across the political spectrum on both the need and means to make the transition.

This report sets out the policy architecture for New Zealand to transition to a low-emissions economy, while continuing to grow incomes and wellbeing. Implementing the recommendations in this report will set New Zealand on the path to meeting its emissions-reduction targets. Inevitably, the journey will be long and punctuated by change and uncertainty. Technological change, climate-change policy in other countries, and unintended consequences stemming from mitigation policies could each conspire to slow or derail progress.

While challenging, the transition is achievable given concerted commitment and effort across government, business, households and communities – up to and beyond 2050.

Findings and recommendations

The full set of findings and recommendations from the report are below.

Chapter 2 – Climate change, emissions and the New Zealand context

Findings

F2.1

As a small country, New Zealand's absolute contribution to global emissions is small. However New Zealand's per person gross emissions are one of the highest among developed countries.

F2.2

New Zealand is yet to see a sustained decline in its emissions. Gross and net emissions have flattened over the last decade after steadily increasing before the mid-2000s.

F2.3

Agriculture makes up nearly half of New Zealand's emissions – more than any other developed country. Transport is the next largest source, contributing about a fifth of emissions. Electricity emissions are relatively low in New Zealand due to the country's heavy use of low-carbon, renewable energy.

F2.4

Forestry offsets just under one-third of New Zealand's gross emissions. Yet, because planting rates have dropped sharply since the planting boom in the 1990s, and many of these forests are shortly due for harvest, carbon offsets from forestry are likely to decline if there is not a significant increase in planting.

F2.5

New Zealand's emissions profile differs markedly to other developed countries, because of its high agricultural emissions and low electricity emissions. While carbon dioxide is New Zealand's most prominent greenhouse gas, over half of emissions are methane and nitrous oxide.

F2.6

Transport has been the biggest contributor to the rise in New Zealand's gross emissions since 1990. The growth in emissions from dairy farming was partially offset by a fall in emissions from sheep and beef farming. Because of the growth in transport emissions, carbon dioxide emissions have risen much more than methane and nitrous oxide.

F2.7

Economic and population growth have been important underlying factors in New Zealand's rising emissions. Over the last 25 years, New Zealand's emissions per person and emissions per unit of output have decreased, but the increase in population and output has caused overall emissions to increase.

F2.8

Meeting New Zealand's first commitment under the Paris Agreement will be highly challenging, even with immediate and strong action to reduce domestic emissions. International offsets can play a part in meeting this commitment, but any delay in domestic reductions will make future commitments even more difficult to achieve.

Chapter 3 – Mitigation pathways

Findings

F3.1

The Commission’s modelling depicts, in a stylised manner, three possible ways that low-emissions technologies could develop. First, they could fail to develop or develop only slowly. Second, they could develop faster in ways that disrupt existing industries. Third, they could also develop faster, but lower the emissions intensity of existing industries. The differences between these ways in which technology could develop are profound and fundamental to New Zealand’s future as it seeks to transition to a low-emissions economy.

F3.2

Modelling indicates that New Zealand can achieve low emissions (25 Mt CO₂e) or even net-zero GHG emissions by 2050. New Zealand’s potential to achieve either of these targets stems from a confluence of factors, most notably the potential for significant increases in afforestation and a low-emissions electricity system facilitating the cost-effective decarbonisation of the wider energy sector. The modelled pathways rely on a combination of three key drivers – the expansion of forestry, changes to the structure and methods of agricultural production, and switching from fossil fuels to clean electricity and other low-emissions fuels in transport and process heat.

F3.3

In meeting the 25 Mt CO₂e target, all modelled pathways achieve or come very close to achieving net-zero emissions of long-lived GHGs by 2050, with declining methane emissions. This would mean that, by 2050, New Zealand would no longer be contributing to further global temperature increases.

F3.4

Land-use change varies across the six modelled pathways. Forestry land expands greatly across the six pathways while land for sheep and beef farming declines. Land for dairy farming increases under those pathways that see the development of a methane vaccine and falls in the other pathways. Without the methane vaccine and with disruptive advances in plant-based meat and dairy substitutes, land for horticulture (and cropping) is likely to expand.

F3.5

Even if New Zealand follows a pathway consistent with net-zero emissions by 2050, it is highly likely that domestic net emissions will overshoot the 2021-2030 emissions budget for New Zealand’s first Nationally Determined Contribution.

F3.6

In Motu’s Land Use in Rural New Zealand model, future changes in land use are highly sensitive to assumptions about relative prices for agricultural and forestry commodities. It is unclear to what extent real-world decision making would be as sensitive as this. Due to the strong reliance on afforestation in most of the modelled pathways, this sensitivity flows through into the emission prices that the model generates. Further research into the economics of land-use decisions is warranted.

F3.7

Modelling indicates that higher population growth and slower removal of free allocation would each modestly increase the emissions prices required to meet targets.

F3.8

All modelling over periods as long as three or more decades needs to be treated with caution. Over such timescales, the economy, technologies and land uses will evolve and change in unpredictable ways. Computable General Equilibrium models are suited to modelling perturbations within an existing economic structure rather than these long-term shifts. Also, modelling a low-emissions transition in New Zealand needs to incorporate land-use change because it is a large source of emissions and sequestration of GHGs.

F3.9

Modelling indicates that New Zealand has the potential to decarbonise towards net-zero GHG emissions at emissions prices in the range of \$150 to \$250 a tonne of CO₂e by 2050. Although a significant increase from today's price, these prices are comparable to those expected to be needed in other developed countries to reduce emissions to levels consistent with the Paris Agreement ambition of keeping global temperature rise to below 2°C.

Should disruptive technological change and associated market conditions eventuate, New Zealand's emissions reduction targets may be achieved at very low emissions prices. If this does not occur and innovations instead allow existing industries to prevail, significantly higher emissions prices may be needed.

F3.10

All the modelled pathways show that the reductions in net GHG emissions come mainly from forestry, agriculture and from replacing fossil fuels with clean electricity and other low-emissions energy sources in transport and process heat. New Zealand's decarbonisation strategy should therefore focus on this portfolio of mitigation opportunities. The dependence on forestry sequestration is particularly strong in the case of the target of net-zero GHG emissions by 2050.

F3.11

Pathways that feature stronger government action in the near term constrain future carbon costs and reduce the risk of long-term targets becoming unattainable if technological progress is slow. If disruptive technological innovation does occur, early action would enable much lower future costs in all cases. This lends support to an approach combining robust early policy action with strong and effective government support for innovation.

F3.12

New Zealand's transition to a low-emissions economy will be a long journey to a known and desired destination, but through very uncertain terrain. It would be foolhardy to try to pin down the best route for this 32-year journey to 2050 in advance. Rather, the situation calls for careful preparation, a capability for adaptation, and a balance between responsiveness to new information and policy stability. This approach will best equip the country to deal well with whatever terrain emerges.

F3.13

While afforestation provides New Zealand with a very effective means for reducing net emissions in the short term and medium term, it is unlikely to continue to do so in the longer term since achieving such reductions would entail planting more and more land in trees. New Zealand will need to make additional cuts in gross emissions in the longer term. Such cuts will be costly in the absence of technological breakthroughs.

Chapter 4 – Transitions

Findings

F4.1

A transition involves an intense period of change and restructuring that is different to the everyday processes of change in a market economy.

F4.2

Five of the key drivers of change in an economic transition are price, technology, social and demographic shifts, culture and values, and policy. These interact and influence each other according to the specifics of time and place.

F4.3

The characteristics of successful, high-productivity economies include openness to innovation, adaptability, and the capacity to mobilise capital, labour and other resources to take advantage of new opportunities. These characteristics are all important for the successful transition to a low-emissions economy.

F4.4

The scale, nature and complexity of the low-emissions challenge combine to produce a very substantial public-policy challenge. Identifying and addressing misalignments between core climate policies and policies outside the climate policy portfolio will be vital.

Chapter 5 – Emissions pricing

Findings

F5.1

A carbon tax and an emissions trading scheme (ETS) are different forms of emissions pricing, yet have much in common. Each is a potentially powerful instrument that can act across the economy in a decentralised manner to reduce greenhouse-gas emissions at least economic cost.

Yet, a carbon tax and an ETS also have important differences such as whether the emissions price is fixed and the quantity of emissions is uncertain, or vice versa. These differences bear on the decision about whether New Zealand should adopt a carbon tax or retain an ETS as the centrepiece of its transition to a low-emissions economy.

F5.2

The additional benefits of emissions pricing using a carbon tax rather than an emissions trading scheme would have to be large to outweigh the significant cost of dismantling the New Zealand Emissions Trading Scheme and setting up and becoming familiar with a new system. While the two instruments are similar in many ways, a reformed NZ ETS is likely to perform better given that New Zealand has an established ETS and has an urgent need for substantial domestic emissions reductions to achieve its targets.

F5.3

An emissions trading scheme can be designed to protect emissions-intensive, trade-exposed (EITE) firms from emissions leakage by allocating free emissions units. New Zealand's method of allocating units incentivises firms to reduce their emissions intensity but not reduce emissions through reducing output. Free allocation costs the government revenue. The case is strong to withdraw the free allocation of units to EITE firms over time as competing firms in other countries also face emissions pricing.

F5.4

Auctioning permits (emissions units) in an emissions trading scheme can enable a government to raise potentially large amounts of revenue. Several legitimate options are available to the government to decide how it spends this revenue. Those options include reducing distortionary taxes, investing in specific initiatives to enable emissions reductions at lower cost, and supporting vulnerable households, communities and businesses adversely affected by emissions pricing.

F5.5

Because decisions that impact on greenhouse-gas emissions often involve a planning horizon of many years, the stability of policy settings and institutional arrangements for emissions pricing is vital. If the stability of policy settings is uncertain, or confidence in them is lacking, then potential investors will hold back from investing to lower their emissions.

F5.6

The choice between abating domestically and through purchasing emissions reductions from other countries must be carefully weighed. When international credits are of a high integrity, investing in reductions overseas may provide a way for New Zealand to deliver global emissions reductions for which it is responsible at lower cost to New Zealand. Even so, comparing international and domestic abatement costs must be done correctly in terms of capital costs, reputation costs, co-benefits, and future opportunities.

F5.7

An emissions trading scheme is an effective form of emissions pricing to incentivise sequestration of carbon dioxide through forestry. Foresters earn emissions units as trees grow and must relinquish them on harvest. They can bank earned units as a hedge against future price uncertainty. Owners of permanent forests can become “carbon farmers” by earning and selling emissions units.

F5.8

The point of obligation to pay for emissions needs to achieve a good balance between broad coverage, low administration costs, and effective transmission of emissions-price incentives combined with effective monitoring, reporting, and compliance. Placing points of obligation upstream or downstream of actual emissions sources (as well as at source) and using minimum-size thresholds may help to achieve the best balance.

F5.9

It is preferable to have a system in which emissions are priced at a level that reflects their harm and will achieve New Zealand’s emissions reduction targets. If, however, emissions prices are absent or too low, then a convincing case exists for governments to use a shadow price of emissions to guide their investment decisions.

F5.10

The co-benefits of mitigating greenhouse gas (GHG) emissions can be substantial, such as better air and water quality. The co-benefits increase the value to society of reducing GHG emissions. Policy options that, in addition to emissions pricing, could incentivise businesses and people to consider co-benefits include a separate tax or subsidy scheme, a separate permit scheme, direct regulation, or the use of a shadow price in cost-benefit analysis.

F5.11

The New Zealand Emissions Trading Scheme began with an impressive all-sectors, all-gases architecture and access to international trading for least-cost mitigation. However, low international prices and various reforms to soften its impact have blunted its effectiveness, particularly in achieving domestic greenhouse-gas reductions. Key policy uncertainties have led to business and investor doubts about future rules and prices, undermining incentives to invest in lower emissions.

F5.12

Some basic building blocks of an effective ETS are present in the NZ ETS, but lack of others has led to low prices and tepid responses from participants. As a result, the NZ ETS has not reduced domestic emissions or increased domestic removals to the extent needed to achieve a significant reduction in New Zealand's domestic greenhouse-gas emissions. A key problem is lack of certainty and credibility about future unit supply and the pathway to achieving New Zealand's long-term targets to meet its international commitments.

F5.13

The current features of the New Zealand Emissions Trading Scheme (NZ ETS) do not meet the criteria for a good system of emissions pricing. The further in-principle reforms announced in July 2017 and the recent proposals released for consultation would take the NZ ETS in the right direction, but require important details to be settled to provide strong and sufficiently clear signals to participants, as well as to households, businesses and investors who are not direct participants.

F5.14

Arguments exist both for and against interventions that try to influence the price of emissions units from exceeding certain high or low thresholds. On the one hand, interventions may create distortions, have unintended consequences and interfere with the market's self-regulating responsiveness. Uncertainty about when and how interventions will happen could exacerbate rather than alleviate large price swings. On the other hand, by adjusting quantities of New Zealand Units that they put into the market when high or low price thresholds are reached, the authorities may achieve benefits such as:

- the use of qualifying international emissions reductions when those are significantly less costly than further reductions in New Zealand; and
- achieving greater reductions in emissions domestically at low cost, while maintaining a minimum incentive for long-term investments and innovations in low-emissions.

F5.15

Substantial modelling and other evidence indicate that emissions prices will need to rise far above their current levels if New Zealand is to decarbonise its economy over the next several decades. Even so, it is notable that emissions prices required to achieve a given emissions-reduction target will generally be lower:

- the better the potential for deploying innovative technologies to reduce emissions;
- the higher the credibility of signals about future emissions prices; and
- the greater the flexibility in the economy to re-allocate resources from high- to low-emitting activities and sectors.

F5.16

An effective system of emissions pricing should form the centrepiece of a strategy to reduce emissions. Yet the strategy needs other elements to back up pricing and take the lead in some situations where pricing is not powerful enough because of market or government failures, or distributional considerations.

Recommendations

R5.1

The Government should reform the New Zealand Emissions Trading Scheme (NZ ETS) rather than replace it with a carbon tax. The reforms should focus on making the NZ ETS effective in achieving New Zealand's post-Paris commitments to substantially reduce net domestic GHG emissions.

R5.2

The Government should progressively withdraw free allocation to EITE firms over the next two to three decades to a pre-announced schedule but, subject to an ability to slow the withdrawal rate if, on independent advice, it finds that major competitors are not, actually or imminently, facing comparable emissions prices.

R5.3

Because international emissions trading could help New Zealand achieve a net greenhouse-gas emissions target at significantly lower economic cost, the Government should:

- support and contribute to UNFCCC efforts to establish rules and an international trading infrastructure with high integrity
- establish sound guidance for New Zealand public or private purchases of offshore emissions reductions that properly cost such purchases against the alternative of investing in additional domestic reductions – in terms of capital and current costs, reputation costs, co-benefits and investment in future economic opportunities for New Zealand; and
- establish sound guidance for New Zealand public or private purchases of offshore emissions reductions that properly cost such purchases against the alternative of investing in additional domestic reductions – in terms of capital and current costs, reputation costs, co-benefits and investment in future economic opportunities for New Zealand; and
- make clear decisions, based on expert advice, about how much international purchasing to allow within specified future time periods.

R5.4

The government should undertake a well-crafted reform to fix the weaknesses in the New Zealand Emissions Trading Scheme that compromise its ability to deliver effective emissions pricing and New Zealand's emissions targets for 2021 to 2030 and beyond. The reform should establish:

- control over the supply of New Zealand Units (NZUs) that is consistent with New Zealand's long-term, low-emissions strategy;
- clarity over the use of international units for reducing greenhouse gases; and
- a new independent agency to sell NZUs and exercise stewardship of the NZU market. The agency should operate within a clear government mandate and be responsible for market stability, transparency and forward guidance to support efficient decision making by investors to lower their net emissions.

R5.5

The Government should be responsible for specifying the New Zealand Unit (NZU) price threshold at which it considers the cost of further domestic emissions reductions would cause net detriment to New Zealand and that other means to achieve its emissions budget (eg, purchasing qualifying international emissions reductions) could be less costly. The Government should also decide at what low price, if any, it would be desirable for the quantity of NZUs supplied to be reduced below the cap and for the

price of NZUs to be maintained as a minimum incentive for long-term investments and innovations in low emissions.

The new independent agency set up to auction NZUs and oversee the NZU market should have responsibility for implementing the Government's decisions cost-effectively and for the market's overall stability and efficiency. This will include setting the quantity caps for NZUs to meet the multi-year emissions budgets and conducting auctions. The agency's "constitution" should require it to act transparently via public notification of its rules and logic, and any changes in them, well in advance.

Chapter 6 – Innovation

Findings

F6.1

Innovation in clean technologies is a key enabler of transitioning to a low-emissions economy while growing incomes and wellbeing. Innovation is positively influenced by pricing emissions, by direct government support for research and development into low emissions, and support for the deployment and adoption of innovation. Innovation is discouraged by subsidies to emissions-intensive activities.

F6.2

Subsidies for fossil fuels act in direct opposition to the world's transition to low greenhouse gas emissions. They reduce the payoffs to innovation in clean energy. New Zealand should continue to campaign for their removal. New Zealand provides only minor (less than \$4 million a year) government support to activities with some relationship to fossil-fuel production and consumption.

F6.3

The transition to a low-emissions economy will require policies that lean against path dependencies that can lock in polluting technologies and patterns of production. These dependencies arise from market size, scale economies, the cumulative nature of knowledge, network effects, sunk investments and political pressures from vested interests.

F6.4

A good low-emissions strategy needs both an effective emission price and support for innovation that creates, disseminates and deploys low-emissions technologies. Relying on emissions pricing alone will require higher prices than otherwise needed, which, in turn, will likely impose unnecessary economic and social costs.

F6.5

Delay in supporting clean technologies is undesirable. The productivity gap between polluting and clean technologies will increase during the delay period and make the transition longer and costlier in terms of slower economic growth during the transition.

F6.6

Evidence indicates that policies to incentivise the development and uptake of clean technologies may be highly effective. Impacts can be both large and rapid and, as such, can help economies break from their existing high-emissions trajectories to low-emissions trajectories. Evidence also indicates that low-emissions innovations induce greater economic benefits through larger knowledge spillovers compared to innovations in mature high-emissions industries.

F6.7

The risks of harmful climate change are very serious. The application of research and knowledge offers the prospect of substantially cutting GHG emissions. A convincing case therefore exists for government resources to target low-emissions innovation as an exceptionally important part of a country's public funding for science and innovation.

F6.8

The effective creation and application of low-emissions knowledge and technologies depend on different facets of the national innovation system being present and working well together. The facets include:

- clear objectives;
- identification of innovation opportunities;
- domestic and international links between firms, investors, researchers and governments;
- timely provision of complementary infrastructure;
- adequate risk capital, management capability, skills and training; and
- flexible markets for resource reallocation from shrinking to growing firms and activities.

F6.9

Both the government and the private sector have important roles to play in a national innovation system geared to achieving a low-emissions transition. The government's role includes setting credible and transparent goals and policies, and enabling market forces to mobilise businesses to redirect resources from dirty technologies towards clean technologies. This role facilitates but does not substitute for private-sector market activities.

F6.10

Current government investment in science and innovation to support a low-emissions transition lacks a clear strategic focus and priority commensurate with the imperative to succeed in achieving the objective, and to taking bold action. Current investments are inadequate in size and scope.

Strong support for innovation as part of an overall low-emissions strategy would be likely to:

- make more emission reductions possible at lower cost;
- lower the emissions price necessary for achieving target emission reductions;
- create economic opportunities in the form of attractive business investments, high-skill jobs, and the potential for profitable export opportunities; and
- enhance New Zealand's reputation internationally through developing innovative, low-emissions technologies that help the world as well as New Zealand to reduce GHG emissions.

F6.11

In many areas New Zealand will be a technology taker. From this follows the need for a capacity and resourcing to identify, absorb, adapt and deploy a wide range of technologies from offshore. At the same time, in areas relevant to New Zealand's emissions profile, and areas of existing research strength relevant to lowering emissions, the country should invest in the full menu of basic and applied research, commercialisation, infrastructure and skills.

F6.12

“Absorptive capacity” is the capacity of firms to learn by using knowledge from their external environment. It appears to be a key driver of a firm’s ability to accumulate knowledge assets and raise its productivity. Absorptive capacity is therefore likely to be important for learning about, and investing in, clean technologies. This suggests a double benefit from better absorptive capacity – reduced emissions and improved productivity.

F6.13

New Zealand needs a framework for prioritising its investments in low-emissions innovation. Three important categories are (1) the problem has something unique to New Zealand; (2) New Zealand is internationally strong in that area; and (3) imported innovations need identification and tailoring for uptake in New Zealand. In addition to greater focus through topic prioritisation, early investment in innovation will likely reap high benefits in the face of inevitable uncertainties about future events and developments.

Recommendations

R6.1

New Zealand should establish the goal of transitioning to a low-emissions economy as a high priority within its national innovation system. It should also recognise that achieving it will require extensive economic transformation and restructuring. The Government should provide major public backing and funding support for innovation so that innovation can play a central role in the transition, alongside effective emissions pricing.

R6.2

The Government should take steps to:

- strengthen the national innovation system by clarifying its low-emissions objectives, improving links, identifying relevant innovation priorities, and fostering knowledge transfer and sharing; and
- align the various complementary parts so they work well together in the transition to a low-emissions economy.

The scope should include not only science and research, but broader innovation, knowledge dissemination and learning, skills, infrastructure, regulation and finance.

R6.3

The Government should investigate and implement any cost-effective institutional models that:

- scan new low-emissions technologies around the world to identify ones with promise for New Zealand but that may need adapting to suit local conditions; and
- help firms to improve their absorptive capacity for external knowledge, including new low-emissions technologies.

R6.4

Policy should keep the market environment competitive and flexible to allow “creative destruction” to take place, so that resources can flow from firms that lag in adopting low-emissions technologies to firms that lead.

Chapter 7 – Investment

Findings

F7.1

To ensure adequate investment for the transition to a low-emissions economy, the government needs to provide a stable and credible climate policy underpinned by enduring institutional arrangements, and effective emissions pricing. However, while necessary, these may not be sufficient. To enable an effective transition, these credible and consistent settings need to be complemented by other interventions that specifically focus on information and inertia barriers, coordination failures, technology and market risks, and scale-of-investment barriers.

F7.2

The green bond market has the potential to accelerate the transition to a low-emissions economy. The market is growing independent of government assistance. Specific government intervention in the New Zealand green bond market does not appear to be required.

F7.3

At present, evidence of a suitably large stream of low-emissions investments, at the stage at which the New Zealand Venture Investment Fund operates, is insufficient to warrant setting a specific investment mandate for low-emissions investments.

F7.4

Depending on design, green investment banks can efficiently use public capital to mobilise substantially greater quantities of private capital to overcome the scale-of-investment barriers that low-emissions investments may encounter. These barriers include significant funds for major infrastructure projects, or coordinating funds for more disaggregated activities. Green investment banks can also stimulate investment by providing information, increasing market confidence, and reducing overall financing costs.

F7.5

Government financial guarantees reduce risk for additional private investors, thereby lowering the cost of finance. A standalone government financial-guarantee scheme does not appear to be required in New Zealand at present. However, an approach based on financial guarantees may be suitable as part of the proposed Green Investment Fund.

F7.6

Public grants and loans can reduce market risk for the development and deployment of low-emissions technology. However, it is unclear how grants and loans should operate in conjunction with other types of Government funding that also aim to support the transition to a low-emissions economy.

F7.7

The recommendations of the Task Force on Climate-related Financial Disclosures relating to governance, strategy, risk management, and metrics and targets, offer a clear and consistent foundation for investors to assess the risks and opportunities related to climate change.

F7.8

Voluntary reporting frameworks (such as the guidelines provided by the New Zealand Stock Exchange) provide a positive foundation for firms to disclose climate-related risks. Yet their lack of coverage across the economy, and varying reporting requirements, means that they will not be sufficient to drive the necessary behaviour change across the New Zealand economy.

F7.9 Existing financial reporting requirements, including those in the Companies Act 1993, will likely be insufficient to adequately incentivise the disclosure of climate risk in a consistent and credible way.

F7.10 A standard issued via the External Reporting Board under section 17(2)(iii) of the Financial Reporting Act 2013 is the most suitable avenue for climate-related disclosure in New Zealand.

F7.11 Central banks can play an important role in assessing the exposure of financial systems to climate risk, particularly in relation to risks of financial instability.

F7.12 Institutional investors, such as pension funds and insurance companies, represent a large potential source of finance for the transition to a low-emissions economy. There do not appear to be any major barriers to New Zealand institutional investors finding adequate low-emissions investments of a suitable type.

Recommendations

R7.1 Any decisions made by the Government about the model or structure of the New Zealand Venture Investment Fund should be informed by further analysis of the potential for giving priority to low-emissions investments, and whether (and if so, how) an investment exclusion should apply to high-emissions investments.

R7.2 A Green Investment Fund (GIF) has potential to stimulate some of the technology and infrastructure needed to achieve the low-emissions transition in New Zealand. In work to establish a GIF, the Government should clearly identify the market failure that it seeks to address. The Government should specify the GIF's mandate, financing approach and funding source, expected duration, institutional structure (including its degree of independence), desired minimum rate of return, relationship to existing infrastructure and clean technology funding sources, and scale of investment (wholesale or retail).

The Government should also state how the GIF will work in conjunction with any other initiatives for providing infrastructure or low-emissions technology finance.

R7.3 The Government should endorse the recommendations of the Task Force on Climate-related Financial Disclosures as one avenue for the disclosure of climate risk.

R7.4 The Government should implement mandatory (on a comply or explain basis), principles-based, climate-related financial disclosures by way of a standard under section 17(2)(iii) of the Financial Reporting Act 2013. These disclosures should be audited and accessible to the general public.

R7.5 The Government should align its project and programme funding so that it discourages high-emissions, path-dependent activities, and encourages low-emissions, path-dependent activities. This alignment should be supplemented by work to define what constitutes low-emissions investment, with the aim of identifying a clear taxonomy.

Chapter 8 – Laws and institutions

Findings

F8.1

The long-term nature of climate change, literally spanning generations, and the deep uncertainty about the future, presents a credible commitment problem in formulating and implementing a long-term policy response.

Well-designed laws and institutions can play a critical role as commitment devices to help drive the development and implementation of long-term response strategies.

F8.2

Long-term political commitment is essential to the success of climate change laws and institutions. Substantial cross-party support for the core elements of the statutory and institutional arrangements will help provide policy permanence regardless of the make-up of the Government.

F8.3

New Zealand's current emission reduction response is not "fit-for-purpose" to transition to a low-emissions economy. A number of deficiencies exist, such as:

- a lack of stability and predictability in climate change policy, reflecting the absence of political consensus about New Zealand's transition to a low-emissions economy;
- lack of a clear plan for reducing domestic emissions and meeting existing emission reduction targets;
- inadequate central government leadership to drive the low-emissions transition; and
- poor policy coherence for supporting a low-emissions transition.

New Zealand's emissions are not yet declining and current policy settings are unlikely to lead to adequate emission reductions in the future.

F8.4

Inquiry participants and others showed strong support for implementing a UK-style Climate Change Act in New Zealand.

F8.5

Key elements of statutory frameworks that promote policy stability and require long-term thinking include:

- clear and explicit high-level, long-term goals and a focus on progress towards those goals;
- core principles of transparency and accountability;
- mechanisms that seek to promote stability but retain a degree of flexibility; and
- mandatory procedural requirements, including reporting obligations.

F8.6

Legislated emissions-reduction targets are important commitment devices that act to bind the political executive to govern in line with the long-term commitment to a low-emissions economy. Such targets would have authority and durability. Well-designed legislative targets are:

- focused on the desired high-level outcome, without being overly prescriptive about how the goal is reached;
- determined through a robust public policy process and achieve broad buy-in from those affected;

- realistic, and require an assessment of the measures needed to achieve the target and an awareness of the policy tools that the government has at its disposal;
- directly related to the underlying climate change problem;
- stable over time, yet have some built-in flexibility to be adjusted in the light of major changes in circumstance, but without undermining their purpose or credibility; and
- clear about the nature of the obligation to meet them.

F8.7

Emissions budgets help to translate long-term targets into clear and specific short-term actions. They provide visible “stepping stones” to achieving long-term targets and help reinforce steady action on, and accountability for, achieving those targets. By setting limits on GHG emissions over a period, emissions budgets can also help to restrict the total quantity of GHGs released to the atmosphere on the path to long-term targets.

F8.8

Matters to consider when formulating a requirement to prepare a low-emissions strategy include the need for:

- flexibility and responsiveness;
- recognition that strategies for the long term will inevitably be less certain and well-defined than those for the short term; and
- a strategy to not only address policies that achieve the required emission reductions, but also how to maximise benefits and minimise the costs of the transition.

F8.9

Political accountability will be a key driver for compliance with obligations in a climate change law, including meeting emissions budgets and targets. Limits to the legal enforceability of emissions budgets and targets do not negate the status and constitutional significance of putting them in law.

F8.10

Given the long-term nature and time-inconsistency problem associated with climate change policy, an independent institution, at “arm’s length” from government, can play an important role as a commitment device. It would help insulate policymaking from short-term political pressures, expand climate policy debate, promote stability and predictability, and improve transparency and accountability. Such an institution will be more enduring if established through broad political consensus.

F8.11

“Independence” is multifaceted, and includes regulatory independence, operational independence, budgetary independence and institutional independence. No single “blueprint” for an independent body exists: successful design and operation relies on a whole suite of elements.

F8.12

Decisions about New Zealand’s transition to a low-emissions economy (including the setting of emissions budgets) are highly political and go to the heart of a Government’s development strategy and political priorities.

Independent institutions can be highly influential and play a valuable role without having decision-making powers.

F8.13

Independence is earned as much as granted. The success of an independent body will therefore depend not only on its statutory design, but also on how the institution operates in practice (including the quality of appointments, its culture and leadership, and adequacy of ongoing funding).

F8.14

Inclusion of a Treaty of Waitangi clause in the legislation would acknowledge both the importance of the kaitiakitanga role of mana whenua and the stability and longevity of the fundamental constitutional arrangements on which a low-emissions future would be achieved.

F8.15

The legislative framework could strongly signal a partnership approach between Māori and the Crown to achieve the goal of a low-emissions economy. However, legislative provisions alone will not be sufficient to uphold Treaty principles of partnership, mutual respect and good faith. Much will depend on the quality of leadership.

F8.16

Developing the government response to the Climate Change Commission's advice will be a substantive and challenging policy process and will present major coordination issues. The organisation(s) responsible for providing advice on the Climate Change Commission's recommendations will need:

- the capability and knowledge to understand and robustly assess the Climate Change Commission's recommended actions in each sector;
- the ability to take an economy-wide, strategic view and to consider the full range of benefits and costs;
- links to the fiscal budget process, to ensure that Cabinet decisions are suitably resourced; and
- the mana to bring together the range of portfolio agencies, work through any differences of view to develop a coherent and robust set of policy proposals, and monitor the Government's progress against Cabinet decisions.

No single agency within the current public sector has this full range of necessary capabilities and attributes. New arrangements will be required to deliver these capabilities.

F8.17

Developing a robust and enduring cross-government emissions reduction strategy will require coordination across both departments and Ministers.

F8.18

Local government will play an important role in any national emissions-reduction strategy, given the responsibilities it has for regulating land use and managing land transport. The development of a government response to the Climate Change Commission recommendations would be a good opportunity to establish new, more effective arrangements for local and central government to work together on issues of common interest.

Recommendations

R8.1

The broad principles and framework of the United Kingdom's Climate Change Act should be used as a basis for designing a new architecture for New Zealand's climate change legislation, but it should be carefully tailored to fit the New Zealand context.

R8.2

The Government should seek to achieve broad political support and consensus for new climate change legislation, so that legislation has a strong prospect of policy and legislative durability regardless of the make-up of the government.

R8.3

Long-term greenhouse gas (GHG) emissions-reduction targets should be set in primary legislation. Legislative emissions targets require careful design and should be formulated following a robust public policy process seeking broad agreement.

R8.4

New Zealand's climate-change legislation should provide for a system of emissions budgets for both short- and long-lived gases. The government should set the budgets periodically at levels consistent with achieving emissions reductions targets. It should report publicly on progress towards them. The system should be credible and durable, while balancing predictability and flexibility.

R8.5

Government should have a statutory duty to prepare and publish a long-term economy-wide low-emissions strategy. The strategy should set out the Government's policies and proposals for meeting both current and future emissions budgets (and with a view to meeting the long-term targets) and should be updated after each new emissions budget is set.

R8.6

Mandatory processes should underpin a Climate Change Act. Legislation should include clear reporting obligations, including requiring regular reporting to Parliament on key aspects of New Zealand's transition to a low-emissions economy (such as GHG emissions, progress towards budgets and targets, and the Government's low-emissions strategy). Timeframes for the suite of processes should ensure regular review and reporting, but avoid over-engineering procedural obligations.

R8.7

The regulatory framework to support New Zealand's transition to a low-emissions economy should include an independent climate change institution (a Climate Change Commission) that operates at "arm's length" from government.

R8.8

The independent Climate Change Commission should take an advisory role. Decision rights should not be delegated to such a Commission.

R8.9

The Climate Change Commission should be responsible for:

- providing advice on emissions budgets, targets and New Zealand Emissions Trading Scheme (NZ ETS) caps (based on clear statutory parameters for that advice), and other matters materially relevant to New Zealand's low-emissions transition;
- reporting on progress towards emissions budgets and targets, including assessing the performance of policy instruments and identifying emerging risks;
- undertaking and publishing relevant research into transitioning to a low-emissions future; and
- engaging in outreach and public communications (as required to carry out its role).

Legislation should also oblige the government to have regard to the Climate Change Commission's advice when making decisions on emissions budgets, targets and NZ ETS caps, and give clear reasons for any material departure from that advice.

R8.10

To properly perform its role, retain credibility over the longer term, and be viewed as independent, the Climate Change Commission should have a high degree of operational and institutional independence.

The Climate Change Commission should have:

- broad discretion to exercise functions at "arm's length" from the executive and legislative branches of government or industry; and
- formal distance, and security of tenure for governors and senior management.

The Climate Change Commission should be set up as an independent Crown entity.

R8.11

The legislative framework for a low-emissions economy should provide mechanisms for Māori to advise the Government on policy, process, and decisions relating to emissions budgets and the Government's strategy to achieve them.

R8.12

Treasury should update the Regulatory Impact Analysis requirements to explicitly include consideration of climate change impacts, where relevant.

The Cabinet Office should update its circular to require agencies making proposals for regulatory changes with climate change implications to consult with the organisation responsible for developing advice on the Climate Change Commission's recommendations, and to ensure that the agency's comments are fairly and accurately reflected in any final assessment.

Chapter 9 – Short-lived and long-lived gases

Findings

F9.1

The contribution of greenhouse gases (GHGs) to warming is a function of their stocks in the atmosphere. The stocks of short- and long-lived GHGs both matter if peak warming is to be limited to 2°C or less as required by the Paris Agreement. Because of their atmospheric persistence, emissions of long-lived gases must reach net-zero or negative levels. Stocks of short-lived gases must stabilise by inflows equalling outflows, but at a lower level than current emissions rates.

F9.2

Because emissions of long-lived gases have an irreversible effect on warming the planet, the sooner their emissions are cut to net-zero (or lower), the more likely warming will not exceed 2°C. This means giving relative priority to reducing emissions of long-lived gases. Reductions in short-lived gas emissions can also contribute to limiting peak warming to well below 2°C. Because the final total stock of long-lived gases is uncertain, the allowable stock of short-lived gases and therefore the needed reduction in short-lived gas emissions is also uncertain.

F9.3

Benefits arise from reducing emissions of short-lived gases over the coming decades. Benefits include allowing a slightly greater carbon budget, helping to avoid or delay dangerous tipping points in the earth's climate system, providing further time to adapt to temperature change, and providing a more gradual low-emissions transition. Yet this does not mean that short-lived gas mitigation can replace reducing emissions of long-lived gases to limit peak warming to 2°C.

F9.4

The choice of emissions metric can make a large difference to the estimated effects of the different GHGs on warming, and so can strongly influence mitigation priorities. The newly developed GWP* emissions metric has potential as a more scientifically-robust metric for calculating carbon-dioxide equivalence because it considers the different atmospheric lifetimes of short- and long-lived gases as well as their relative potency.

F9.5

The idea of prioritising emissions reductions of short- or long-lived gases is not new in New Zealand. Researchers and policy officials have previously highlighted the possibility, or recommended, that New Zealand distinguish between short- and long-lived gases in terms of policy mechanisms and targets.

F9.6

Biogenic CH₄ is unsuitable for inclusion in a single-cap NZ ETS due to the difficulty such a scheme would have in driving emissions reductions in a manner that recognises the different atmospheric properties of short- and long-lived gases. A dual-cap NZ ETS with separate trading units for biogenic CH₄ and other GHGs, or a methane quota system, are two suitable alternative permit and pricing mechanisms for incentivising mitigation of biogenic CH₄.

Recommendations

R9.1

The Government should seek to enact a long-lived gas target of net-zero by a specified point in time (eg, 2050) in primary legislation.

R9.2

The Government should establish separate emissions budgets for short-lived and long-lived gases and set their sizes based on the advice of the Climate Change Commission.

R9.3

The New Zealand Emissions Trading Scheme (NZ ETS) should include all long-lived greenhouse gases, as well as fossil methane (CH₄) and all fluorinated gases.

R9.4

The Government should enact in primary legislation the principle that New Zealand's emissions of biogenic CH₄ should be lowered to a specified level by a specified date, consistent with the Paris temperature limit. The legislation should also specify a framework for guiding how the target level of CH₄ should be set.

The legislation should establish an obligation on the Government to set the specific target level of emissions for biogenic CH₄ based on the advice of the proposed Climate Change Commission. The legislation would include the power to change the target from time to time in the light of new information.

R9.5

The Government should establish separate emissions budgets for biogenic CH₄ based on the advice of the Climate Change Commission.

R9.6

Biogenic CH₄ should be included in an emissions pricing mechanism that recognises its different atmospheric properties compared to long-lived gases. The Interim Climate Change Committee should assess both a dual-cap NZ ETS and a methane quota system in its report to the Government on recommended policy for agricultural GHG mitigation due at the end of April 2019.

Chapter 10 – An inclusive transition

Findings

F10.1

Central and local government agencies and providers of state-funded research, education and training services have a significant role in a transition to a low-emissions economy by making investments to complement those being made by businesses and households. Government provides or funds support for innovation, education and training and infrastructure. Building effective mechanisms to coordinate these investments will help reduce the costs and smooth the path of the transition.

F10.2

Opportunities for new types of economic activity will arise during the transition. While these cannot be anticipated with certainty, industry sectors and government agencies can keep options open and work together on support for innovation, skills development and infrastructure that enable these opportunities to be realised when they arise.

F10.3

Actions to reduce greenhouse gas emissions have many associated benefits such as improved quality of waterways, reduced air pollution, and better adaptation to climate change. Attention to these co-benefits can help build support for the transition. For this reason, alternative approaches (such as promoting planting of native forests) will sometimes be more effective than approaches that focus only on climate-change mitigation.

F10.4

Actions to mitigate climate change can sometimes have harmful effects (such as erosion of vulnerable land after forests are harvested, debris from harvests clogging waterways, or distress from the visual and noise effects of wind farms). Local and central government will need to manage these effects effectively to maintain wide support for a transition to a low-emissions economy.

F10.5

Consumption-based emissions accounting helps identify the role that consumption of emissions-intensive goods and services play in driving global greenhouse gas emissions. Better information on consumption-based emissions will materially contribute to reducing global emissions.

F10.6

Providing financial assistance to firms facing closure or decline as the result of policy change would be risky, encourage unproductive lobbying and raise questions of fairness. Assistance is also unlikely to be successful in retaining struggling firms or helping them remain viable.

F10.7

Interventions that respond to the “shock” of the loss of a major employer in a region should focus on the labour market and skills needs of individuals, and should be targeted to those who will have the most difficulty gaining new employment. This may include helping people move out of the affected region to areas where employment prospects are stronger.

F10.8 The current education and training system is not well set up to meet the needs of people seeking mid-career retraining.

F10.9 A large number of studies have analysed the impact of emissions pricing policies – such as cap-and-trade or carbon taxes – in developed countries. While the results vary depending on the sources of emissions and the characteristics of household expenditure, emissions-pricing policies are commonly found to be regressive in their impact.

F10.10 In New Zealand, low-income households spend a greater proportion of their income on food, transport energy and household energy. This suggests that emissions pricing may impact more heavily on low-expenditure households. But emissions pricing also leads to price increases for commodities on which households with higher expenditure spend proportionally more.

F10.11 Lower-income households are less able to make investments that enable them to reduce the emissions intensity of their consumption.

F10.12 The existing suite of benefits and tax credits should be adequate for offsetting direct impacts of emissions-reducing policies on the cost of living for lower-income households, provided tax credits are regularly adjusted for inflation.

F10.13 Public interventions to promote investments such as home insulation have a number of benefits, especially for individual and household health.

F10.14 The shift to low or zero-emissions vehicles may be difficult for some low-income households, given the current high price premia for electric vehicles and hybrid vehicles over fossil-fuel vehicles. Compensatory policies may be appropriate to assist these households in the short term. Yet, depending on the rate of change in technology and consumer demand, the price premium may fall rapidly, minimising the need for government intervention in the longer term.

Recommendations

R10.1 Stats NZ working with the Ministry for the Environment and the proposed Climate Change Commission should evaluate the benefits of a system of consumption-based emissions accounting that recognises emissions embodied in the import and export of goods and services.

Chapter 11 – Land use

Findings

F11.1 Land use will need to change substantially if New Zealand is to transition to a low-emissions economy by 2050. In particular, the transition will require a large and sustained increase in afforestation.

F11.2

The rate of land change needed to transition to a low-emissions economy over the next three decades is comparable in magnitude to the overall rate of change over the last three decades. Yet high rates of afforestation will need to be sustained for a much longer period in the future than happened in the past; and the past movement into horticulture may need to accelerate.

F11.3

The need for investments in upstream supply capacity, new on-farm productive capacity, and downstream processing, distribution and marketing capacity; and the time taken to acquire skills and knowledge, may delay changes in land use, even when they otherwise appear profitable. Policy uncertainty affecting future profitability is also a cause of delay.

F11.4

New Zealand's agriculture sector achieved steady productivity gains over the last 25 years, leading to a reduction in emissions per unit of milk and meat produced. Yet, because dairy cattle numbers and total production rose substantially, absolute emissions have risen.

F11.5

Current options to reduce pastoral agricultural emissions are modest, without substantially reducing production. Farmers can achieve reductions of up to 15%, through productivity gains and shifting to low-emissions practices. Some approaches can also improve farm profitability. More options are currently available for reducing nitrous oxide emissions than methane. Options for sheep and beef farming are much more limited than for dairying.

F11.6

Despite the present opportunities for mitigating on-farm emissions, New Zealand's absolute pastoral agricultural emissions are projected to remain at least stable or to rise. Reducing absolute emissions will require a combination of constraining production and achieving significant breakthroughs in developing new mitigation technologies.

F11.7

The development of an effective mitigation technology could have a significant impact on New Zealand's agricultural emissions. While options such as a methane vaccine and inhibitor show some promise, the prospects of a successful technology are highly uncertain and the benefits dependent on their suitability to New Zealand's farm systems.

F11.8

Based on past experience, adoption of low-emissions farming practices and technology could be slow and complex. Yet, the pastoral agricultural industries are putting in place peer and industry support for farmers to accelerate the adoption of new practices to meet ambitious emissions-reduction goals. The industries' efforts to reduce biological emissions from pastoral agriculture will be central to sustaining the industries' role in a future low-emissions economy.

F11.9

Applying a price to agricultural emissions would give farmers more incentives to adopt mitigation options, though the size of the effect is uncertain. An emissions price would encourage more private investment in developing mitigation technologies and also improve the efficiency and equity of mitigation efforts across the economy.

F11.10

New Zealand's trade competitors do not yet face a price on their agricultural emissions. Given New Zealand's agricultural sector is highly trade-exposed, introducing a price for agricultural emissions without support would reduce the international competitiveness of New Zealand farms and potentially result in emissions leakage.

Yet, with adequate support for farmers (eg, provision of free allocations), pricing agricultural emissions will provide incentives to reduce emissions, while lessening any risk to the viability of New Zealand's agricultural businesses. Also, the risk may not be as severe as some suggest, since New Zealand's core competitors in international trade are likely eventually to face comparable regulation of emissions.

F11.11

The impact of a price on agricultural emissions differs depending on the point of obligation. A point of obligation at the processor level mostly incentivises reduction of output (either through reducing stock numbers where this is profitable, or through changing land use), and therefore provides a blunt price signal to reduce emissions. A point of obligation at the farm level provides stronger incentives for a farmer to change the way they manage their farm as well as to reduce their output.

F11.12

OVERSEER is currently the main tool for monitoring emissions at the farm level, and is already widely used by dairy farmers for nutrient management. While its overall structure is suitable for monitoring farm-level emissions, further work is under way to improve its transparency, the extent to which it captures a wide range of on-farm mitigation options, and to better align the model to the methodology used in preparing the national inventory.

F11.13

A point of obligation at the farm level would require monitoring, verifying, and enforcing compliance for a large number of small emitters. Carrying out this process for all emitters would likely be costly and difficult. Modifying this approach by, for instance, limiting a requirement for farm-level reporting to farms with total emissions larger than a certain threshold could help to minimise these transactions costs.

F11.14

New Zealand has sufficient suitable land to greatly expand afforestation to sequester carbon. This land includes over a million hectares of highly erodible land unsuited to pastoral agriculture (though some of this is also unsuited to forestry). The land is both privately and publicly held. The availability of privately held land will depend on the economics, including the prospective price of NZUs over the growing period and at harvest. The availability of government-controlled land for further afforestation is uncertain.

F11.15

Forestry offers New Zealand a path to reducing net emissions to a very low level or to zero by 2050 at moderate cost. Yet a risk remains that a low or moderate emissions price will, at least for a period, weaken incentives for other sectors to reduce emissions. Even so, as forestry options to sequester carbon are used up over the next 30 to 50 years, they will become more expensive. Emitters who anticipate a rising emissions price will instead seek non-forest options to reduce emissions.

F11.16

Only a minority of eligible foresters participate in the NZ ETS. Many owners of small forests find participating in the NZ ETS costly and risky relative to any benefits afforded by earning New Zealand Units. Simplifying administration of the NZ ETS for small forests, allowing an averaging approach to surrender obligations over time (on a voluntary basis), and providing policy certainty are all ways to encourage more forest owners to participate.

F11.17

Any feasible on-farm planting outside the current NZ ETS eligibility criteria for forests would make only a minor contribution to off-setting New Zealand's annual gross GHG emissions. Under current international GHG accounting rules, such off-sets could not be used to meet New Zealand's international climate change commitments. Also, the financial benefit for farmers would likely be small.

F11.18

Emissions prices above \$20 and rising to \$70 and above for a NZU in the NZ ETS will likely lead to a substantial increase in afforestation rates, mostly on marginal land currently used for beef and sheep farming. A rising emissions price is likely required to incentivise sustained afforestation over future decades.

Recommendations

R11.1

The Government should increase its yearly funding for research on agricultural mitigation technologies to a level that better reflects the potential value of successful outcomes. Funds could, for instance, be allocated from the proceeds of auctioning New Zealand Units (NZUs).

R11.2

Agricultural nitrous oxide emissions should be fully included in the New Zealand Emissions Trading Scheme (NZ ETS). Agricultural methane emissions should be fully included in the NZ ETS if that is the option recommended by the Interim Climate Change Committee in its report to Government due at the end of April 2019.

R11.3

Unless and until there is a better alternative, the Government should use OVERSEER to monitor emissions at the farm level. The Ministry of Primary Industries should undertake work with AgResearch and the Fertiliser Association of New Zealand to further improve the capabilities of OVERSEER as a tool for modelling farm-level emissions. The improvements should capture as far as possible the full range of on-farm actions that can reduce emissions.

R11.4

Fertiliser manufacturers and importers should be the point of obligation in the NZ ETS for nitrous oxide emissions caused by the use of fertilisers.

R11.5

The Government should establish a farm-level emissions threshold for the point of obligation for pastoral agricultural emissions not caused by the use of fertilisers.

- Farms with emissions above the threshold should have a farm-level point of obligation.
- Farms with emissions below the threshold should have the option of a farm-level point of obligation.
- Meat and dairy food processors should be the point of obligation for remaining pastoral agricultural emissions not covered by a farm-level point of obligation (and not caused by the use of fertilisers).

The threshold should be adjusted down over time as the cost to farmers of participating in a farm-level point of obligation falls relative to the value of obligations to surrender NZUs.

R11.6

The Ministry for Primary Industries (MPI) should review expert research into the potential for permanent exotic forests to convert to native forests and the conditions under which such conversion could reliably and economically occur. MPI should commission further expert research, if this is likely to resolve doubts about the efficacy or not of this approach to establishing native forests.

R11.7

The Ministry for Primary Industries, working with Land Information New Zealand and Landcare Research, should undertake a complete audit of the availability of government-controlled land suited for afforestation (whether native or exotic), and develop policy options that would cost-effectively establish forestry on such land as is available.

R11.8

The Government should continue to refine the NZ ETS for forestry to make it easier and less risky for small foresters to participate; and to provide recognition for carbon sequestered in harvested wood products.

Chapter 12 – Transport

Findings

F12.1

At the current low-emissions price, the New Zealand Emissions Trading Scheme (NZ ETS) has a small effect on fuel prices, and therefore, a small effect on consumer behaviour and transport emissions. A higher emissions price would have a greater impact on behaviour, and make production of alternative fuels more viable. Yet, additional measures will be required to achieve large emissions reductions.

F12.2

The use of electric vehicles (EVs) leads to substantial emissions reductions compared to fossil-fuel vehicles, due to New Zealand's low-emissions sources of electricity generation. EVs also contribute to reduced air and noise pollution, and involve lower fuel and maintenance costs.

F12.3

Modelling indicates that a rapid uptake of light EVs will be a critical part of achieving a low-emissions economy. To electrify the bulk of the light vehicle fleet by 2050, nearly all newly registered vehicles would need to be electric by the early 2030s.

F12.4

The most significant barriers inhibiting the uptake of EVs in New Zealand are:

- the upfront price premium compared to petrol and diesel vehicles;
- limited travel range, and associated range anxiety;
- the lack of public awareness and understanding of EVs; and
- constraints on supply and lack of model options.

F12.5

A large uptake of EVs would add significant load to the electricity grid. Without cost-reflective pricing of electricity, electricity emissions could rise significantly due to increasing peak demand (with EVs being charged at peak periods). The additional electricity load could also put significant pressure on the existing network and require large investments to provide additional capacity.

F12.6

In choosing a vehicle, consumers are likely to under-value the large emissions locked in over the vehicle's lifetime (eg, due to high discounting of future running costs and uncertainty about future emissions prices). Additionally, under-pricing of CO₂ emissions and air pollution from fossil-fuel vehicles and over-pricing of off-peak electricity mean that the running costs of EVs (relative to fossil-fuel vehicles) are higher than they should be. This provides a case for the Government to provide some form of transitional price support to incentivise the uptake of EVs.

F12.7

A well-designed price feebate scheme based on the greenhouse gas emissions of light vehicles entering the fleet would provide a cost-effective approach to incentivising the uptake of low-emissions vehicles. The approach:

- provides an incentive for purchasing lower-emitting vehicles (including more fuel-efficient fossil-fuel powered vehicles; and
- can be designed to be revenue neutral.

F12.8

The effective design of a feebate scheme is critical for its success, and for avoiding perverse outcomes. An important design element is the point at which the feebate is applied. Applying a feebate when a vehicle enters the fleet is the most suitable option, as it specifically addresses the upfront price premium for low-emissions vehicles.

F12.9

New Zealand's fast-charging network for EVs is fairly developed, compared to the size of its EV fleet. Funding support from the Government has played an important role. Some gaps exist in specific regions.

F12.10

Light vehicles entering New Zealand's fleet emit significantly more CO₂ than in most developed countries, and efficiency improvements have stalled since 2013. Vehicle manufacturers tend to provide less efficient variants of vehicle models to the New Zealand market compared to markets where CO₂ emissions standards apply.

F12.11

Vehicle CO₂ emissions standards are warranted because buyers tend to discount future fuel savings at a much higher rate than is socially optimal. Domestic standards could also mitigate risks around "dumping" of high-emissions vehicles in New Zealand due to stringent standards and regulations adopted in other regions.

F12.12

There could be value in the Government specifying a long-term policy target that signals a transition to a very low (or zero) emissions fleet and covers the full range of potentially feasible mitigation options. Committing to phase out the importing of fossil-fuel vehicles for the light fleet could give a signal to households and businesses of the need to transform the vehicle fleet that could accelerate uptake of EVs. But, such a commitment could also impede the use of biofuels and other internal combustion engine technologies that may be important for uses where EVs may be less suitable.

F12.13

Biofuels can potentially deliver considerable emissions reductions across a range of transport modes, including aviation and shipping. New Zealand's current production of biofuels is small. Drop-in technologies using non-food feedstocks (eg, wood-based sources) appear to be most promising opportunity for developing biofuels in New Zealand over the long term, but these are not yet commercially proven. Although biofuels tend not to be cost-competitive at current fossil-fuel prices, a higher emissions price in the NZ ETS would create a stronger incentive to develop and switch to biofuels.

F12.14

Some technical advantages of hydrogen fuel-cell vehicles (HFVs), including the lower weight and greater travel range, make them suited to long-haul heavy freight. However, the significant investment needed in new infrastructure to produce, transport and distribute hydrogen as a fuel, along with the higher cost of HFVs, provide large barriers to the development of an HFV market in New Zealand.

F12.15

The most effective solution for decarbonising heavy transport is not yet clear, and may involve a mix of technologies. Given this, heavy transport policy should provide even-handed support for different technologies to deliver greater optionality and avoid unnecessarily raising the cost of mitigation efforts. At present, government policy provides relatively weaker incentives for investing in biofuels than for adopting low-emissions vehicles.

F12.16

Stable policy is critical to encourage significant upfront investments in heavy transport solutions. Biofuel policy, in particular, has been highly unstable, creating uncertainty for prospective investors in production plants.

F12.17

Significant health benefits (from reduced air pollution) provide an even greater rationale for supporting the uptake of lower-emission heavy vehicles than for light vehicles. Yet, designing policies such as feebates or vehicle emissions standards is much more difficult for the heavy fleet. This is because the heavy vehicle market is more complex, with a wider range of vehicle types, sizes and applications. Simpler forms of price support (eg, upfront grants for heavy EVs) are likely more appropriate, although these should not prevent vehicle owners from contributing to road-user charges.

F12.18

Achieving significant reductions in heavy transport emissions will largely rely on further advances in mitigation technologies. New Zealand's reliance on fossil fuels for tourism and long-haul freight provides a strong impetus for government support of innovation in promising emissions-reducing technologies where it has a comparative advantage, such as producing drop-in biofuels.

F12.19

Greater use of public transport, cycling and walking will reduce light vehicle emissions, but a substantial mode shift is needed to deliver meaningful reductions. Reducing congestion (eg, using road pricing) and increasing uptake of technologies that enable mobility-as-a-service and minimise the need to travel can also reduce emissions. Shifting to lower-emitting patterns of travel can achieve significant other benefits, including improved accessibility, better health outcomes and overall productivity gains.

F12.20

Using rail and coastal shipping to move freight is less emissions intensive than using road transport. Because a large proportion of freight carried by road is not economically contestable, the potential for large mode shift in the freight sector is limited. Yet, freight trips over longer distances tend to be more suited to mode shift. This suggests some potential for modest reductions in emissions.

F12.21

New Zealand's current transport investment system is biased towards investment in roading. An efficient transition to a low-emissions transport future requires an investment system that is:

- better integrated across modes;
- more flexible, with greater competition for funding across different transport modes and activities, and greater autonomy for councils;
- more neutral, by removing distortions and biases that favour particular modes or activities, and fully accounting for the social, economic and environmental costs and benefits.

Recommendations

R12.1

The Government should introduce a price feebate scheme for new and used vehicles entering the fleet, subject to identifying the most suitable design features for the New Zealand context (including features to limit the burden on low-income households). The feebate scheme should replace the existing road-user charge exemptions for light EVs.

R12.2

The Government should continue to provide financial support for charging infrastructure projects to support the uptake of EVs. Support should be limited to specific gaps in the charging network that are not commercially attractive to the private sector (eg, charging stations in lowly populated regions).

R12.3

The Government should encourage government agencies where practical to procure low-emissions vehicles. It should regularly review its procurement catalogue with a view to increasing the model range of lower-cost low-emissions vehicles.

R12.4

The Government should introduce CO₂ emissions standards for light vehicles entering the New Zealand fleet, subject to detailed consideration of design issues (for example, the treatment of small traders).

R12.5

The Ministry of Transport should further evaluate the benefits and costs of incentivising the early scrapping of fossil-fuel vehicles to be replaced by low-emissions vehicles, taking into consideration any impacts of other mitigation policies (eg, feebates and the emissions price) on low-income households.

R12.6

The Ministry of Transport should work with the Ministry of Business, Innovation and Employment to remove any remaining tariffs on low-emissions vehicles, or parts for low-emissions vehicles.

R12.7

The Ministry of Transport, with other relevant agencies, should explore the suitability of low-carbon fuel standards, and a grant scheme for low-carbon fuels, for decarbonising New Zealand's heavy transport fleet.

R12.8

The Ministry of Transport and the Energy Efficiency Conservation Authority should investigate the suitability of specific emissions-reducing technologies for regulating heavy vehicles in New Zealand.

R12.9

The Government should take steps to amend the pricing system for transport so that a greater share of the external costs associated with private vehicle use are internalised. For example, the Government should continue to work with councils to enable and encourage the use of road pricing tools to reduce congestion and emissions in main urban centres. It should also investigate the potential for a comprehensive network pricing of road use through an expanded Road User Charges system.

R12.10

The Government should make emissions reductions an ongoing strategic focus in transport investment and broaden the scope of the Government Policy Statement on Land Transport to cover the whole land transport system.

Chapter 13 – Electricity

Findings

F13.1

The future mix of electricity generation by 2050 in a low-emissions electricity system and its effect on wholesale prices are both very uncertain. For example, different models envisage different paths for the cost of wind generation for each megawatt hour of electricity produced. This, in turn, leads to a different role for wind versus geothermal generation in the system, and different effects on wholesale electricity prices. In the most favourable scenarios, prices fall; while in other scenarios, they rise.

F13.2

Technologies that generate low-emissions electricity are advancing rapidly with falling costs, changing design and new options emerging. If governments favour particular current technologies (for instance through subsidies), they risk locking in higher electricity costs without commensurate benefits in reducing emissions.

F13.3

Under current technology and technology costs, reducing emissions from electricity generation will likely entail an increase in wholesale electricity prices. Rising electricity prices, if substantial, could dissuade adoption of emissions-reducing technology in process heat and in transport, as well as increasing costs throughout the economy. Yet rapid advances in, and falling prices for, low-emission electricity technology may make this trade-off less acute in the future. An effective emissions price will help weigh the efficiency of reducing emissions in electricity against possibly lower-cost options to do so in other sectors.

F13.4

The National Policy Statement for Renewable Electricity Generation 2011 (NPS-REG) is not well-reflected in the planning documents of local authorities and has made no difference to the time, complexity and cost of obtaining consents for renewable electricity generation investments (particularly wind- and hydro-generation). The language of the NPS-REG is not sufficiently directive to give weight to the central role of renewable electricity generation in New Zealand's transition to a low-emissions economy over the next several decades.

F13.5

Uncertainty about water rights has the potential to reduce the economic viability of, and so dissuade, further investment in maintaining hydro-electric generating capacity. Allocation of water rights in New Zealand is controversial and successive governments have been cautious in taking steps to increase certainty about them.

F13.6

Investments in transmission grid and distribution network upgrades will be needed to complement the expansion of renewable electricity generation to meet increasing demand for electricity. The National Policy Statement on Electricity Transmission 2008 (NPS-ET) is currently under review. The owner of the transmission grid, Transpower, reports that despite the provisions of the NPS-ET, decisions on resource consents for grid investment projects are highly time consuming and costly and increase uncertainty and risk. Similar types of costs and risks are likely to apply to upgrades of the distribution network, though at a smaller scale.

F13.7

With rapidly changing electricity distribution technology, including distributed energy resources and demand response capabilities, the mix of monopoly and contestable electricity distribution services is also changing rapidly. These changes are posing challenges to the role of the regulatory agencies (the Commerce Commission and the Electricity Authority) in promoting competition that will stimulate ongoing innovation in electricity distribution and in services that use electricity distribution networks as a platform. This innovation will likely both benefit consumers through lower-cost and better-quality services and reduce the need for fossil-fuelled generation.

F13.8

Integrating distributed energy resources (DER) and demand response (DR) into the electricity system will require significant adjustment to the current distribution pricing and regulatory regime. The Electricity Authority is leading or sponsoring a substantial programme of work to address the need for pricing and regulatory adjustment. The programme covers changes to pricing to better incentivise investment in DER and DR capability; and changes to regulation to provide for:

- consumers to be involved in multiple trading relationships;
- more fluid data exchange between retailers and electricity distribution businesses;
- a default distribution agreement between EDBs and electricity retailers to support competition, efficiency and innovation in retail and related markets;
- consumers to become active buyers and sellers of electricity and related services; and
- equal access of participants to electricity networks.

F13.9

The Electricity Authority, in conjunction with its work programme to update pricing and regulation of the electricity distribution sector, is undertaking a review of, and developing measures to raise, the capabilities of the electricity distribution businesses to:

- ensure all power system resources (including distributed energy resources – DER) have competitive access to a well-configured common distribution infrastructure, at a reasonable cost;
- coordinate DER (including smart, flexible demand) to meet participants' preferences for security, quality and reliability; and
- provide rewards and allocate costs commensurate with the marginal costs and benefits of each load and generating source.

F13.10

With an effective emissions-pricing system, a statutory objective for the Electricity Authority (EA) to have regard to reducing greenhouse gas emissions in electricity is unlikely to incentivise efficient emissions reductions across the economy as a whole. There may be some case to amend the EA's objectives to include minimising any regulatory barriers to efficient emissions reductions in the electricity sector.

Recommendations

R13.1

Given rapid changes in electricity-generation technology and potential effects of rising electricity prices on adoption of low-emissions technology in other parts of the economy, the Government should not use subsidies or regulation to favour particular technologies that generate low-emissions electricity.

R13.2

The Government should rely on an effective emissions-pricing system as the main instrument to achieve an efficient trade-off between emissions reductions in electricity and emissions reductions in other parts of the economy. The Government should be cautious in specifying targets for emissions within the electricity sector, and make sure that technology is available to meet them without significantly increasing wholesale electricity prices above the levels achieved with current technology.

R13.3

The Government should give priority to revising both the NPS-REG and the NPS-ET to ensure that local authorities give sufficient weight to the role that renewable electricity generation and upgrades to the transmission network and distribution grid will play in New Zealand's transition to a low-emissions economy. This will likely require making the language of the NPS-REG and the NPS-ET more directive, and to be more explicit about how the benefits of renewable electricity generation should be recognised and given effect in regional and territorial authority planning instruments.

R13.4

The Government should issue a new National Environmental Standard for Renewable Electricity Generation that sets out the conditions under which renewable energy activities are either permitted, controlled, restricted discretionary or non-complying activities under the Resource Management Act 1991. This should be drafted to increase the speed, and lower the cost and uncertainty for obtaining resource consents for a significant proportion of renewable electricity generation projects that have only minor environmental and social impacts.

R13.5

The Electricity Authority should continue its programme of work to update pricing and regulation to facilitate the integration of distributed energy resources (DER) and demand response (DR) into the electricity system. The programme should cover changes to pricing to better incentivise investment in DER and DR capability; and changes to regulation to provide for:

- consumers to be involved in multiple trading relationships;
- more fluid data exchange between retailers and electricity distribution businesses;
- a default distribution agreement between EDBS and electricity retailers to support competition, efficiency and innovation in retail and related markets;
- consumers to become active buyers and sellers of electricity and related services; and
- equal access of participants to electricity networks.

R13.6

The Government should review and amend the legislative framework for regulation of electricity distribution network businesses to:

- ensure that the regulatory agencies (the Commerce Commission and the Electricity Authority) are able to respond in a flexible and timely manner to technology-driven changes in the mix of monopoly and contestable electricity-distribution services, network-support services and activities where regulated firms are competing with non-regulated firms;
- clarify and provide stronger checks and balances on regulated electricity distribution businesses (EDBs) owning contestable activities which erode their neutrality in operating electricity distribution networks; and
- provide simpler, quicker and lower-cost methods for holding regulated EDBs accountable for equal access to their networks of parties providing contestable services.

R13.7

More collaboration among electricity distribution businesses (EDBs) could increase their efficiency and their collective capability to use emerging technologies for the benefit of consumers. The Government should review and, if appropriate, amend the legislative framework for regulation of electricity distribution network businesses to provide clearer incentives for EDBs to collaborate where this will deliver net benefits for consumers.

Chapter 14 – Heat and industrial processes

Findings

F14.1

For many industrial heat users, opportunities exist to materially reduce emissions through demand reduction measures such as energy and process efficiency improvements. Some of these mitigation options are already economically viable at current emissions prices.

F14.2

Substantial emissions reductions will be challenging for high-temperature heat users in the short term. Smaller, but material, emissions reductions are likely to be possible through measures such as demand reduction, efficiency improvements, and co-firing with lower-emissions fuels.

F14.3

Reducing the use of coal is particularly important, as it has roughly double the emissions intensity of natural gas. However, in order to reach New Zealand's emissions targets the use of both fuels will need to decline significantly.

F14.4

Electrification can be a cost-effective mitigation option for process heat at current prices, provided that it is applied using a technology that has a coefficient of performance (CoP) well above 1. Electricity is currently a relatively high-cost fuel for process heat when is applied using a technology that has a CoP of 1.

F14.5

Sustainably sourced biomass is a low-carbon fuel source that is widely used to generate process heat in New Zealand. Concerns about reliability of supply, higher (in most circumstances) costs per unit of heat, and sunk costs in incompatible infrastructure are the main barriers to further uptake.

F14.6 Rising emissions prices will be central to driving emissions-reducing investments in industrial heat processes.

F14.7 Greater understanding of mitigation opportunities in the area of process heat could be facilitated through a stronger and better-resourced innovation system that makes funding available for research into the optimal application and integration of known technologies.

F14.8 Barring technological breakthroughs, opportunities to significantly reduce emissions from iron, steel, cement and aluminium production remain limited.

Recommendations

R14.1 The statutory functions of the Energy Efficiency and Conservation Authority should be changed to encourage, promote, and support the use of low-emissions energy sources and materials. Functions relating to energy efficiency and conservation should be retained.

R14.2 MBIE and EECA should review targets relating to industrial emissions reductions to determine whether a reduction in excess of that already forecast would be more helpful in driving emissions reductions.

R14.3 EECA and MBIE should review existing initiatives related to information about fuel switching, co-firing, demand reduction and efficiency improvements for process heat, to minimise any information-related barriers to mitigation opportunities.

R14.4 EECA and MBIE should consider a wider roll-out of policy initiatives to support the supply and use of biomass.

R14.5 Government should take the lead in phasing out the use of coal and other fossil fuels for heating by limiting any future installation of fossil-fuel-powered heating systems in government buildings.

R14.6 New legislation should be prepared to regulate carbon capture and storage activities (CCS). Regulation should address issues including the long-term regulatory supervision of CCS, including after an operation's closure, and procedures and assessment criteria for permits.

R14.7 Once new CCS legislation is in place, the New Zealand Emissions Trading Scheme should be amended to make CCS a recognised removal activity, no matter the source of emissions being captured and stored.

Chapter 15 – Waste

Findings

F15.1

Mitigation of emissions from the disposal of waste at solid waste disposal facilities, and at wastewater treatment plants, does not require the development of new technology. Waste emissions can be effectively mitigated by current technologies such as landfill gas recovery systems or anaerobic digestion.

F15.2

Good quality data on waste in New Zealand is lacking. This has major implications for understanding emissions management practices related to waste in New Zealand, and identifying subsequent opportunities to further reduce emissions. In response to these issues, the Ministry for the Environment (MfE) is developing a project to collect better waste data in New Zealand.

F15.3

A large number of solid waste sites are known and consented, yet technically considered “unmanaged”. Reducing emissions from these sites is vital because current data estimates that they comprise nearly two-thirds of all waste emissions. The most effective solution to achieving emissions reductions at these sites is to apply an effective waste disposal levy. MfE plans to take a staged approach to extending the levy to unlevied solid waste disposal sites to encourage waste reduction and support New Zealand’s transition to a circular economy.

F15.4

Emissions reductions at farm dumps and other, unknown, waste disposal sites, could be encouraged by the creation of bylaws as allowed under the Waste Minimisation Act 2008 (and Part 8 of the Local Government Act 2002), or resource consenting processes under the Resource Management Act 1991.

F15.5

The most effective actions to reduce emissions at managed municipal solid waste sites are a reduction in organic waste volumes to landfill and better management of CH₄ at landfill. An effective emissions price will help to achieve both, while giving facility operators (particularly local authorities) the flexibility to determine which strategy is likely to be the most cost-effective at reducing emissions in their own jurisdiction.

F15.6

Waste-to-energy provides an opportunity to reduce emissions by diverting waste from landfill and substituting for fossil fuels. Anaerobic digestion (eg, at wastewater treatment plants) is a current cost-effective approach to reduce emissions, but the potential to incinerate waste (especially household waste) is less clear.

F15.7

A circular economy approach has significant potential to reduce waste emissions in New Zealand and drive the transition to a low-emissions economy by acting as a platform for innovation.

Recommendations

R15.1

The Ministry for the Environment (MfE) should ensure that its project to collect better waste data allows for the direct measurement or estimation of emissions-related data. This is to reduce the very large uncertainty about waste emissions, and to identify opportunities to reduce emissions in the future.

R15.2

The Government should, under the Waste Minimisation Act 2008, apply the waste disposal levy to all known, consented waste disposal facilities. The rate of the levy should be steadily increased over time, and a differentiated levy rate introduced where active waste is charged at a higher rate than inert waste.

R15.3

Local government should be better supported, as needed, to develop effective bylaws or consenting requirements for farm dumps and other, unknown, waste disposal sites, through an overarching regulatory framework for wastes such as agricultural waste. MfE should investigate whether a national environmental standard about waste is an appropriate mechanism to deliver this framework.

R15.4

All managed solid waste sites subject to the NZ ETS should be included in an emissions pricing scheme that recognises the nature of biogenic CH₄ as a short-lived gas.

R15.5

When determining the rate of the waste disposal levy, the Government should consider whether a partial levy offset is required to avoid unnecessary overlap with the emissions price. This work should consider the role of default and unique emissions factors in properly incentivising emissions reductions.

R15.6

In principle, wastewater treatment plants (WWTPs) should be incentivised to reduce emissions. To enable the case to be assessed for including WWTPs into emissions pricing schemes, MfE and Local Government New Zealand should begin a project to improve measurement methodologies for WWTPs. Any inclusion of WWTPs into emissions pricing schemes should occur after relevant recommendations from the Department of Internal Affairs' three waters review have been enacted.

Chapter 16 – The built environment

Findings

F16.1

Greenhouse gas emissions are generated across the life of a building. Calculation of life-cycle emissions when a building is being designed, for example using BRANZ's *LCAQuick* tools, presents an opportunity to identify low-emissions building designs.

F16.2

The main direct emissions from buildings arise from the combustion of fossil fuels for space and water heating. Higher emissions prices, greater clarity about future emissions prices, and limits on the use of fossil-fuel powered heating systems in government buildings will be important in transitioning to the use of low-emission fuels for heating buildings.

F16.3

Increasing the density of urban areas, combined with good public transport and accessibility, can generate small, but material reductions in vehicular travel. The associated reductions in emissions will be influenced heavily by the rate of uptake of electric vehicles and other low-emission vehicles.

F16.4

On a per square metre basis, high-density dwellings such as apartment buildings typically have higher embodied emissions when compared with standalone dwellings. However, because such high-density dwellings typically have much smaller floor areas, when examined on a per capita basis, the relationship with standalone dwellings reverses.

F16.5

Urban areas and technology will evolve in ways that are difficult to predict, and in ways that could significantly alter the emissions associated with different urban forms. It is important that urban planning systems are able to respond and adapt to these changes over time.

Recommendations**R16.1**

The Energy Efficiency and Conservation Authority should, where cost-effective, develop programmes to support the use of low-emissions building materials in a way that lowers the overall emissions of a building across its full life-cycle, including the operational phase and end-of-life.

R16.2

Future reviews of the New Zealand Building Code should examine whether the Code is sufficiently flexible to enable practitioners to adopt building materials and techniques with low embodied emissions, including the re-use of buildings and materials.

R16.3

Forthcoming reviews of New Zealand's Building Code should assess whether there is scope to materially reduce peak demand for electricity through the introduction of more stringent energy efficiency standards.

R16.4

The Ministry of Business, Innovation and Employment should review the costs and benefits of additional programmes (including those aligning New Zealand's lighting standards with Australia) to deliver energy savings in existing housing and buildings.

R16.5

Councils should review and if justified remove, barriers to higher-density development, particularly in inner suburbs and in areas close to public transport routes. Councils should also ensure that infrastructure charges reflect the full costs of dispersed development.

R16.6

The proposed Climate Change Commission should work with the Treasury to develop guidelines on how to apply shadow prices for GHG emissions to decisions about government infrastructure investment. Shadow pricing should be used as a transitional measure until recommended changes to the NZ ETS come into effect and the emissions price has responded to these changes.

Appendix A Public consultation

Submissions

Individual or Organisation	Submission numbers
35 Christchurch	DR 162
ADLS	7
Adrian Macey	13, DR 16
Advanced Materials Technologies	DR 136
AgResearch Ltd	DR 191
Ahika Consulting	DR 196
Air New Zealand	13
Alan Barraclough	DR 149
Alec Milne	DR 146
American Council for an Energy-Efficient Economy (ACEEE)	DR 163
Andre Koekemoer	DR 292
Andrew Osborn	DR 295
Andy Reisinger	28, DR 233
Anne Spicer	DR 345
Apiculture New Zealand	DR 372
Auckland Council	97, DR 273
Auckland Regional Public Health Service	15
Auckland University of Technology	DR 194
Azwood Energy	DR 168
Ballance Agri-Nutrients Limited	34, DR 285
Barry Coates	DR 374
Bay of Plenty Regional Council	5, DR 335
Beef + Lamb New Zealand and Deer Industry New Zealand	98, DR 389
Bernard Bromell	DR 176
Bernard Jennings	DR 141
Bioenergy Association	37, DR 352
Blueskin Resilient Communities Trust	DR 236
Branislav Petricek	DR 145
BRANZ	DR 398
Brendon Harre	DR 269
BusinessNZ	89, DR 347
Calibre Consulting Ltd	DR 327
Canterbury District Health Board	16
Canterbury Mayoral Forum	DR 393
Carbon Neutral Waiheke	DR 381
Carbon South	5
Catherine Leining	DR 279
Catherine Murupaenga-Ikenn	DR 34
Chartered Accountants Australia and New Zealand	DR 28
Chris Boxall	DR 19
Chris Hook	132, DR 157
Chris Livesey	DR 247
Chris Newman	DR 375
Christchurch City Council	13, DR 284

Clare St Pierre	115
ClientEarth	DR 238
Concrete New Zealand Incorporated	DR 33
Conrad Healy	113
Contact Energy	29, DR 225
Counties Power Consumer Trust	DR 262
Counties Power Limited	DR 331
Dairy NZ	18, DR 365
Dame Anne Salmond	DR 135
Dave Read	DR 223
David Bull	DR 159
David Boyes	42
David Evison and Euan Mason	27
David Frame	DR 27
David Henley (Centre for Sustainability – University of Otago)	9, DR 212
David Lurie	86
DCANZ	DR 38
Deidre Kent	87
Democrats for Social Credit	1
Denis Hocking	DR 224
Department of Conservation	DR 37
Derek Parkes	DR 138
Derek Vance	DR 155
Doctors for Active, Safe Transport (DAST)	DR 369
Don J Cleland	DR 395
Dr David Geraghty, University of Otago	DR 313
Dr Geoff Scott	DR 154
Dr Martin Atkins	DR 361
Dr Rocky Renquist	DR 29
Dr Wayne Cartwright	DR 392
Drive Electric Incorporated	DR 257
Earl Bardsley	DR 156
Edward Pilbrow	DR 14
Electricity Authority	DR 384
Electricity Engineers' Association	DR 25
Electricity Retailers' Association of New Zealand (ERANZ) and Electricity Networks Association (ENA)	8, DR 211
Emsol	66
Energy Efficiency and Conservation Authority (EECA)	DR 326
Energy Management Association of New Zealand	7, DR 242
Energy Trusts of New Zealand Inc	DR 258
Engineering Leadership Forum	DR 28
Engineering New Zealand	DR 325
Engineers for Social Responsibility Inc	DR 237
Enrique del Rey Castillo	DR 137
Environment Canterbury	26
Environment Institute of Australia and New Zealand (EIANZ)	DR 26
Environmental Protection Society	38
EROAD Ltd	DR 182
Esperance Capital Ltd	DR 184

Evonik Industries	46
Export New Zealand	91
External Report Board (XRB)	DR 164
Federated Farmers	39, DR 31
Fertiliser Association of New Zealand	61
First Gas Limited	47, DR 316
Fletcher Building	DR 349
Fonterra	88, DR 355
Forestry Leadership Group - Climate Change	1
Fossil Fuels Aotearoa Research Network	DR 178
G L Hedley	DR 388
Gas NZ	DR 36
Gavin Bell	DR 351
Generation Zero	119
Genesis Energy Limited	118, DR 31
Geoff Thompson	19, DR 34
GNS Science	DR 39
Golden Bay Cement	DR 197
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Engagement meetings

Associate Professor Ralph Chapman, Victoria University of Wellington
Azwood Energy
Baroness Worthington (U.K.)
Beef + Lamb New Zealand
Bioenergy Association of New Zealand

Biological Emissions Reference Group
BlueScope New Zealand
BRANZ
BusinessNZ
Carbon Match Limited
Chiltern Power Limited
Chris Hook and Dr John Baker
Climate Change Iwi Leaders Group
Commerce Commission
Concept Consulting Group
Contact Energy
Delegation of the European Union to New Zealand
Department of Conservation
Dr Abrie Swanepoel, Department of Industry, Australian Government
Dr Adrian Macey, Victoria University of Wellington
Dr Andy Reisinger, New Zealand Agricultural Greenhouse Gas Research Centre
Dr Dirk Pilat, Directorate for Science, Technology and Industry, OECD
Dr Kingi Tanira - Scion
Dr Martin Atkins - The University of Waikato
Eco Stock Supplies Limited
Electricity Authority
Electricity Networks Association
Electricity Retailers' Association of New Zealand and Electricity Industry Representatives
Energy Efficiency and Conservation Authority (EECA)
Energy Management Association of New Zealand
Engineering Leadership Forum
Enviro-Mark Solutions Limited
Environmental Protection Authority
External Reporting Board
Federated Farmers
Fertiliser Association of New Zealand
First Gas Limited
Fonterra Co-operative Group Limited
Foreign and Commonwealth Office
Garth Harmsworth, Landcare Research
Golden Bay Cement
GLOBE New Zealand
HMI Technologies Limited
Horticulture New Zealand
Indigo Limited
Interim Climate Change Committee
Insurance Council of New Zealand
Jill Duggan (U.K.)
Jim McKinlay
John Scott, Chiltern Power
Jonathan Church
KiwiRail
Local Government New Zealand
Low-Emissions Transition Hub, Ministry for the Environment

Mainfreight Limited
MartinJenkins
McGuinness Institute
Mercury NZ Limited
Meridian Energy
Ministry for Primary Industries
Ministry for the Environment
Ministry of Business, Innovation & Employment
Ministry of Foreign Affairs and Trade
Ministry of the Environment, Government of Japan
Ministry of Transport
Motu Economic and Public Policy Research
National Energy Research Institute
New Zealand Agricultural Greenhouse Gas Research Centre
New Zealand Aluminium Smelter
New Zealand Carbon Farming
New Zealand Green Building Council
New Zealand Super Fund
New Zealand Transport Agency
New Zealand Venture Investment Fund Limited
Office of the Parliamentary Commissioner for the Environment
Pāmu (Landcorp Farming Limited)
Parliamentary Commissioner for the Environment – Dr Jan Wright
Parliamentary Commissioner for the Environment – Simon Upton
Paul Ridley-Smith and Tim Brown
Petroleum Exploration & Production Association New Zealand
Portchester Consulting
Professor David Evison, University of Canterbury
Professor Dave Frame, Victoria University of Wellington
Professor Geoffrey Heal, Columbia Business School
Professor Jonathan Boston, Victoria University of Wellington
Professor Ralph E Sims, Massey University
Responsible Investment Association Australasia
Rory Christian, New York Environmental Defense Fund
Sapere Research Group
Scion
Simon Corbell
Stephen Drew
Sustainability Council of New Zealand
Sustainable Business Council
Te Rūnanga o Ngāi Tahu
The Morgan Foundation
The New Zealand Initiative
The Policy Observatory
The Royal Society of New Zealand
The Treasury
Transpower New Zealand Limited
Venture Southland
Victoria University of Wellington - Deep South National Science Challenge

Vivid Economics
 Water New Zealand
 Westpac New Zealand
 Westpac New Zealand – ETS Trading
 Willis Re
 Z Energy

Roundtables

Infometrics, Statistics NZ, Ministry for the Environment, Ministry for Primary Industries and Ministry of Business Innovation & Employment – Data Modelling

E-Mission Possible Roundtables:

- Roundtable 1: Unlocking our low-emission future
- Roundtable 2: Mitigation in the Land Sector
- Roundtable 3: Low-emission investment and ETS reform
- Roundtable 4: Directing mitigation policy and action for result

Modelling New Zealand's transition to a low-emissions economy

London/Paris engagement meetings

25 Pathways Platform

Bank of England's Prudential Regulation Authority

Committee on Climate Change

Confederation of British Industry

Department for Business, Energy and Industrial Strategy

Grantham Research Institute on Climate Change and the Environment (LSE)

International Energy Agency

OECD Environment Directorate

Principles for Responsible Investment

Vivid Economics

Willis Re International/Willis Towers Watson

Conferences, seminars and presentations

Automobile Association National Council

Bioenergy Association Workshop

BusinessNZ Affiliated Industries Group

BusinessNZ Corporate Affairs and Regulatory Forum

BusinessNZ Energy Council

CEO Forum Breakfast – Climate Change

Climate Change 2017 (Chatham House)

Climate Leaders Coalition – On a Mission to Reduce Emissions in New Zealand

Construction and Demolition Waste: Reducing, Re-using and Reporting on Waste in NZ

Deep South Challenge: Climate-resilient Māori forestry and agriculture

EDS Climate Change and Business Conference

EMANZ – Energising A Low Emissions Economy

Environmental Defence Society: Green Light or Light Green? 2018

Environmental Defence Society: Tipping Points 2017

Electricity Retailers' Association of New Zealand – Talking Heads

EWWorld NZ Industry Conference

Improving Foresight in Government and Safeguarding the Future

Local Government New Zealand Conference

Local Government New Zealand – Metro Mayors Forum
Major Electricity User’s Group (MEUG)
Ministry of Business, Innovation & Employment – Expert Advisory Panel
Ministry for Primary Industries – Biological Emissions Reference Group (BERG)
Ministry for Primary Industries – Climate Change Forestry Reference Group (CCFRG)
New Zealand Wind Energy Conference 2018
NIWA – The Emergence of Climate Change
NZIER – Annual General Meeting 2018
Productivity Conference on Technological Change and Productivity
Red Meat Sector Conference

References

- 2° Investing Initiative. (2017a). All swans are black in the dark: How the short-term focus of financial analysis does not shed light on long-term risks. New York: 2° Investing Initiative and Generation Foundation.
- 2° Investing Initiative. (2017b). Limited visibility: The current state of corporate disclosure on long-term risks. New York: 2° Investing Initiative and Generation Foundation.
- AA Motoring. (2018). Running costs. Auckland: New Zealand Automobile Association.
- Aalsborg CSP. (2015). 36.6MWTH integrated energy system based on CSP, Australia. Retrieved from www.aalsborgcsp.com/projects/366mwth-integrated-energy-system-based-on-csp-australia/
- ACC. (2017). Investing in New Zealanders: Annual Report 2017. Wellington: Accident Compensation Corporation.
- ACCA. (2018). Rules, principles and Sarbanes-Oxley. Retrieved from <http://www.accaglobal.com/an/en/student/exam-support-resources/professional-exams-study-resources/p1/technical-articles/rules-principles-sarbanesoxley.html>
- Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. *American Economic Review*, 102(1), 131-166.
- ACIL Allen. (2015). Commercial building disclosure, program review. Brisbane, Australia: ACIL Allen.
- Adams, T., & Turner, J. A. (2012). An investigation into the effects of an emissions trading scheme on forest management and land use in New Zealand. *Forest Policy and Economics*, 15, 78-90.
- Adger, W. N., Quinn, T., Lorenzoni, I., & Murphy, C. (2016). Sharing the pain: Perceptions of fairness affect private and public response to hazards. *Annals of the American Association of Geographers*, 106(5), 1079-1096.
- Afionis, S., Sakai, M., Scott, K., Barrett, J., & Gouldson, A. (2017). Consumption-based carbon accounting: does it have a future? *Wiley Interdisciplinary Reviews: Climate Change*, 8(1), e438.
- Aghion, P., Dechezleprêtre, A., Hemous, D., Martin, R., & Van Reenen, J. (2012). Carbon taxes, path dependency and directed technical change: Evidence from the auto industry. NBER working paper 18596. Cambridge, MA: National Bureau of Economic Research.
- Aghion, P., Hepburn, C., Teytelboym, A., & Zenghelis, D. (2014). Path dependence, innovation and the economics of climate change. London: The New Climate Economy.
- Ahika Consulting. (2017). Otago wood energy project scoping study. Retrieved from https://www.bioenergy.org.nz/documents/resource/Reports/Wood-Energy-Otago-Project-Scoping-Report-FINAL_12Feb2018.pdf
- Ahrens, J. (2007). Governance in the process of economic transformation. In M. Jovanović, L. Daigon, Yeon-Chean-Oh, S.-J. Park, & B. Seliger (Eds.), *System transformation in comparative perspective: Affinity and diversity in institutional, structural and cultural patterns*. Berlin: LIT Verlag.
- AIA Canada. (2017). Yearbook 2017: Canadian collision repair industry. Ottawa: Automotive Industries Association of Canada.
- Airbus. (2017, 28 November 2017). Airbus, Rolls-Royce and Siemens team up for electric future. Retrieved from <https://www.airbus.com/newsroom/press-releases/en/2017/11/airbus--rolls-royce--and-siemens-team-up-for-electric-future-par.html>
- Alamdari, H. (2017). Aluminium production process: Challenges and opportunities. *Metals*, 7(133), 1-3.
- Alcott, B. (2005). Jevons' paradox. *Ecological Economics*, 54(1), 9-21.
- Allan, C., Kerr, S., & Will, C. (2015). Are we turning a brighter shade of green? The relationship between household characteristics and greenhouse gas emissions from consumption in New Zealand. Motu Working Paper 15-06. Wellington: Motu Economic and Public Policy Research.
- Allen, M. (2015). Short-lived promise? The science and policy of cumulative and short-lived climate pollutants. Oxford: Oxford Martin School, University of Oxford.
- Allen, M., Cain, M., & Shine, K. P. (2017). Climate metrics under ambitious mitigation. Oxford: Oxford Martin School.
- Allen, M., Fuglestedt, J. S., Shine, K. P., Reisinger, A., Pierrehumbert, R. T., & Forster, P. M. (2016). New use of global warming potentials to compare cumulative and short-lived climate pollutants. *Nature Climate Change*, 6(8), 773-776.
- Allen, M., Shine, K. P., Fuglestedt, J. S., Millar, R. J., Cain, M., Frame, D. J., & Macey, A. H. (2018). A solution to the misrepresentations of CO₂-equivalent emissions of short-lived climate pollutants under ambitious mitigation. *npj Climate and Atmospheric Science*, 1(1), 16.
- Allianz. (2010). The sixth Kondratieff – long waves of prosperity. Frankfurt: Allianz Global Investors.
- Allianz. (2013). Turning point: The "green" Kondratieff - or why crises can be a good thing. Frankfurt and Milan: Allianz Global Investors GmbH.

- Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., . . . Hamburg, S. P. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. *Science*, *10.1126/science.aar7204*.
- Amin, A.-L., Dimsdale, T., & Jaramillo, M. (2014). *Designing smart green finance incentive schemes: The role of the public sector and development banks*. London: E3G.
- Anastasiadis, S., & Kerr, S. (2013). Mitigation and heterogeneity in management practices on New Zealand dairy farms. Motu Working Paper 13-11. Wellington: Motu Economic and Public Policy Research.
- Anderson, B., Bernauer, T., & Baliotti, S. (2017). Effects of fairness principles on willingness to pay for climate change mitigation. *Climatic Change*, *142*(3), 447-461.
- Anderson, M. (2016). Submission on the NZ ETS Review discussion document. Retrieved from http://www.mfe.govt.nz/sites/default/files/media/NZETS_reviewstage2%20-%20Anderson%2C%20Marlene%2000110%20%282%29.pdf
- Antarciuc, E., Zhu, Q., Almarri, J., Zhao, S., Feng, Y., & Agyemang, M. (2018). Sustainable venture capital investments: An enabler investigation. *Sustainability*, *10*(4), 1204.
- Anthony, C. (2015). Anaerobic digestion. Retrieved from <https://www.fwi.co.uk/academy/lesson/anaerobic-digestion>
- ANZ. (2016). GBCNZ: Green bond market overview. Sydney: ANZ.
- APC. (2005). The private cost effectiveness of improving energy efficiency. Canberra: Australian Productivity Commission.
- APC. (2017a). Trade and assistance review, 2015-16. Canberra: Australian Productivity Commission.
- APC. (2017b). Transitioning regional economies. Study report. Canberra: Australian Productivity Commission.
- APC, & NZPC. (2012a). Strengthening trans-Tasman economic relations. Canberra and Wellington: Australian Productivity Commission and New Zealand Productivity Commission.
- APC, & NZPC. (2012b). Strengthening trans-Tasman economic relations. Supplementary paper D: Cross-border movement of people. Canberra and Wellington: Australian Productivity Commission and New Zealand Productivity Commission.
- Arbib, J., & Seba, T. (2017). Rethinking transportation 2020-2030: RethinkX.
- ARENA. (2018). Welcome to ARENA, the Australian Renewable Energy Agency. Retrieved from <http://arena.gov.au/about/>
- Arlinghaus, J. (2015). Impacts of carbon prices on indicators of competitiveness. Paris: OECD.
- Arrow, K. J., & Fisher, A. C. (1974). Environmental preservation, uncertainty, and irreversibility. *The Quarterly Journal of Economics*, *88*(2), 312-319.
- ARUP, & Verdant Vision. (2015). Life cycle assessment of electric vehicles: Final report. Melbourne: Arup.
- Asafu-Adjaye, J. (2005). *Environmental economics for non-economists: Techniques and policies for sustainable development* (2nd ed.). Singapore: World Scientific Publishing Company.
- Assamoi, B., & Lawryshyn, Y. (2012). The environmental comparison of landfilling vs. incineration of MSW accounting for waste diversion. *Waste Management*, *32*(5), 1019-1030.
- Astrup, T., Møller, J., & Fruergaard, T. (2009). Incineration and co-combustion of waste: Accounting of greenhouse gases and global warming contributions. *Waste Management & Research*, *27*(8), 789-799.
- Asuncion, J., Rednall, S., Murray, D. R., & Krumdieck, S. (2012). New Zealand intermodal freight network and the potential for mode shifting. Christchurch: University of Canterbury.
- ASX. (2014). Corporate governance principles and recommendations (3rd ed.). Sydney: Australian Stock Exchange Corporate Governance Council.
- Atkins, M. J., Neale, J. R., Wu, Y.-H., & Walmsley, M. R. W. (2018). Regional and national greenhouse gas emissions reduction planning. *Chemical Engineering Transactions*, *70*, 19-24.
- Atlantis Resources. (2018). MeyGen. Edinburgh: Atlantis Resources.
- Auckland Council. (2018). Green bond issue a success with \$200 million raised for electric trains. Retrieved from <http://ourauckland.aucklandcouncil.govt.nz/articles/news/2018/6/green-bond-issue-a-success-with-200-million-raised-for-electric-trains/>
- Auckland Transport. (2017). Annual report. Auckland: Auckland Transport.
- Australian Automobile Association. (2017). Benefits of reducing the age of Australia's light vehicle fleet: Summary report. Canberra: Australian Automobile Association.
- Australian Competition & Consumer Commission. (2018). Restoring electricity affordability and Australia's competitive advantage: Retail Electricity Pricing Inquiry—Final Report. Canberra: Australian Competition & Consumer Commission.
- Australian Energy Market Commission. (2018). Final rule determination: National electricity amendment (inertia ancillary service market) rule 2018. Sydney: Australian Energy Market Commission.
- Australian Productivity Commission. (2010). Bilateral and regional trade agreements, Research report. Canberra.

- Averchenkova, A., & Bassi, S. (2016). Beyond the targets: Assessing the political credibility of pledges for the Paris Agreement. Policy brief February 2016. London: Grantham Research Institute for Climate Change and the Environment, Centre for Climate Change Economics and Policy.
- Awatere, S. (2018). Climate-resilient Māori forestry and agriculture. Retrieved from <https://www.deepsouthchallenge.co.nz/news-updates/dsc-seminar-8-climate-resilient-maori-forestry-and-agriculture>
- Baker McKenzie, & PRI. (2017). Climate disclosure country reviews: Recommendations of the FSB Task Force on Climate-related Financial Disclosures. Chicago: Baker McKenzie and Principles for Responsible Investment.
- Bank of England. (2017). Quarterly Bulletin 2017 Q2. Topical article: The Bank of England's response to climate change. *Bank of England Quarterly Bulletin*, 2017 Q2, 97-109.
- Barns, S., & Young, J. (2012). Cap-and-trade of diffuse emissions of nitrogen in Lake Taupo Catchment. Reviewing the policy decisions and the market. Waikato Regional Council Technical Report 2013/34. Hamilton: Waikato Regional Council.
- Baron, R. (2016). The role of public procurement in low-carbon innovation. Paris: OECD.
- Barton, B. (2014). Energy efficiency and rental accommodation: Dealing with split incentives *Law as change: Engaging with the life and scholarship of Adrian Bradbrook* (pp. 59-81). Adelaide: University of Adelaide Press.
- Barton, B., Jordan, K., & Severinsen, G. (2013). Carbon capture and storage: Designing the legal and regulatory framework for New Zealand. A report for the Ministry of Business, Innovation and Employment and the New Zealand Carbon Capture and Storage Partnership. Hamilton: Centre for Environmental, Resources and Energy Law, University of Waikato.
- Barton, B., & Schütte, P. (2015). Electric vehicle policy: New Zealand in a comparative context. Hamilton: Centre for Environmental, Resources and Energy Law, University of Waikato.
- Batstone, S., & Reeve, D. (2014). Trends in residential electricity consumption. Report for the Electricity Networks Association. Wellington: Sapere Research Group Ltd.
- BCG. (2017). Total societal impact: A new lens for strategy. Boston: Boston Consulting Group.
- BECA. (2018). TC assessment of the administration costs and barriers of scenarios to mitigate biological emissions from agriculture. Wellington: BECA.
- Beeby, N. (2017). 'Alternative proteins is not a new concept': Beef + Lamb NZ on the threat of synthetic meat. Retrieved from <https://thespinoff.co.nz/business/01-11-2017/alternative-proteins-is-not-a-new-concept-beef-lamb-nz-on-the-threat-of-synthetic-meat/>
- Beef + Lamb New Zealand. (2018). Environment strategy and implementation plan 2018-22. Wellington: Beef + Lamb New Zealand.
- Beer, A. (2015). Structural adjustment programmes and regional development in Australia. *Local Economy*, 30(1), 21-40.
- BEIS. (2018a). 2016 UK greenhouse gas emissions, final figures. London: Department for Business, Energy & Industrial Strategy.
- BEIS. (2018b). Streamlined energy & carbon reporting: Government response. London: Department for Business, Energy & Industrial Strategy.
- Bennett, B., Bradbury, M., & Prangnell, H. (2006). Rules, principles and judgments in accounting standards. *Abacus*, 42(2), 189-204.
- Bennett, L. (2018). \$240m more from Provincial Growth Fund for Govt's One Billion Trees programme initiatives. Retrieved from https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12106229
- Benson, D., & Lorenzoni, I. (2014). Examining the scope for national lesson-drawing on climate governance. *Political Quarterly*, 85(2), 202-211.
- Bentley, R. (2017). *Innovate! Transforming New Zealand's technology-based economy*. Wellington: Steele Roberts Aotearoa.
- Berg, B., Dowdell, D., & Curtis, M. (2016). New Zealand whole-building whole-of-life framework: Development of reference office buildings for use in early design. Porirua: BRANZ.
- Beyond Zero Emissions. (2017). Zero carbon industry plan: rethinking cement. Victoria, Australia: Beyond Zero Emissions.
- Billington, P., Abel Smith, C., & Ball, M. (2017). Financing the transition: Harnessing UK cities' ambition for clean energy. Leeds and Peterborough: UK100.
- Bioenergy Association. (2016). Submission on the NZ ETS Review discussion document. Wellington: Ministry for the Environment.
- Blakeley, N., Lewis, G., & Mills, D. (2005). The economics of knowledge: what makes ideas special for economic growth? Policy Perspectives Paper 05/05. Wellington: The Treasury.
- Blick, G., & Comendant, C. (2018). A circular economy for Auckland: Scoping the potential economic benefits. Report prepared for the Sustainable Business Network. Auckland: Sapere Research Group Ltd.

- Blind, K. (2012). The influence of regulations on innovation: A quantitative assessment for OECD countries. *Research Policy*, 41(2), 391-400.
- Bloomberg New Energy Finance. (2017). Electric cars to reach price parity by 2025. Retrieved from <https://about.bnef.com/blog/electric-cars-reach-price-parity-2025/>
- Bloomberg New Energy Finance. (2018a). Electric buses in cities: Driving towards cleaner air and lower CO₂. Retrieved from <https://data.bloomberglp.com/bnef/sites/14/2018/05/Electric-Buses-in-Cities-Report-BNEF-C40-Citi.pdf>
- Bloomberg New Energy Finance. (2018b). Electric vehicle outlook: 2018. London: Bloomberg New Energy Finance.
- Bloomberg, S., Lovett, A., & Rissmann, C. (2018). Calculation of greenhouse gas emissions for Queenstown and Wanaka wastewater treatment plants. Invercargill: Land and Water Science.
- BMWi. (2011). Research for an environmentally sound, reliable and affordable energy supply: 6th Energy Research Programme of the Federal Government. Berlin: Federal Ministry of Economics and Technology (BMWi).
- Bogner, J., Pipatti, R., Hashimoto, S., Diaz, C., Mareckova, K., Diaz, L., . . . Gregory, R. (2008). Mitigation of global greenhouse gas emissions from waste: Conclusions and strategies from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation). *Waste Management & Research*, 26(1), 11-32.
- Boston, J. (2016). Anticipatory governance: How well is New Zealand safeguarding the future? *Policy Quarterly*, 12(3), 11-24.
- Boston, J. (2017). Protecting long-term interests in a short-term world: an agenda for better governmental stewardship. *New Zealand Journal of Public and International Law*, 15(1), 93-121.
- Bosworth, R. (2015). The future of food and agriculture. Retrieved from <http://pureadvantage.org/news/2015/12/10/the-future-of-food-and-agriculture/>
- Bosworth, R. (2017). Synthetic meats are on their way, and our farmers are going to be left behind. Retrieved from <https://thespinoff.co.nz/business/24-10-2017/synthetic-meats-are-on-their-way-and-our-farmers-are-going-to-be-left-behind/>
- Boušková, A. (2018). Assessment of potential for energy generation from expanding industrial wastewater treatment facilities. Hamilton: BPO Ltd.
- Bowen, A., & Dietz, S. (2016). The effects of climate change on financial stability, with particular reference to Sweden. London: Grantham Research Institute on Climate Change and the Environment.
- Bowerman, N. H. A., Frame, D. J., Huntingford, C., Lowe, J. A., Smith, S. M., & Allen, M. R. (2013). The role of short-lived climate pollutants in meeting temperature goals. *Nature Climate Change*, 3(12), 1021-1024.
- Bradley, J. (n.d.). Maori cultural considerations in developing and operating wastewater systems: Case history experiences. Wellington: MWH New Zealand Ltd.
- Brand, C., Anable, J., & Tran, M. (2013). Accelerating the transformation to a low carbon passenger transport system: The role of car purchase, taxes, feebates, road taxes and scrappage incentives in the UK. *Transportation Research Part A: Policy and Practice*, 49, 132-148.
- Brander, M. (2012). Greenhouse gases, CO₂, CO₂e, and carbon: What do all these terms mean? Edinburgh: Ecometrica.
- BRANZ. (2015). House condition survey. Porirua: BRANZ.
- BRANZ. (2018a). About BRANZ. Retrieved from <https://www.branz.co.nz/about-branz>
- BRANZ. (2018b). REBRI. Retrieved from https://www.branz.co.nz/cms_display.php?st=1&sn=106
- Bridges, S. (2017). Next generation roads of national significance: Press release. Retrieved from <https://www.national.org.nz/next-generation-roads-of-national-significance>
- Brown, E. G., Jr. (2016). Governor Brown signs nation's toughest super pollutant restrictions into law [Press release]. Retrieved from <https://www.gov.ca.gov/news.php?id=19549>
- Brown, M. (2001). Market failures and barriers as a basis for clean energy policies. *Energy Policy*, 29(14), 1197-1207.
- Brown, M. (2018). Company develops 'green' graphite from forestry waste. *The Malborough Express*. Retrieved from <https://www.stuff.co.nz/business/104690686/company-develops-green-graphite-from-forestry-waste>
- Brunner, S., Flachsland, C., & Marschinski, R. (2012). Credible commitment in carbon policy. *Climate Policy*, 12(2), 255-271.
- Bryant, J. (2003). Demographic change and New Zealand's economic growth. Working Paper 03/04. Wellington: The Treasury.
- Buchanan, A., & Levine, B. (1999). Wood-based building materials and atmospheric carbon emissions. *Environmental Science & Policy*, 2, 427-437.
- Buchner, B. K., Trabacchi, C., Mazza, F., Abramskiehn, D., & Wang, D. (2015). Global landscape of climate finance 2015. Venice: Climate Policy Initiative.

- Buller District Council. (2016). Agenda: Meeting of the Economic Development Committee. Westport: Buller District Council.
- Burgess, J. (2011). Sustainability of the New Zealand housing stock. Porirua: BRANZ.
- Burgess, J., Buckett, N., & Page, I. (2013). Prefabrication impacts in the New Zealand construction industry. Porirua: BRANZ.
- Burr, L. (2017). Government hints at KiwiRail overhaul as company under review. Retrieved from <http://www.newshub.co.nz/home/politics/2017/05/government-hints-at-kiwirail-overhaul-as-company-under-review.html>
- Burrows, L., Easdale, T. A., Wakelin, S. J., Quinn, J., Graham, E., & Mackay, A. (2018). Carbon sequestration potential of non-ETS land on farms. Wellington: Ministry for Primary Industries.
- BusinessNZ Energy Council. (2015). New Zealand energy scenarios: Navigating energy futures to 2050. Wellington.
- C2ES. (2015). Market mechanisms: Understanding the options. Arlington VA: Center for Climate and Energy Solutions.
- Cabinet Office. (2017). Cabinet Manual. Wellington: Department of the Prime Minister and Cabinet.
- Calel, R., & Dechezleprêtre, A. (2016). Environmental policy and directed technological change: Evidence from the European carbon market. *The Review of Economics and Statistics*, 98(1), 173-191.
- Calibre Consulting. (2017). Biogas fuel potential in municipal wastewater treatment. Retrieved from <https://www.bioenergy.org.nz/documents/events/WtE-Jurgen1-Potential-for-further-biogas.pdf>
- California Air Resources Board. (2013). Heavy-Duty (Tractor-Trailer) Greenhouse Gas Regulation. Retrieved from <https://www.arb.ca.gov/cc/hdghg/hdghg.htm>
- California Climate Investments, & California Air Resources Board. (2018). Implementation manual for the clean vehicle rebate project. Sacramento: California Air Resources Board.
- Callister, P., & Didham, R. (2010). Workforce composition - Changing industries, Te Ara - the encyclopedia of New Zealand. Retrieved from <https://teara.govt.nz/en/workforce-composition/page-3>
- Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., & Tanaka, M. (2018). Climate change challenges for central banks and financial regulators. *Nature Climate Change*, 8, 462-468.
- Campos, J. L., Valenzuela-Heredia, D., Pedrouso, A., Val del Rio, A., Belmonte, M., & Mosquera-Corral, A. (2016). Greenhouse gases emissions from wastewater treatment plants: Minimization, treatment, and prevention. *Journal of Chemistry*, 2016, 1-12.
- Cann, G. (2017). Emissions Trading Scheme costs could force Wellington landfill bills to soar. *Stuff*. Retrieved from <https://www.stuff.co.nz/dominion-post/news/93962891/emissions-trading-scheme-costs-could-force-wellington-landfill-bills-to-soar>
- Carbon Brief. (2015, 16 September 2015). Paris 2015: Tracking country climate pledges. Retrieved from <https://www.carbonbrief.org/paris-2015-tracking-country-climate-pledges>
- Carbon Brief. (2017, 5 April 2017). Analysis: Just four years left of the 1.5C carbon budget. Retrieved from <https://www.carbonbrief.org/analysis-four-years-left-one-point-five-carbon-budget>
- Carbon Brief. (2018, 28 February 2018). OECD: Fossil fuel subsidies added up to at least \$373 billion in 2015. Retrieved from <https://www.carbonbrief.org/oecd-fossil-fuel-subsidies-373-billion-2015>
- Carbon Tracker. (2013). Wasted capital and stranded assets. Retrieved from <https://www.carbontracker.org/reports/unburnable-carbon-wasted-capital-and-stranded-assets/>
- Carbon Trust. (2018a). Mandatory carbon reporting. Retrieved from <https://www.carbontrust.com/resources/guides/carbon-footprinting-and-reporting/mandatory-carbon-reporting/>
- Carbon Trust. (2018b). What are scope 3 emissions, how can they be measured and what benefit is there to organisations measuring them? Retrieved from <https://www.carbontrust.com/resources/faqs/services/scope-3-indirect-carbon-emissions/>
- Carden, S. (2018). Farming must respect the past but build a different future. Retrieved from <http://pureadvantage.org/news/2018/01/22/farming-must-respect-past-build-different-future/>
- Cardia, E. (2008). Household technology: Was it the engine of liberation? 2008 meeting papers: Society for Economic Dynamics.
- Carney, M. (2015). Breaking the tragedy of the horizon: Climate change and financial stability. Speech by Mark Carney, Governor of the Bank of England, Chair of the Financial Stability Board, at Lloyd's of London, London, 29 September 2015. London: Bank of England.
- Carney, M. (2016). Resolving the climate paradox. Speech given by Mark Carney, Governor of the Bank of England, Chair of the Financial Stability Board. Arthur Burns Memorial Lecture, Berlin, 22 September 2016. London: Bank of England.
- Carter, N. (2014). The politics of climate change in the UK. *Wiley Interdisciplinary Reviews: Climate Change*, 5(3), 423-433.
- Carver, T., Dawson, P., & Kerr, S. (2017). Including forestry in an emissions trading scheme: Lessons from New Zealand. Wellington: Motu Economic and Public Policy Research.

- Carver, T., & Kerr, S. (2017). Facilitating carbon offsets from native forests. Motu Working Paper 17-01. Wellington: Motu Economic and Public Policy Research.
- CCILG. (2016a). NZ ETS Review submission to the Ministry for the Environment 2016, priority matters, Part 1: mitigation (reducing emissions – the ETS). Wellington: Climate Change Iwi Leaders Group.
- CCILG. (2016b). NZ ETS Review submission to the Ministry for the Environment 2016, priority matters, Part 1: mitigation (reducing emissions – the ETS). Retrieved from http://www.mfe.govt.nz/sites/default/files/media/NZETS_reviewstage1%20-%20Climate%20Change%20Iwi%20Leaders%20Group%20180.pdf
- CDP. (2014). Climate action and profitability: CDP S&P 500 Climate Change Report. New York: CDP North America.
- CDSB. (2016). Comply or explain: A review of FTSE 350 companies' environmental reporting and greenhouse gas emission disclosures in annual reports. London: Climate Disclosure Standards Board.
- Cenek, P. D., Kean, R. J., Kvatch, I. A., & Jamieson, N. J. (2012). Freight transport efficiency: A comparative study of coastal shipping, rail and road modes. Wellington: New Zealand Transport Agency.
- CEWEP. (2017). Landfill taxes and bans overview. Retrieved from <http://www.cewep.eu/wp-content/uploads/2017/12/Landfill-taxes-and-bans-overview.pdf>
- Chapman, R. (2015). *Time of useful consciousness: Acting urgently on climate change*. Wellington: Bridget Williams Books Ltd.
- Chapman Tripp. (2017). *Te Ao Māori: Trends and insights*. Auckland: Chapman Tripp.
- ChargeNet. (2018). ChargeNet Map. Retrieved from <https://charge.net.nz/map/>
- Church, J. (2015). Enforcing the climate change act. *UCL Journal of Law and Jurisprudence*, 4, 109-134.
- Citi GPS. (2015). *Energy Darwinism II: Why a low carbon future doesn't have to cost the earth*. London: Citi GPS: Global Perspectives and Solutions.
- Civil Aviation Authority. (2014). *New Southern Sky: National airspace and air navigation plan*. Wellington: Civil Aviation Authority.
- Clark, H. (2006). Helen Clark annual party conf. keynote address. Retrieved from <http://www.scoop.co.nz/stories/PA0610/S00539.htm>
- Clean Energy Council. (2016). *Clean energy Australia report 2016*. Melbourne: Clean Energy Council.
- Climate Bonds Initiative. (2016). *Green bonds highlights 2016*. London: Climate Bonds Initiative.
- Climate Bonds Initiative. (2017a). *Bonds and climate change: The state of the market 2017*. London: Climate Bonds Initiative.
- Climate Bonds Initiative. (2017b). *Climate bonds standard and certification*. Retrieved from <https://www.climatebonds.net/standards>
- Climate Bonds Initiative. (2017c). *Labelled green bonds data*. Retrieved from https://www.climatebonds.net/cbi/pub/data/bonds?items_per_page=100&order=field_bond_currency&sort=asc&page=6
- Climate Change Authority. (2014). *Light vehicle emissions standards for Australia: Research report*. Melbourne: Climate Change Authority.
- Clothier, B., Müller K, Hall A, Thomas S, van den Dijssel C, Beare M, . . . S, G. (2017). *Futures for New Zealand's arable and horticultural industries in relation to their land area, productivity, profitability, greenhouse gas emissions and mitigations*. Auckland: Plant & Food Research.
- Coase, R. H. (1960). The problem of social cost. *The Journal of Law & Economics*, 3, 1-44.
- Coleman, A. (2011). *Financial contracts and the management of carbon emissions in small scale plantation forests*. Wellington: Motu Economic and Public Policy Research.
- Collins, B. (2017). *Landlords neglect govt insulation offer*. Retrieved from <http://www.radionz.co.nz/news/political/333390/landlords-neglect-govt-insulation-offer>
- Columbia Climate Center. (2012). *Mitigating emissions from aluminium*. New York: Columbia Climate Center.
- Commerce Commission. (2016). *Topic paper 3: The future impact of emerging technologies in the energy sector*. Wellington: Commerce Commission.
- Commerce Commission. (2018). *Open letter: Our intention to gather information relating to emerging technologies*. Wellington: Commerce Commission.
- Committee on Climate Change. (2017a). *Meeting carbon budgets: Closing the policy gap. 2017 Report to Parliament*. London: Committee on Climate Change.
- Committee on Climate Change. (2017b). *Quantifying greenhouse gas emissions*. London: Committee on Climate Change.
- Committee on Climate Change. (2018). *UK's ambitious Clean Growth Strategy must be translated urgently into action*. Retrieved from <https://www.theccc.org.uk/2018/01/17/uks-ambitious-clean-growth-strategy-must-translated-urgently-action/>
- Commonwealth of Australia. (2016). *Improving the efficiency of new light vehicles: Draft regulation impact statement*. Canberra: Australian Government.

- Concept Consulting. (2016a). Electric cars, solar panels and batteries – how will they affect New Zealand's greenhouse gas emissions? Wellington: Concept Consulting Group Ltd.
- Concept Consulting. (2016b). Electric cars, solar panels, and batteries in New Zealand Vol 2: The benefits and costs to consumers and society. Wellington: Concept Consulting Group Ltd.
- Concept Consulting. (2017a). Cost-effective energy options for transitioning New Zealand to a low-carbon economy. Wellington: Concept Consulting Group Ltd.
- Concept Consulting. (2017b). Summary insights on energy-related carbon-abatement opportunities. Wellington: Concept Consulting
- Concept Consulting. (2018a). "Driving change" - Issues and options to maximise the opportunities from large-scale electric vehicle uptake in New Zealand. Wellington: Concept Consulting Group Ltd.
- Concept Consulting. (2018b). What is the case for electricity efficiency initiatives? Wellington: Concept Consulting Group Ltd.
- Concept Consulting, Motu Economic and Public Policy Research, & Vivid Economics. (2018a). Modelling the transition to a lower net emissions New Zealand: Interim results. Wellington: NZ Productivity Commission.
- Concept Consulting, Motu Economic and Public Policy Research, & Vivid Economics. (2018b). Modelling the transition to a lower net emissions New Zealand: Uncertainty analysis. Wellington: NZ Productivity Commission.
- Constitutional Advisory Panel. (2013). New Zealand's Constitution: A report on a conversation. Wellington: Constitutional Advisory Panel.
- Contact. (2017). Contact Energy green borrowing programme framework July 2017. Wellington: Contact Energy Limited.
- Conway, P. (2016). Achieving New Zealand's productivity potential. Research paper 2016/1. Wellington: New Zealand Productivity Commission.
- Conway, P. (2018). Can the kiwi fly? Achieving productivity lift-off in New Zealand. *International Productivity Monitor*, 34, 40-63.
- Cooper, R. W. (2005). Economic policy in the presence of coordination problems. *Revue d'économie politique*, 115(4), 379-390.
- COP23 Fiji. (2017). Countries reach historic agreement on agriculture [Press release]. Retrieved from <https://cop23.com.fj/countries-reach-historic-agreement-agriculture/>
- Coster, M. N. (n.d.). Greenhouse gas emissions from wastewater treatment schemes - New Zealand case study examples. Wellington: Water New Zealand.
- Costi, A. (2016). International law: Principles reissue 2. In Justice O'Regan (Ed.), *The laws of New Zealand*. Wellington: LexisNexis.
- Coughlan, T. (2018). Orr sells \$1 bln worth of over-priced carbon assets. Retrieved from <https://pro.newsroom.co.nz/articles/2481-orr-sells-1-bln-worth-of-over-priced-carbon-assets>
- Council of the European Union. (1999). Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Brussels: European Union.
- Covec. (2007). Recycling: Cost benefit analysis. A report prepared for the Ministry for the Environment. Auckland: Covec Ltd.
- Covec. (2012). Economic factors of waste minimisation in New Zealand. Prepared for Ministry for the Environment. Auckland: Covec Ltd.
- Creedy, J., & Sleeman, C. (2006). Carbon taxation, prices and welfare in New Zealand. *Ecological Economics*, 57(3), 333-345.
- Creutzig, F., Roy, J., Lamb, W. F., Azevedo, I. M. L., Bruine de Bruin, W., Dalkmann, H., . . . Weber, E. U. (2018). Towards demand-side solutions for mitigating climate change. *Nature Climate Change*, 8(4), 268-271.
- CRL. (2018). CRL and its benefits. Auckland: City Rail Link.
- Curran, P. (2016). What is climate finance? Retrieved from <http://www.lse.ac.uk/GranthamInstitute/faqs/what-is-climate-finance-and-where-will-it-come-from/>
- Daigneault, A. (2015). Modelling the economic impact of New Zealand's post-2020 climate change contribution. A report for the Ministry for Primary Industries & Ministry for the Environment. Auckland: Landcare Research.
- DairyNZ. (2017). Dairy action for climate change 2017-2018. Wellington: DairyNZ.
- DairyNZ. (2018). DairyNZ facility a world first in methane measurement. Retrieved from <https://www.dairynz.co.nz/news/latest-news/dairynz-facility-a-world-first-in-methane-measurement/>
- Daley, J., & Lancy, A. (2011). Investing in regions: Making a difference. Melbourne: Grattan Institute.
- Daniel, J. S., Solomon, S., Sanford, T. J., McFarland, M., Fuglestedt, J. S., & Friedlingstein, P. (2012). Limitations of single-basket trading: Lessons from the Montreal Protocol for climate policy. *Climatic Change*, 111(2), 241-248.
- Darby, M. (2018). UK will legislate net-zero carbon emissions target, says minister. Retrieved from <http://www.climatechangenews.com/2018/04/17/uk-calls-advisory-body-test-net-zero-carbon-target/>

- Davis, L. W. (2011). Evaluating the slow adoption of energy efficient investments: Are renters less likely to have energy efficient appliances? In D. Fullerton & C. Wolfram (Eds.), *The design and implementation of US climate policy* (pp. 301-316). Chicago: University of Chicago Press.
- Davis, S. J., Haltiwanger, J., & Jarmin, R. (2008). Turmoil and growth: Young businesses, economic churning, and productivity gains. Kansas City: Ewing Marion Kauffman Foundation.
- Davis, S. J., Lewis, N. S., Shaner, M., Aggarwal, S., Arent, D., Azevedo, I. L., . . . Caldeira, K. (2018). Net-zero emissions energy systems. *Science*, *360*(6396).
- de Klein, C., van der Weerden, T., Kelliher, F., Wheeler, D., & Rollo, M. (2017). Initial review of the suitability of OVERSEER Nutrient Budgets Model for farm scale greenhouse gas reporting. Hamilton: AgResearch.
- De Long, J. B., & Summers, L. H. (1991). Equipment investment and economic growth. *The Quarterly Journal of Economics*, *106*(2), 445-502.
- de Serres, A., Yashiro, N., & Boulhol, H. (2014). An international perspective on the New Zealand productivity paradox. Wellington: New Zealand Productivity Commission.
- Deakins, D., North, D., & Bensemman, J. (2015). Paradise lost? The case of technology-based small firms in New Zealand in the post-global financial crisis economic environment. *Venture Capital*, *17*(1/2), 129-150.
- Dechezleprêtre, A., Martin, R., & Bassi, S. (2016). Climate change policy, innovation and growth. Policy brief. London: Grantham Research Institute on Climate Change and the Environment, Global Green Growth Institute.
- Dechezleprêtre, A., Martin, R., & Mohnen, M. (2017). Knowledge spillovers from clean and dirty technologies (pp. 113). London: Grantham Research Institute on Climate Change and the Environment, Centre for Climate Change Economics and Policy.
- Deloitte. (2014). National freight demand study. Wellington: Ministry of Transport.
- Deloitte. (2016). New Zealand ports and freight yearbook 2016. Auckland: Deloitte.
- Deloitte. (2018). Unlocking commercial opportunities from intelligent transport systems.
- Demirgüç-Kunt, A., Martinez-Peria, M. S., & Tressel, T. (2015). The impact of the global financial crisis on firms' capital structure. Policy Research Working Paper No. 7522. Washington D.C.: The World Bank.
- Department of Energy and Climate Change (UK). (2014). Triennial Review of the Committee on Climate Change. London: Department of Energy and Climate Change.
- Devlin, C. (2017). Wellingtonians taking part in 'virtual' solar and battery trial. Retrieved from <https://www.stuff.co.nz/business/94018297/wellingtonians-taking-part-in-virtual-solar-and-battery-power-plant-trial>
- DIA. (2018a). Cabinet paper - Review of three waters infrastructure: key findings and next steps. Wellington: Department of Internal Affairs.
- DIA. (2018b). Three waters review. Retrieved from <https://www.dia.govt.nz/Three-waters-review>
- Dietrich, A. (2012). Does growth cause structural change, or is it the other way around? A dynamic panel data analysis for seven OECD countries. *Empirical Economics*, *43*(3), 915-944.
- Dietz, S., & Stern, N. (2015). Endogenous growth, convexity of damage and climate risk: How Nordhaus' framework supports deep cuts in carbon emissions. *The Economic Journal*, *125*(583), 574-620.
- DNB. (2017). Waterproof? An exploration of climate-related risks for the Dutch financial sector. Amsterdam: De Nederlandsche Bank.
- Dorreen, M., Wright, L., Matthews, G., Patel, P., & Wong, D. S. (2017). Transforming the way electricity is consumed during the aluminium smelting process. In L. Zhang, J. Drelich, N. R. Neelameggham, D. P. Guillen, N. Haque, J. Zhu, Z. Sun, T. Wang, J. A. Howarter, F. Tesfaye, S. Ikhmayies, E. Olivetti, & M. W. Kennedy (Eds.), *Energy Technology 2017* (pp. 15-25). Switzerland: Springer International Publishing.
- DPMC. (2017). Impact analysis requirements. Cabinet Office circular CO (17) 3. Wellington: Cabinet Office.
- Duhon, M., McDonald, H., & Kerr, S. (2015). Nitrogen trading in Lake Taupo. An analysis and evaluation of an innovative water management policy. Motu Working Paper 15-07. Wellington: Motu Economic and Public Policy Research.
- Eaqub, S., & de Raad, J. (2018). Codebreakers: Constructing KiwiBuild homes to a standard above the New Zealand Building Code. Wellington: Sense Partners, New Zealand.
- East Harbour Energy. (2014). The economics of geothermal heat (presentation to the Direct Heat Workshop, 18-19 February) Retrieved from www.bayofconnections.com/downloads/Mike%20Suggate%20-%20East%20Harbour%20Energy%20-%20The%20Economics%20of%20Geothermal%20Heat.pdf
- Easton, B. (2012). The Maori urban migration. Retrieved from <https://www.eastonbh.ac.nz/2012/08/the-maori-urban-migration/>
- EC. (2015). Closing the loop - An EU action plan for the Circular Economy. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2015) 614 final. Brussels: European Commission.

- EDS. (2016, 29 April). Submission on discussion document - New Zealand Emissions Trading Scheme. Retrieved from http://www.mfe.govt.nz/sites/default/files/media/NZETS_reviewstage2%20-%20Environmental%20Defence%20Society%2000065%20%282%29.pdf
- Edwards, B. (2018, 9 February 2018). Shaw hopes for National's support on climate change legislation. *National Business Review*.
- EECA. (2012). EECA Awards 2012. Retrieved from <https://www.eeca.govt.nz/assets/Resources-EECA/EECA-Awards-2016/eeca-awards-winners-booklet-2012.pdf>
- EECA. (2017a). Biofuels. Wellington: EECA.
- EECA. (2017b). Electric vehicles. Retrieved from <https://www.energywise.govt.nz/on-the-road/electric-vehicles/>
- EECA. (2017c). Our programmes. Retrieved from www.eeca.govt.nz/about-eeca/our-programmes
- EECA. (2017d). Standards, rating and labels. Retrieved from <https://www.eeca.govt.nz/standards-ratings-and-labels/>
- EECA. (2018a). Crown Loans. Retrieved from <https://www.eecabusiness.govt.nz/funding-and-support/crown-loans/>
- EECA. (2018b). Energy end use database. Retrieved from <https://www.eeca.govt.nz/resources-and-tools/tools/energy-end-use-database/>
- EECA. (2018c). Low Emission Vehicles Contestable Fund. Retrieved from <https://www.eeca.govt.nz/funding-and-support/low-emission-vehicles-contestable-fund/>
- EECA. (2018d). Summaries of approved projects. Retrieved from <https://www.eeca.govt.nz/funding-and-support/low-emission-vehicles-contestable-fund/low-emission-vehicles-contestable-fund-successful-projects/previiously-approved-projects/>
- EECA. (2018e). Thermal mass. Retrieved from <https://www.energywise.govt.nz/at-home/building/thermal-mass/>
- EESI. (2017). Environmental impact bonds: Could they help save America's aging infrastructure? Retrieved from <http://www.eesi.org/articles/view/environmental-impact-bonds-could-they-help-save-americas-aging-infrastructure>
- EFI. (2008). Solid waste to energy opportunities; theory and experience with the beneficial use of burnable wastes as fuel in NZ. Presentation by David Reid to the WasteMINZ Conference 2008: Energy for Industry.
- EHINZ. (2018). Home heating. Wellington: Centre for Public Health Research, Massey University.
- EIB. (2017). 2016 activity report: Impact for inclusion. Luxembourg: European Investment Bank Group.
- EIU. (2015). The cost of inaction: Recognising the value at risk from climate change. New York: The Economist Intelligence Unit.
- Electricity Authority. (2013). Investigation into the value of lost load in New Zealand: Report on methodology and key findings. Wellington: Electricity Authority.
- Electricity Authority. (2014). Analysis of historical electricity industry costs: Final report. Wellington: Electricity Authority.
- Electricity Authority. (2016). Electricity in New Zealand. Wellington: Electricity Authority.
- Electricity Authority. (2017). Enabling mass participation: Response and next steps: Decision. Wellington: Electricity Authority.
- electrive.com. (2017). Paris sets up €6,000 EV rebate and includes electric buses. Retrieved from <https://www.electrive.com/2017/12/19/paris-doubles-french-ev-rebates-includes-electric-buses/>
- Ellen MacArthur Foundation. (2018). Circular economy overview. Retrieved from <https://www.ellenmacarthurfoundation.org/circular-economy/overview/concept>
- Ellis, J., & Moarif, S. (2016). Enhancing transparency of climate finance under the Paris Agreement: Lessons from experience. Climate Change Expert Group Paper No. 2016(3). Paris: OECD and International Energy Agency.
- emhTrade. (2018). Micro-grid/embedded network platform. Retrieved from <https://emhtrade.co/micro-grid/>
- Emissions Trading Scheme Review Panel. (2011). Doing New Zealand's fair share: Emissions Trading Scheme Review 2011/ Final report. Wellington: Ministry for the Environment.
- Energywise. (2018). Energy efficient light bulbs. Retrieved from <https://www.energywise.govt.nz/tools/lighting/>
- Environment Audit Committee. (2014). Green finance: Twelfth report of session 2013-14. Volume 1. London: House of Commons.
- Environment Canterbury. (2018). Change 5 - nutrient management and Waitaki. Retrieved from <https://www.ecan.govt.nz/your-region/plans-strategies-and-bylaws/canterbury-land-and-water-regional-plan/change-5-nutrient-management-and-waitaki/>
- EPA. (2017). Privately-held units. Wellington: Environmental Protection Authority.
- EPA. (2018a). New Zealand Emissions Trading Register: Public information and reports. Retrieved from <https://emissionsregister.govt.nz/Common/InformationReports.aspx>

- EPA. (2018b). Privately-held units. Retrieved from <https://www.epa.govt.nz/industry-areas/emissions-trading-scheme/market-information/privately-held-units/>
- ERANZ. (2017). Smart meters - everything you needed to know and more. Wellington: The Electricity Retailers Association of New Zealand.
- ESRB Advisory Scientific Committee. (2016). Too late, too sudden: Transition to a low-carbon economy and systemic risk. Brussels: European Systemic Risk Board.
- EU High-Level Expert Group on Sustainable Finance. (2018). Financing a sustainable European economy: Final Report 2018 by the High-Level Expert Group on Sustainable Finance. Brussels: EU High-Level Expert Group on Sustainable Finance.
- Euronews. (2018). Can Denmark's solar power solution be a blueprint for sun-starved countries? Retrieved from www.euronews.com/2017/04/27/denmark-is-using-solar-to-heat-and-power-all-in-one-plant
- European Automobile Manufacturers' Association. (2016). Average vehicle age. Retrieved from <https://www.acea.be/statistics/tag/category/average-vehicle-age>
- European Commission. (2010). Being wise with waste: The EU's approach to waste management. Brussels: European Union.
- European Commission. (2016). An EU Strategy on Heating and Cooling. Brussels: European Commission.
- European Commission. (2017). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: The role of waste-to-energy in the circular economy. COM (2017) 34 final. Brussels: European Commission.
- European Commission. (2018a). Commission action plan on financing sustainable growth. Retrieved from https://ec.europa.eu/info/publications/180308-action-plan-sustainable-growth_en
- European Commission. (2018b). Proposal VAT rates. Retrieved from https://ec.europa.eu/taxation_customs/business/vat/action-plan-vat/proposal-vat-rates_en
- European Environment Agency. (2017). Fuel efficiency improvements of new cars in Europe slowed in 2016. Retrieved from <https://www.eea.europa.eu/highlights/fuel-efficiency-improvements-of-new>
- European Parliament and Council. (2014). Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups. *Official Journal of the European Union*, L330, 1-9.
- European Parliamentary Research Service. (2018). Briefing: CO₂ emissions from aviation. Brussels: European Parliamentary Research Service.
- Evans, G. (2018). Why electricity will replace coal in dairy plants. Retrieved from <https://pro.newsroom.co.nz/articles/3506-1-why-electricity-will-replace-coal-in-dairy-plants>
- Evison, D. (2016). The New Zealand forestry sector's experience in providing carbon sequestration services under the New Zealand Emissions Trading Scheme, 2008 to 2012. *Forest Policy and Economics*, 75, 89-94.
- Ewing, R., Bartholomew, K., Walters, J., Winkelman, S., & Anderson, G. (2010). Urban development, VMT and CO₂. In P. Howden-Chapman, K. Stuart, & R. Chapman (Eds.), *Sizing up the city: Urban form and transport in New Zealand* (pp. 18-33). Wellington: New Zealand Centre for Sustainable Cities.
- Ewing, R., & Rong, F. (2008). The impact of urban form on U.S. residential energy use. *Housing Policy Debate*, 19(1), 1-30.
- EY. (2018a). How climate risk can provide opportunities. Retrieved from <https://www.ey.com/gl/en/services/assurance/ey-how-can-climate-risk-provide-opportunities>
- EY. (2018b). How materiality can help reporting meet the demands of investors. Retrieved from <https://www.ey.com/gl/en/services/assurance/ey-how-materiality-can-help-reporting-meet-the-demands-of-investors>
- Fankhauser, S., Averchenkova, A., & Finnegan, J. (2018). 10 years of the UK Climate Change Act. London: The Centre for Climate Change Economics and Policy and the Grantham Research Institute on Climate Change and the Environment.
- FAO. (2011). Southeast Asian forests and forestry to 2020: Subregional report of the second Asia-Pacific forestry sector outlook study. Bangkok: Asia-Pacific Forestry Commission, Food and Agriculture Organization of the United Nations.
- FAO. (2016). Fishery and aquaculture statistics. Global capture production 1950-2014: Food and Agriculture Organisation: Fisheries and Aquaculture Department.
- Farla, J., Markard, J., Raven, R., & Coenen, L. (2012). Sustainability transitions in the making: A closer look at actors, strategies and resources. *Technological Forecasting and Social Change*, 79(6), 991-998.
- Farm Forestry New Zealand. (2007). An introduction to growing radiata pine. Retrieved from http://www.nzffa.org.nz/farm-forestry-model/resource-centre/information-leaflets/nzffa-guide-sheets-2007/nzffa-guide-sheet-no-1/#Stocking_Rates
- Federal Energy Regulatory Commission. (2017). Reports on demand response & advanced metering. Washington, DC, United States: Federal Energy Regulatory Commission.

- Feng, K., Hubacek, K., Guan, D., Contestabile, M., Minx, J., & Barrett, J. (2010). Distributional effects of climate change taxation: The case of the UK. *Environmental Science & Technology*, 44(10), 3670-3676.
- Figueres, C. (2013). 1st GLOBE Climate Legislation Summit. Retrieved from <http://newsroom.unfccc.int/unfccc-newsroom/1st-globe-climate-legislation-summit>
- Figueres, C., Schellnhuber, H. J., Whiteman, G., Rockstrom, J., Hobley, A., & Rahmstorf, S. (2017). Three years to safeguard our climate. *Nature*, 546(7660), 593-595.
- Finans Norge. (2018). Norway's financial sector produces 2030 roadmap to support a low-carbon, sustainable economy. Retrieved from <https://www.finansnorge.no/en/aktuelt/nyheter/2018/06/a-profitable-and-sustainable-norwegian-financial-sector/>
- Finon, D. (2017). The carbon prices making low carbon plants competitive. Paris, France: CIREN.
- Fisher, D. (2018). Māori leaders pitch to Māori landowners - let us pay to plant trees and we will share the carbon credit profits. Retrieved from https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=12108276
- Fleming, D. A., & Kerr, S. (2017). Agricultural mitigation options and policies. Presentation at E-Mission Possible Roundtable, 8 December 2017. Wellington: Motu Economic and Public Policy Research.
- FMA. (2017). KiwiSaver annual report 2017. Auckland: Financial Markets Authority.
- Foerster, A., Peel, J., Osofsky, H., & McDonnell, B. (2017). Keeping good company in the transition to a low carbon economy? An evaluation of climate risk disclosure practices in Australia. *Corporate and Securities Law Journal*, 35, 154-183.
- Fonterra. (2016). Fonterra Farmers' Handbook 2016/2017. Retrieved from <https://nzfarmsource.co.nz/assets/Resources/Dairy-Diary/Fonterra-Farmers-Handbook.pdf>
- Forbes, A. S., Norton, D. A., & Carswell, F. E. (2016). Artificial canopy gaps accelerate restoration within an exotic *Pinus radiata* plantation. *Restoration Ecology*, 24(3), 336-345.
- Forest & Bird. (2018). What are the solutions? Retrieved from <http://forestandbird.org.nz/saving-our-environment/climate-change-what-are-the-solutions>
- Forster, P., Ramaswamy, V., Artaxo, P., Bernsten, T., Betts, R., Fahey, D. W., . . . Van Dorland, R. (2007). Changes in atmospheric constituents and in radiative forcing. In S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M. Tignor, H. L. Miller, & Z. Chen (Eds.), *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 129-234). Cambridge: Cambridge University Press.
- Fouquet, R., & Pearson, P. J. G. (2012). Past and prospective energy transitions: Insights from history. *Energy Policy*, 50, 1-7.
- Gayer, T., & Parker, E. (2013). Cash for clunkers: An evaluation of the car allowance rebate system. Washington DC: Brookings Institution.
- Geels, F. W. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy*, 39(4), 495-510.
- Geels, F. W., Berkhout, F., & van Vuuren, D. P. (2016). Bridging analytical approaches for low-carbon transitions. *Nature Climate Change*, 6, 576.
- Generation Zero. (2017). Zero Carbon Act Summary. Retrieved from <http://zerocarbonact.nz/zca-summary/>
- Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., . . . Tempio, G. (2013). Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Rome: Food and Agriculture Organization of the United Nations.
- German, J., & Meszler, D. (2010). Best practices for feebate program design and implementation. Washington DC: The International Council on Clean Transportation.
- GHK. (2011). Impacts of structural change: Implications for policies supporting a transition to a green economy. Birmingham: GHK.
- Gibbs, M. T. (2008). The historical development of fisheries in New Zealand with respect to sustainable development principles. *The Electronic Journal of Sustainable Development*, 1(2), 23-33.
- Giesekam, J., Barrett, J., Taylor, P., & Owen, A. (2014). The greenhouse gas emissions and mitigation options for materials used in UK construction. *Energy and Buildings*, 78(1), 202-214.
- Gillard, R. (2016). Unravelling the United Kingdom's climate policy consensus: The power of ideas, discourse and institutions. *Global Environmental Change*, 40, 26-36.
- Gillingham, K., Harding, M., & Rapson, D. (2012). Split Incentives in Residential Energy Consumption. *The Energy Journal*, 33(2), 37-62.
- Glanville, K., & Chang, H.-C. (2015). Remote sensing analysis techniques and sensor requirements to support the mapping of illegal domestic waste disposal sites in Queensland, Australia. *Remote Sensing*, 7, 13053-13069.
- Global CCS Institute. (2017). Large scale CCS projects. Retrieved from <https://www.globalccsinstitute.com/projects/large-scale-ccs-projects>

- GLOBE International. (2018). The Global Legislators Organisation (GLOBE). Retrieved from <https://globelegislators.org/about-globe/25-globe-international>
- GNS Science. (2017). Geothermal energy driving Asaleo Care's Kawerau operation. Retrieved from <https://www.gns.cri.nz/content/download/12066/64286/file/Paper%20Processing%20-%20Asaleo.pdf>
- GNS Science. (2018). Geothermal energy: enabling widespread sustainable utilisation of geothermal resources. Retrieved from <https://www.gns.cri.nz/Home/Our-Science/Energy-Resources/Geothermal-Energy>
- Goodman, A., Koupil, I., & Lawson, D. W. (2012). Low fertility increases descendant socioeconomic position but reduces long-term fitness in a modern post-industrial society. *Proceedings of the Royal Society B: Biological Sciences*, 279(1746), 4342-4351.
- Gouin, D. M., Jean, N., & Fairweather, J. R. (1994). New Zealand agricultural policy reform and impacts on the farm sector. Lincoln: Agribusiness & Economics Research Unit, Lincoln University.
- Goulder, L. H., & Schein, A. R. (2013). Carbon taxes versus cap and trade: A critical review. *Climate Change Economics*, 4(3), 1350010.
- Government of Australia. (2017a). Emissions Reduction Fund: Overview. Canberra: Australian Department of Environment and Energy.
- Government of Australia. (2017b). National inventory report 2015: Volume 2. Canberra: Australian Department of Environment and Energy.
- Government of Australia. (2018). Australian greenhouse emissions information system: National greenhouse gas inventory - Kyoto Protocol classifications. Retrieved from <http://ageis.climatechange.gov.au/>
- Government of Brazil. (2015). Intended nationally determined contribution towards achieving the objective of the United Nations Framework Convention on Climate Change. Brasília: Government of the Federative Republic of Brazil.
- Government of Québec. (2018a). The Québec cap and trade system for greenhouse gas emissions allowances: Frequently asked questions. Québec: Government of Québec.
- Government of Québec. (2018b). Register of offset credit projects. Retrieved from http://www.mddelcc.gouv.qc.ca/changements/carbone/credits-compensatoires/registre_creditscompensatoires-en.htm
- GRA. (n.d.). New Zealand. Retrieved from <https://globalresearchalliance.org/country/new-zealand/>
- Grantham Research Institute on Climate Change and the Environment, & Law, S. C. f. C. C. (2018). Climate Change Laws of the World database. Retrieved from <http://www.lse.ac.uk/GranthamInstitute/climate-change-laws-of-the-world/>
- Green Construction Board. (2013). Case study: Anglian Water – Covenham to Boston Transfer Scheme. Retrieved from http://www.greenconstructionboard.org/images/stories/pdfs/case_studies/GCB%20CS7_Covenham_Boston_web.pdf
- Green Party of Aotearoa New Zealand. (2015). Climate impact disclosure statement. Retrieved from <https://www.greens.org.nz/policy/cleaner-environment/climate-impact-disclosure-statement>
- Green Party of Aotearoa New Zealand. (2017). Green Infrastructure Fund: For a stronger economy. Wellington: Green Party of Aotearoa New Zealand.
- Grieverson, L. (2017). Challenges and opportunities in clean, green synthetic foods. Retrieved from <https://www.newsroom.co.nz/2017/10/12/53154/challenges-and-opportunities-in-clean-green-synthetic-foods>
- Griffith, R., Redding, S., & Van Reenen, J. (2000). Mapping the two faces of R&D. Productivity growth in a panel of OECD industries. The Institute for Fiscal Studies Working Paper 02/00. London: Institute of Fiscal Studies.
- Grimes, A., Denne, T., Howden-Chapman, P., Arnold, R., Telfar-Barnard, L., Preval, N., & Young, C. (2012a). Cost benefit analysis of the Warm Up New Zealand: Heat Smart Programme.
- Grimes, A., Denne, T., Howden-Chapman, P., Arnold, R., Telfar-Barnard, L., Preval, N., & Young, C. (2012b). Cost benefit analysis of the Warm Up New Zealand: Heat Smart Programme. Retrieved from http://www.healthyhousing.org.nz/wp-content/uploads/2012/05/NZIF_CBA_report-Final-Revised-0612.pdf
- Grimes, A., & Young, C. (2011). Spatial effects of 'mill' closures: Does distance matter? *Australasian Journal of Regional Studies*, 17(3), 264-299.
- Grimes, A., Young, C., Arnold, R., Denne, T., Howden-Chapman, P., Preval, N., & Telfar-Barnard, L. (2011). Warming up New Zealand: Impacts of the New Zealand Insulation Fund on metered household energy use. Wellington: Motu Economic and Public Policy Research.
- Gruen, N. (2018). Now is the time for complacency: RBA vs Bank of England edition. Retrieved from <https://www.themandarin.com.au/87423-now-time-complacency-rba-vs-bank-england-edition/>
- Guerin, K. (2002). Protection against government takings: Compensation for regulation. Wellington: The Treasury.

- Guterres, A. (2017). Remarks at One Planet summit. Retrieved from <https://www.un.org/sg/en/content/sg/speeches/2017-12-12/remarks-one-planet-summit>
- Hale & Twomey Ltd. (2008). 2007 ACCC report into Australian petrol prices. Review of applicability to the New Zealand petrol market prepared for Ministry of Economic Development. Wellington: Hale & Twomey Ltd.
- Hall, D. (2017a). Greening the future: A case for environmental impact bonds. *Policy Quarterly*, 13(2), 41-48.
- Hall, D. (2018). The interwoven world te ao i whiria: Towards an integrated landscape approach in Aotearoa New Zealand. Auckland: The Policy Observatory, Auckland University of Technology.
- Hall, D., & Lindsay, S. (2017). Climate finance landscape for Aotearoa New Zealand: A preliminary survey. Report prepared for the Ministry of the Environment. Auckland: Mōhio.
- Hall, G. M. J. (2001). Mitigating an organization's future net carbon emissions by native forest restoration. *Ecological Applications*, 11(6), 1622-1633.
- Hall, P. (2017b). Residual biomass fuel projections for New Zealand - indicative availability by region and source. Rotorua: Scion.
- Hanley, S. (2018). Shenzhen completes switch to fully electric bus fleet. Electric taxis are next. Retrieved from <https://cleantechnica.com/2018/01/01/shenzhen-completes-switch-fully-electric-bus-fleet-electric-taxis-next/>
- Hansen, T., & Coenen, L. (2015). The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field. *Environmental Innovation and Societal Transitions*, 17, 92-109.
- Hardin, G. (1968). The tragedy of the commons. *Science*, 162(3859), 1243-1248.
- Harker, J., Taylor, P., & Knight-Lenihan, S. (2017). Multi-level governance and climate change mitigation in New Zealand: lost opportunities. *Climate Policy*, 17(4), 485-500.
- Harmesen, N. (2017). Australia's power grid weakened by wind, solar generation, AEMC calls for plan for security. Retrieved from <http://www.abc.net.au/news/2017-03-24/aemc-says-australias-power-system-weakened-by-wind-solar/8381356>
- Harmsworth, G., Tahī, M., & Insley, C. K. (2010). Climate change business opportunities for Māori land and Māori organisations. Wellington: Ministry for Primary Industries.
- Harris, R., & Le, T. (2018). Absorptive capacity in New Zealand firms. Motu working paper 18-01. Wellington: Motu Economic and Public Policy Research.
- Harvey, F. (2018). UK to review climate target raising hopes of a zero emissions pledge. Retrieved from <https://www.theguardian.com/environment/2018/apr/17/uk-to-review-climate-target-raising-hopes-of-a-zero-emissions-pledge>
- Hausfather, Z. (2018). Analysis: How much 'carbon budget' is left to limit global warming to 1.5C? Retrieved from <https://www.carbonbrief.org/analysis-how-much-carbon-budget-is-left-to-limit-global-warming-to-1-5c>
- Hawken, P. (Ed.) (2017). *Drawdown: The most comprehensive plan ever proposed to reverse global warming*. New York: Penguin Books.
- Heal, G. (2018). Financial & technological prerequisites of the energy transition. Presentation at the 2018 Productivity Hub Conference on Technological Change and Productivity, 13 February 2018. Wellington.
- Heid, B., Hensley, R., Knupfer, S., & Tschiesner, A. (2017). What's sparking electric-vehicle adoption in the truck industry. Retrieved from <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/whats-sparking-electric-vehicle-adoption-in-the-truck-industry>
- Helm, D. (2017). Cost of energy review. London: Department for Business, Energy & Industrial Strategy.
- Hiscock, G. (2014). Molten salt storage gives push to US solar power. *The Australian*. Retrieved from <https://www.theaustralian.com.au/business/mining-energy/molten-salt-storage-gives-push-to-us-solar-power/news-story/cd63fc183793abc3663327ed852dfd49?sv=f663d277c902b5ccb65abdc76cf07132>
- HM Government. (2007). Taking forward the UK Climate Change Bill: The Government response to pre-legislative scrutiny and public consultation. October 2007. Cm 7225. Norwich: HMSO.
- HMRC. (2017). Landfill tax rates. Retrieved from <https://www.gov.uk/government/publications/rates-and-allowances-landfill-tax/landfill-tax-rates-from-1-april-2013>
- Holdaway, R. J., Easdale, T. A., Carswell, F. E., Richardson, S. J., Peltzer, D. A., Mason, N. W. H., . . . Coomes, D. A. (2016). Nationally representative plot network reveals contrasting drivers of net biomass change in secondary and old-growth forests. *Ecosystems*, 20(5), 944-959.
- Hollis, M., de Klein, C., Frame, D. J., Harvey, M., Manning, M., Reisinger, A., . . . Robinson, A. (2016). Cows, sheep and science: A scientific perspective on biological emissions from agriculture. Motu Working Paper 16-17. Wellington: Motu Economic and Public Policy Research.
- Hood, C., & Heald, D. (2006). *Transparency: The key to better governance?* (Vol. 135). Oxford: Oxford University Press for The British Academy.
- Hoorweg, D., & Bhada-Tata, P. (2015). What a waste: A global review of solid waste management. Washington DC: Urban Development and Local Government Unit, World Bank.

- Horticulture New Zealand, & Plant & Food Research. (2015). Fresh facts. Auckland: The New Zealand Institute for Plant & Food Research Ltd.
- HortResearch. (1999). Horticulture facts and figures 1999. Palmerston North: The Horticulture and Food Research Institute of New Zealand Ltd.
- Hovi, J., Sprinz, D. F., & Underdal, A. (2009). Implementing long-term climate policy: Time inconsistency, domestic politics, international anarchy. *Global Environmental Politics*, 9(3), 20-39.
- Howard, R. (2018). Synlait commits to significantly shrinking environmental footprint over 10 years. Retrieved from <http://www.scoop.co.nz/stories/BU1806/S00715/synlait-commits-to-shrinking-environmental-footprint.htm>
- Hughes, R., & Molloy, P. (2017). Is the ETS worth the carbon it is written on for small-scale forest owners? *New Zealand Journal of Forestry*, 61(4), 33-36.
- Hutchings, J. A., & Myers, R. A. (1994). What can be learned from the collapse of a renewable resource? Atlantic cod, *Gadhus morhua*, of Newfoundland and Labrador. *Canadian Journal of Fisheries and Aquatic Sciences*, 51(9), 2126-2146.
- IAI. (2010). Results of the 2009 anode effect survey. Report on the aluminium industry's global perfluorocarbon gases emissions reduction programme London: International Aluminium Institute.
- ICAO. (n.d.). What is CORSIA and how does it work? Retrieved from https://www.icao.int/environmental-protection/Pages/A39_CORSIA_FAQ2.aspx
- ICCT. (2017). Passenger vehicle fuel economy. Retrieved from <https://www.theicct.org/chart-library-passenger-vehicle-fuel-economy>
- ICMA. (2017). The Green Bond principles 2017. Paris: International Capital Market Association.
- ICNZ. (2014). Protecting New Zealand from natural hazards: An Insurance Council of New Zealand perspective on ensuring New Zealand is better protected from natural hazards. Wellington: Insurance Council of New Zealand.
- IEA. (2015a). Carbon capture and storage: The solution for deep emissions reductions. Paris: International Energy Agency.
- IEA. (2015b). Renewable transport fuels obligation (RTFO). Retrieved from <https://www.iea.org/policiesandmeasures/pams/unitedkingdom/name-22849-en.php>
- IEA. (2016a). Energy, climate change and environment: 2016 insights. Paris: International Energy Agency.
- IEA. (2016b). Evaluation of Embodied Energy and CO₂eq for Building Construction. Retrieved from http://www.ecbcs.org/Data/publications/EBC_Annex_57_ST4_Case_Studies_Recommendations.pdf
- IEA. (2016c). Global EV outlook 2016. Paris: International Energy Agency.
- IEA. (2016d). *World energy outlook 2016*. Paris: International Energy Agency.
- IEA. (2017a). Energy policies of IEA countries: New Zealand 2017 review. Paris: International Energy Agency.
- IEA. (2017b). The future of trucks: Implications for energy and the environment. Paris: International Energy Agency.
- IEA. (2017c). *World energy outlook 2017*. Paris: International Energy Agency.
- IEA. (2018a). Carbon neutrality. Retrieved from <http://www.ieabioenergy.com/iea-publications/faq/woodybiomass/carbon-neutrality/>
- IEA. (2018b). Global EV outlook 2018. Paris: International Energy Agency.
- IEA. (2018c). Nordic EV outlook 2018: Insights from leaders in electric mobility. Paris: International Energy Agency.
- IEA Greenhouse Gas R&D Programme. (2000). Greenhouse gas emissions from major industrial sources – III. Iron and steel production. Retrieved from http://ieaghg.org/docs/General_Docs/Reports/PH3-30%20Iron-steel.pdf
- IFC. (2016). Climate investment opportunities in emerging markets: An IFC analysis. Washington D.C.: International Finance Corporation.
- ILO. (2018). Greening with jobs: World employment and social outlook 2018. Geneva: International Labour Organization.
- IMF. (2017). New Zealand financial system stability assessment. Washington DC: International Monetary Fund.
- IMO. (2016). Frequently asked questions: The 2020 global sulphur limit. Retrieved from http://www.imo.org/en/MediaCentre/HotTopics/GHG/Documents/FAQ_2020_English.pdf
- Impossible Foods. (2017). Our burger. Retrieved from <https://www.impossiblefoods.com/burger/>
- Indigenous Corporate Solutions. (2008). Summary of key themes from Emission Trading Scheme consultation hui with Māori. Hamilton: Indigenous Corporate Solutions.
- Infometrics. (2015). A general equilibrium analysis of options for New Zealand's post-2020 climate change contribution. A report for the Ministry for the Environment. Wellington: Infometrics.
- Infometrics. (2017). The impact of the ETS on lowering transport emissions. Report for the Ministry of Transport. Wellington: Infometrics.
- Infometrics. (2018). From education to employment: Megatrends affecting NZ's working environment. Wellington: Infometrics.

- Insley, C., & Meade, R. (2008). Māori impacts from the emissions trading scheme: Detailed analysis and conclusions. Wellington: Ministry for the Environment.
- IPCC. (2007). Climate change 2007: Working Group III: Mitigation of climate change. Intergovernmental Panel on Climate Change Fourth Assessment Report: Climate Change 2007. Geneva: IPCC.
- IPCC. (2013). Summary for policymakers. In T. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, & P. Midgley (Eds.), *Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, New York: Cambridge University Press.
- IPCC. (2014a). Climate change 2014: Synthesis report: Summary for policymakers. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC.
- IPCC. (2014b). Summary for policymakers. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1-32). Cambridge: Cambridge University Press.
- IRENA. (2017). Renewable power: Sharply falling generation costs. Abu Dhabi: International Renewable Energy Agency.
- Jackson, R. B., Le Quéré, C., Andrew, R. M., Canadell, J. G., Peters, G. P., Roy, J., & Wu, L. (2017). Warning signs for stabilizing global CO₂ emissions. *Environmental Research Letters*, 12(11), 110202.
- Jackson, S. C. (2009). Parallel pursuit of near-term and long-term climate mitigation. *Science*, 326(5952), 526-527.
- James, C. (1999). The New Zealand economy and politics: The revolution and the future. Retrieved from <http://www.colinjames.co.nz/1999/11/08/the-new-zealand-economy-and-politics-the-revolution-and-the-future/>
- Janssen, J. (2001). New Zealand's fiscal policy framework: Experience and evolution. Treasury Working Paper 01/25. Wellington: The Treasury.
- Jewell, C. (2017). Banks: The good, the bad and the slow. Retrieved from <https://www.thefifthestate.com.au/business/investment-deals/banks-the-good-the-bad-and-the-slow>
- Jha, A. (2008). Revealed: The cement that eats carbon dioxide. *The Guardian*. Retrieved from www.theguardian.com/environment/2008/dec/31/cement-carbon-emissions
- John, S., Nebel, B., Perez, N., & Buchanan, A. (2009). Environmental impacts of multi-storey buildings using different construction materials. Christchurch: Department of Civil and Natural Resources Engineering, University of Canterbury.
- Johnston, I. (2017). Government facing legal action over failure to fight climate change. Retrieved from <https://www.independent.co.uk/environment/climate-change-legal-action-emissions-reduction-plan-theresa-may-clientearth-a7550676.html>
- Jones, H. S. (2018a). New forestry service unveiled in Rotorua [Press release]. Retrieved from <https://www.beehive.govt.nz/release/new-forestry-service-unveiled-rotorua>
- Jones, H. S. (2018b). One billion tree programme under way [Press release]. Retrieved from <https://www.beehive.govt.nz/release/one-billion-tree-programme-under-way>
- Journeaux, P., van Reenen, E., Pike, S., Manjala, T., Miller, D., & Austin, G. (2017). Literature review and analysis of farmer decision making with regard to climate change and biological gas emissions: A report prepared for the Biological Emissions Reference Group. Whangarei: Agfirst.
- Jun, M., Kaminker, C., Kidney, S., & Pfaff, N. (2016). Green bonds: Country experiences, barriers and options. Paris: OECD, International Capital Markets Association, Climate Bonds Initiative, and the Green Finance Committee of China Society for Finance and Banking.
- Karpas, E., & Kerr, S. (2011). Preliminary evidence on responses to the New Zealand Forestry Emissions Trading Scheme. Wellington: Motu Economic and Public Policy Research.
- Keiha, P., & Moon, P. (2008). The emergence and evolution of urban Māori authorities: A response to Māori urbanisation. *Te Kaharoa*, 1(1), 1-17.
- Kelly, G. (2011). History and potential of renewable energy development in New Zealand. *Renewable and Sustainable Energy Reviews*, 15(5), 2501-2509.
- Kerr, S. (2009). How can agriculture be included in an emissions trading scheme? Some thoughts from New Zealand. Paper presented at the Agriculture, Greenhouse and Emissions Trading Conference, Maroochydore.
- Kerr, S. (2016). Agricultural emissions mitigation in New Zealand: Answers to questions from the Parliamentary Commissioner for the Environment. Motu Working Paper 16-16. Wellington: Motu Economic and Public Policy Research.

- Kerr, S., Anastasiadis, S., Olssen, A., Power, W., Timar, L., & Zhang, W. (2012). Spatial and temporal responses to an emissions trading scheme covering agriculture and forestry: Simulation results from New Zealand. *Forests*, 3, 1133-1156.
- Kerr, S., Leining, C., Silver, J., Brown, P., Brunel, N., Cortes-Acosta, S., . . . Young, P. (2017). An effective NZ ETS: Clear price signals to guide low-emission investment. Motu Note #27. Wellington: Motu Economic and Public Policy Research.
- Kerr, S., Lubowski, R., & Heilmayr, R. (2018). Climate teams: A new model for investor-host climate cooperation. In R. N. Stavins & R. C. Stowe (Eds.), *International cooperation in East Asia to address climate change* (pp. 73-76). Cambridge, MA: Harvard Project on Climate Agreements.
- Kerr, S., Newell, R. G., & Sanchirico, J. N. (2003). Evaluating the New Zealand individual transferable quota market for fisheries management. Wellington: Motu Economic & Public Policy Research.
- Kerr, S., & Olssen, A. (2012). Gradual land-use change in New Zealand: Results from a dynamic econometric model. Motu Working Paper 12-06. Wellington: Motu Economic and Public Policy Research.
- Kerr, S., & Sweet, A. (2007). Inclusion of agriculture in a domestic emissions trading scheme: New Zealand's experience to date. *Farm Policy Journal*, 5(4), 19-29.
- Khalamayzer, A. (2017). How green bonds can bridge infrastructure financing gaps. Retrieved from <https://www.greenbiz.com/article/how-green-bonds-can-bridge-infrastructure-financing-gaps>
- Kingi, T., West, G., & Journeaux, P. (2015). Monitoring greenhouse gas emissions on Māori farms. Palmerston North: New Zealand Agricultural Greenhouse Gas Research Centre.
- Kivimaa, P., & Kern, F. (2016). Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Research Policy*, 45(1), 205-217.
- KiwiRail. (2016a). Better business case: NIMT performance improvement. Retrieved from <http://www.kiwirail.co.nz/uploads/Publications/Better%20Business%20Case%20NIMT%20Performance%20Improvement.pdf>
- KiwiRail. (2016b). Q&A. Wellington: KiwiRail.
- Klinsky, S., Dowlatabadi, H., & McDaniels, T. (2012). Comparing public rationales for justice trade-offs in mitigation and adaptation climate policy dilemmas. *Global Environmental Change*, 22(4), 862-876.
- Knowles, S., & Wilson, C. (n.d.). Planning for waste facilities under the RMA. Auckland: EnviroWaste Services Ltd.
- Lambert, F. (2018). All-electric ferry cuts emission by 95 and costs by 80%, brings in 53 additional orders. Retrieved from <https://electrek.co/2018/02/03/all-electric-ferry-cuts-emission-cost/>
- Lazarus, M., Tempest, K., Klevnas, P., & Korsbakken, J. (2015). Natural gas: Guidrails for a potential climate bridge. Stockholm: Stockholm Environment Institute and New Climate Economy.
- Lechtenberg, D., & Diller, H. (2012). *Alternative Fuels and Raw Materials Handbook for the Cement and Lime Industry*. Duisburg, Germany: MWV, Lechtenberg & Partner.
- Legislation Advisory Committee. (2014). Guidelines on Process and Content of Legislation: 2014 edition. Wellington: Legislation Advisory Committee.
- Leining, C. (2017). Improving emission pricing in New Zealand. Wellington: Motu Economic and Public Policy Research.
- Leining, C., Allan, C., & Kerr, S. (2017a). Evolution of the New Zealand Emissions Trading Scheme: Sectoral coverage and point of obligation. Motu Working Paper 17-05. Wellington: Motu Economic and Public Policy Research.
- Leining, C., & Kerr, S. (2016a). Lessons learned from the New Zealand Emissions Trading Scheme. Motu Working Paper 16-06. Wellington: Motu Economic and Public Policy Research.
- Leining, C., & Kerr, S. (2016b). New Zealand's low-emission future: Transformational pathways. Wellington: Motu Economic and Public Policy Research.
- Leining, C., Ormsby, J., & Kerr, S. (2017b). Evolution of the New Zealand Emissions Trading Scheme: Linking. Motu Working Paper 17-06. Wellington: Motu Economic and Public Policy Research.
- Lempriere, M. (2017). Heating systems: it's time to talk about hydrogen. Retrieved from <https://www.power-technology.com/features/featureheating-systems-its-time-to-talk-about-hydrogen-5889033/>
- Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2012). Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change. *Policy Sciences*, 45(2), 123-152.
- LGNZ. (2016). The 2050 challenge: Future proofing our communities. A discussion paper. Wellington: Local Government New Zealand.
- LIC, & DairyNZ. (2016). New Zealand dairy statistics. Hamilton: LIC and DairyNZ.
- Lindenberg, N. (2014). Definition of green finance. Bonn: German Development Institute.
- Lloyd, M. (1992). The New Zealand approach to central bank autonomy. *Reserve Bank Bulletin*, 55(3), 203-220.
- Lloyds. (2014). Catastrophe modelling and climate change. London: Lloyds.
- Local Councils. (2018). Forecast capital expenditure. Retrieved from http://www.localcouncils.govt.nz/lqip.nsf/wpg_url/Profiles-Local-Government-Statistical-Overview-Forecast-Capital-Expenditure

- Lock, K., & Leslie, S. (2007). New Zealand's quota management system: A history of the first 20 years. Motu Working Paper 07-02. Wellington: Motu Economic & Public Policy Research.
- Locke, S. (2015). Climate talks in Paris commit to boosting carbon in soils to limit global warming. Retrieved from <http://www.abc.net.au/news/rural/2015-12-02/soil-carbon-paris-agreement/6993592>
- Lockwood, M. (2013). The political sustainability of climate policy: The case of the UK Climate Change Act. *Global Environmental Change*, 23(5), 1339-1348.
- Loomis, T. (2017). Ending government oil & gas subsidies. Wellington: Fossil Fuels Aotearoa Research Network.
- Lord Rooker. (2007). United Kingdom Hansard HL Deb vol 696 col 1209 (27 November 2007).
- Love Food Hate Waste New Zealand. (2018). About us. Retrieved from <https://lovefoodhatewaste.co.nz/about-us/>
- LSEG. (2018). Revealing the full picture: Your guide to ESG reporting. London: London Stock Exchange Group.
- Mace, P. M., Sullivan, K. J., & Cryer, M. (2014). The evolution of New Zealand's fisheries science and management systems under ITQs. *ICES Journal of Marine Science*, 71(2), 204-215.
- Macfie, R. (2018). The pine problem. *The Listener*, 263, 20-27.
- MacGregor, C., Dowdell, D., Jaques, R., Bint, L., & Berg, B. (2018). The built environment and climate change: A review of research, challenges and the future. Porirua: BRANZ.
- Macrory, R. B. (2014). *Regulation, enforcement and governance in environmental law*. Oxford: Bloomsbury Publishing.
- Magnusson, S. (2018). New Zealand electric car guide. Retrieved from <http://www.gw.govt.nz/assets/NZ-Electric-Car-Guide-4April2017.pdf>
- Magnusson, T. (1999). Sovereign financial guarantees. Paper prepared for the UNCTAD, UNDP, and UNITAR workshop on Management of a Debt Office in Tbilisi 19-22 April 1999. Stockholm: Swedish National Debt Office.
- Mahaanui Kurataiao Ltd. (2013). Papatūānuku. Mahaanui Iwi Management Plan. Christchurch: Mahaanui Kurataiao Ltd.
- Make it Wood. (2018). Wood encouragement policies. Retrieved from <https://makeitwood.org/wep/>
- Maloney, T., & Pacheco, G. (2012). Assessing the possible antipoverty effects of recent rises in age-specific minimum wages in New Zealand. *Review of Income and Wealth*, 58(4), 648-674.
- Manatū Taonga. (2018). The 1980s: Overview. Retrieved from <https://nzhistory.govt.nz/culture/the-1980s/overview>
- Manley, B. (2010). Deforestation survey final report 2009. Christchurch: University of Canterbury.
- Manley, B. (2011). Deforestation survey final report 2010. Wellington: Ministry of Agriculture and Forestry.
- Manley, B. (2012). Deforestation survey 2011. Wellington: Ministry of Agriculture and Forestry.
- Manley, B. (2013). Deforestation survey 2012. Wellington: Ministry for Primary Industries.
- Manley, B. (2014). Deforestation survey 2013: Final report. Wellington: Ministry for Primary Industries.
- Manley, B. (2015). Deforestation survey 2014. Wellington: Ministry for Primary Industries.
- Manley, B. (2016). Deforestation intentions survey 2015. Wellington: MPI.
- Manley, B. (2017). Deforestation intentions survey 2016: Final report. Wellington: Ministry for Primary Industries.
- Manley, B., & Evison, D. (2017). Quantifying the carbon in harvested wood products from logs exported from New Zealand. *New Zealand Journal of Forestry*, 62(3), 36-44.
- Manley, B., & Maclaren, P. (2009). Modelling the impact of carbon trading legislation on New Zealand's plantation estate. *New Zealand Journal of Forestry*, 54(1), 39-44.
- Manning, M., Reisinger, A., & Bodeker, G. (2009). Global warming potentials and alternate metrics. Prepared for the Ministry of Agriculture and Forestry. Wellington: New Zealand Climate Change Research Institute, Victoria University of Wellington.
- Manzo, S., & Salling, K. B. (2016). Integrating life-cycle assessment into transport cost-benefit analysis. *Transportation Research Procedia*, 14, 273-282.
- Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, 41(6), 955-967.
- Maslin, M. (2009). *Global warming: A very short introduction*. Oxford: Oxford University Press.
- Mason, E. (2013). The New Zealand Emissions Trading Scheme: What has gone wrong and what might we achieve? . *NZ Journal of Forestry*, 58(2), 35-39.
- Mason, E. G., & Morgenroth, J. (2017). Potential for forestry on highly erodible land in New Zealand. *New Zealand Journal of Forestry*, 62(1), 8-15.
- Mason, I. G., Page, S. C., & Williamson, A. G. (2013). Security of supply, energy spillage control and peaking options within a 100% renewable electricity system for New Zealand. *Energy Policy*, 60, 324-333.
- Mason, S. (2015). UCLA scientists confirm: New technique could make cement manufacturing carbon-neutral. Retrieved from <http://newsroom.ucla.edu/releases/ucla-scientists-confirm-new-technique-could-make-cement-manufacturing-carbon-neutral>

- Matheson, R. (2017). Making renewable power more viable for the grid. Cambridge, MA: Massachusetts Institute of Technology
- Mathur, A., & Morris, A. C. (2014). Distributional effects of a carbon tax in broader U.S. fiscal reform. *Energy Policy*, 66, 326-334.
- Matikainen, S. (2017a). Financing low-carbon growth and innovation in the UK Industrial Strategy. London: Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy.
- Matikainen, S. (2017b). The UK has endorsed recommendations for financial reporting of climate risks – but are voluntary guidelines enough? Retrieved from <http://www.lse.ac.uk/GranthamInstitute/news/the-uk-has-endorsed-recommendations-for-financial-reporting-of-climate-risks-but-are-voluntary-guidelines-enough/>
- Matikainen, S., Campiglio, E., & Zenghelis, D. (2017). The climate impact of quantitative easing. Policy paper. London: Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy.
- Matthews, H. D., & Caldeira, K. (2008). Stabilizing climate requires near-zero emissions. *Geophysical Research Letters*, 35(4), 1-5.
- Mauritsen, T., & Pincus, R. (2017). Committed warming inferred from observations. *Nature Climate Change*, 7, 652.
- MBIE. (2015). Chronology of New Zealand electricity reform. Wellington: Ministry of Business, Innovation and Employment.
- MBIE. (2016a). Energy in New Zealand 2016. Wellington: Ministry of Business Innovation and Employment.
- MBIE. (2016b). Energy statistics. Retrieved from <http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics>
- MBIE. (2016c). Programme review: Heavy vehicle fuel efficiency. (Released under the Official Information Act). Retrieved from <http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-efficiency-environment/energy-efficiency/documents-images/final-review-heavy-vehicles.pdf>
- MBIE. (2016d). Programme reviews Wood Energy South. Wellington: MBIE.
- MBIE. (2017a). Briefing for the incoming Minister for Economic Development. Wellington: Ministry of Business, Innovation & Employment.
- MBIE. (2017b). Energy statistics – Electricity. Retrieved from <http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics/electricity>
- MBIE. (2017c). Strategic Science Investment Fund: Investment Plan 2017-2024. 2017 update. Wellington: Ministry for Business, Innovation and Employment.
- MBIE. (2017d). Unlocking our energy productivity and renewable potential. Wellington: Ministry for Business, Innovation and Employment.
- MBIE. (2018a). *Aide Memoire: Meeting with the Minister for Climate Change on fossil fuel subsidy reform.* (1674 17-18). Wellington: Ministry for Business, Innovation and Employment.
- MBIE. (2018b). Electricity. Retrieved from <http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics/electricity>
- MBIE. (2018c). Energy prices. Retrieved from: <http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics/prices>
- MBIE. (2018d). Occupation outlook: Electricians. Retrieved from <http://occupationoutlook.mbie.govt.nz/construction-and-infrastructure/electricians/>
- MBIE. (2018e). Sales-based electricity costs. Retrieved from <http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics/prices/electricity-prices/sales-based-residential-prices.pdf>
- MBIE. (2018f). Weekly fuel price monitoring. Retrieved from <http://www.mbie.govt.nz/info-services/sectors-industries/energy/liquid-fuel-market/weekly-fuel-price-monitoring>
- MBIE. (n.d.). Technical fact sheet on the proposed industrial emissions intensity target. Retrieved from <http://www.mbie.govt.nz/info-services/sectors-industries/energy/previous-reviews-consultations/consultation-draft-replacement-new-zealand-energy-efficiency-and-conservation-strategy/consultation-draft-replacement-new-zealand-energy-efficiency-and-conservation-strategy/factsheet-on-industrial-emissions-intensity-target.pdf>
- Mcbeth, P. (2017). Fonterra confident dairy will always trump synthetic alternatives: National Business Review. Retrieved from <https://www.nbr.co.nz/article/fonterra-confident-dairy-will-always-trump-synthetic-alternatives-b-208764>
- McConnell, D. (2017). SA's battery is massive, but it can do much more than store energy. Retrieved from <http://www.abc.net.au/news/2017-12-05/yes-sa-battery-is-a-massive-battery-but-it-can-do-more/9227288>
- McGee, D. (2017). *Parliamentary practice in New Zealand*. 4th ed. Auckland: Oratia Books.
- McGuinness Institute. (2018). Analysis of climate change reporting in the public and private sectors. Working Paper 2018/03. Wellington: McGuinness Institute.

- McGuinness Institute, & XRB. (2018). Survey insights: An analysis of the 2017 Extended External Reporting Surveys. Wellington: McGuinness Institute.
- McHarg, A. (2011). Climate change constitutionalism? Lessons from the United Kingdom. *Climate Law*, 2(4), 469-484.
- McKibbin, W. J., & Wilcoxon, P. J. (2002). The role of economics in climate change policy. *Journal of Economic Perspectives*, 16(2), 107-129.
- McKinsey & Company. (2018). Decarbonization of industrial sectors: the next frontier. Amsterdam: McKinsey & Company.
- McMaster, P. (2008). Climate change—Statutory duty or pious hope? *Journal of Environmental Law*, 20(1), 115-119.
- McNally, S., Beare, M., Curtin, D., Meenken, E., Kelliher, F., Pereira, R., . . . Baldock, J. (2017). Soil carbon sequestration potential of permanent pasture and continuous cropping soils in New Zealand. *Global Change Biology*, 23(11), 4544-4555.
- Mead, D. (2013). Auckland's density. Retrieved from <http://www.hillyoungcooper.co.nz/assets/Uploads/Aucklands-Density-Part-1.pdf>
- Meade, R. (2017). Incidence of emissions charges and other climate change policies: Implications for Māori cost of living. Wellington: Ministry for the Environment and Climate Change Iwi Leaders Group.
- MED. (2009). Evaluation of the Venture Investment Fund. Wellington: Ministry of Economic Development.
- Meduna, V. (2015). *Towards a warmer world: What climate change will mean for New Zealand's future*. Wellington: Bridget Williams Books Ltd.
- Meduna, V. (2017). New offset options for New Zealand. Wellington: Motu Economic and Public Policy Research.
- Meehan, L. (2014). Structural change and New Zealand's productivity performance. Wellington: New Zealand Productivity Commission.
- Meledandri, C. (2018). Nanotechnology can save your teeth. Retrieved from <https://www.radionz.co.nz/national/programmes/sunday/audio/2018632547/nanotechnology-can-save-your-teeth-carla-meledandri>
- Mercury. (2017). EV drivers enjoy incentive to charge off-peak [Press release]. Retrieved from https://issuu.com/mercurynz/docs/media_release_ev_drivers_enjoy_ince
- Meredith, P. (2015). Urban Māori, Te Ara - the encyclopedia of New Zealand. Retrieved from <https://teara.govt.nz/en/urban-maori>
- Metal Bulletin. (2018). Elysis could revolutionize aluminium smelting technology Retrieved from <https://www.metalbulletin.com/Article/3806461/HOTTER-ON-METALS-Elysis-could-revolutionize-aluminium-smelting-technology.html>
- MFAT. (2017). International treaty making: Guidance for government agencies on practice and procedures for concluding international treaties and arrangements. Wellington: Ministry of Foreign Affairs and Trade.
- MfE. (2004). Review of targets in the New Zealand Waste Strategy. Wellington: Ministry for the Environment.
- MfE. (2008). SWAP waste data programme 2007/08: Summary of results. Retrieved from <http://www.mfe.govt.nz/publications/waste/solid-waste-audits-ministry-environment-waste-data-programme-200708-solid-waste-1>
- MfE. (2010a). The New Zealand waste strategy. Wellington: Ministry for the Environment.
- MfE. (2010b). Regulatory impact statement. Climate Change Response (Disposal Facilities) Regulations 2010. Agency Disclosure Statement. Wellington: Ministry for the Environment.
- MfE. (2011a). A guide to landfill methane in the New Zealand Emissions Trading Scheme. Wellington: Ministry for the Environment.
- MfE. (2011b). National Policy Statement for Renewable Electricity Generation 2011. Wellington: Ministry for the Environment.
- MfE. (2015a). New Zealand's climate change target: Our contribution to the new international climate change agreement. Discussion document. Wellington: Ministry for the Environment.
- MfE. (2015b). New Zealand Emissions Trading Scheme Review 2015/16: Discussion document and call for written submissions. Wellington: Ministry for the Environment.
- MfE. (2016a). Climate change impacts in New Zealand. Retrieved from <http://www.mfe.govt.nz/climate-change/how-climate-change-affects-nz/climate-change-impacts>
- MfE. (2016b). New Zealand's 2050 target. Retrieved from <http://www.mfe.govt.nz/climate-change/reducing-greenhouse-gas-emissions/new-zealands-greenhouse-gas-emissions-reduction-1>
- MfE. (2016c). The New Zealand Emissions Trading Scheme evaluation 2016. Wellington: Ministry for the Environment.
- MfE. (2016d). The New Zealand Emissions Trading Scheme review 2015/16 forestry technical note. Wellington: Ministry for the Environment.

- MfE. (2016e). New Zealand Emissions Trading Scheme Review 2015/16: Summary of Stage Two: Other issues consultation responses. Annex One - Forestry technical note responses. Wellington: Ministry for the Environment.
- MfE. (2016f). Phase out of the one-for-two transitional measure from the New Zealand Emissions Trading Scheme. Retrieved from <http://www.mfe.govt.nz/climate-change/reducing-greenhouse-gas-emissions/new-zealand-emissions-trading-scheme/legislative>
- MfE. (2016g). Synthetic greenhouse gases in the NZ ETS. Retrieved from <http://www.mfe.govt.nz/climate-change/reducing-greenhouse-gas-emissions/new-zealand-emissions-trading-scheme/synthetic-0>
- MfE. (2017a). About the waste disposal levy. Retrieved from <http://www.mfe.govt.nz/waste/waste-disposal-levy/about-levy>
- MfE. (2017b). Latest update on New Zealand's 2020 net position. Retrieved from <http://www.mfe.govt.nz/climate-change/reporting-greenhouse-gas-emissions/latest-2020-net-position>
- MfE. (2017c). Mandatory product stewardship. Retrieved from <http://www.mfe.govt.nz/node/15017/>
- MfE. (2017d). National Communication and Biennial Report 2017 Snapshot. Wellington: Ministry for the Environment.
- MfE. (2017e). New Zealand's greenhouse gas inventory 1990-2015: Snapshot. Wellington: Ministry for the Environment.
- MfE. (2017f). New Zealand's greenhouse gas inventory, 1990-2015. Wellington: Ministry for the Environment.
- MfE. (2017g). New Zealand's greenhouse gas inventory, 1990-2015: CRF tables. Wellington: Ministry for the Environment.
- MfE. (2017h). New Zealand Emissions Trading Scheme review 2015/16: Stage two submissions. Wellington: Ministry for the Environment.
- MfE. (2017i). New Zealand's phase down of hydrofluorocarbons to ratify the Kigali Amendment to the Montreal Protocol and associated supporting measures: Consultation document. Wellington: Ministry for the Environment.
- MfE. (2017j). New Zealand's Seventh National Communication – Fulfilling reporting requirements under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Wellington: Ministry for the Environment.
- MfE. (2017k). Outcomes from stage two of the NZ ETS Review 2015/16. Retrieved from <http://www.mfe.govt.nz/nzets/2015-16-review-outcomes>
- MfE. (2017l). Resource Legislation Amendments 2017: Fact sheet 3. Changes to Māori participation in the Resource Management Act 1991. Retrieved from <https://www.mfe.govt.nz/sites/default/files/media/fact-sheet-3-%20changes-to-m%C4%81ori-participation-in-the-rma.pdf>
- MfE. (2017m). Review of the effectiveness of the waste disposal levy 2017 in accordance with Section 39 of the Waste Minimisation Act 2008. Wellington: Ministry for the Environment.
- MfE. (2017n). Roles and responsibilities of government for climate change. Retrieved from <http://www.mfe.govt.nz/node/16661>
- MfE. (2018a). About New Zealand's greenhouse gas emissions reduction targets. Retrieved from <http://www.mfe.govt.nz/climate-change/reducing-greenhouse-gas-emissions/emissions-reduction-targets>
- MfE. (2018b). Government-accredited product stewardship schemes. Retrieved from <http://www.mfe.govt.nz/waste/we-all-have-role-play/responsible-product-management/government-accredited-product-stewardship>
- MfE. (2018c). Improvements to the New Zealand Emissions Trading Scheme: Consultation document (pp. 87). Wellington: Ministry for the Environment.
- MfE. (2018d). New Zealand's greenhouse gas inventory 1990-2016. Wellington: New Zealand.
- MfE. (2018e). New Zealand's interactive emissions tracker. Retrieved from <https://emissionstracker.mfe.govt.nz/>
- MfE. (2018f). Proposed National Environmental Standard for the outdoor storage of tyres. Retrieved from <http://www.mfe.govt.nz/proposed-nes-outdoor-storage-of-tyres>
- MfE. (2018g). Understanding our emissions reduction targets. Retrieved from <http://www.mfe.govt.nz/climate-change/what-government-doing/new-zealands-emissions-reduction-targets/understanding-our>
- MfE. (2018h). Zero carbon bill economic analysis: a synthesis of economic impacts (pp. 39): Ministry for the Environment.
- MfE, & MBIE. (2016). Report of the outcome evaluation of the National Policy Statement for Renewable Electricity Generation. Wellington: New Zealand Government.
- MfE, & Stats NZ. (2017). New Zealand's environmental reporting series: Our atmosphere and climate 2017. Wellington: Ministry for the Environment and Statistics New Zealand.

- MfE, & The Treasury. (2007). The framework for a New Zealand Emissions Trading Scheme. Wellington: New Zealand Government.
- Milet, A., Rowarth, J. S., & Scrimgeour, F. G. (2015). Potential for anaerobic digestion of dairy farm effluent in New Zealand. *Journal of New Zealand Grasslands*, 77, 71-76.
- Miliband, D. (2007). Written ministerial statements: Climate change bill. Retrieved from <https://publications.parliament.uk/pa/cm200607/cmhansrd/cm070313/wmstext/70313m0001.htm>
- Miliutenko, S., Kluts, I., Lundberg, K., Toller, S., Brattebø, H., Birgisdóttir, H., & Potting, J. (2014). Life cycle energy use and GHG emissions in road infrastructure planning processes. *Journal of Environmental Assessment Policy and Management*, 16(4), 1-26.
- Millar, R. J., Fuglestvedt, J. S., Friedlingstein, P., Rogelj, J., Grubb, M. J., Matthews, H. D., . . . Allen, M. R. (2017). Emission budgets and pathways consistent with limiting warming to 1.5°C. *Nature Geoscience*, 10, 741-747.
- Millar, R. J., Hepburn, C., Beddington, J., & Allen, M. R. (2018). Principles to guide investment towards a stable climate. *Nature Climate Change*, 8(1), 2-4.
- Miller, A., Hwang, M., Lemon, S., Read, E. G., & Wood, A. (2015). Economics of photovoltaic solar power and uptake in New Zealand. Paper presented at the Delivering leadership: Technology, safety & quality. Electricity Engineers' Association Conference and Trade Exhibition, Wellington. <https://ir.canterbury.ac.nz/handle/10092/11137>
- Ministry of Education. (2017). Designing quality learning spaces. Indoor air quality and thermal comfort. Retrieved from <http://education.govt.nz/assets/Documents/Primary-Secondary/Property/School-property-design/Flexible-learning-spaces/DQLSIndoorAirQualityThermalComfortV1.0.pdf>
- Ministry of Education. (n.d.). Fact sheet: changes to the performance-based research fund. Retrieved from <http://www.education.govt.nz/assets/Documents/Further-education/Policies-and-strategies/Performance-based-research-fund/PBRFFactSheet.pdf>
- MIT. (2014). How to calculate emissions impacts using climate metrics. Massachusetts: Trancik Lab, Engineering Systems Division, Massachusetts Institute of Technology.
- Mitchell, C. (2018). Fresh start for water quality standards. Wellington: Stuff. Retrieved from <https://www.stuff.co.nz/environment/100641348/fresh-start-for-water-quality-standards>
- Mock, P. (2016). The automotive sector in Turkey: A baseline analysis of vehicle fleet structure, fuel consumption and emissions. Berlin: International Council on Clean Transportation Europe.
- Mokyr, J. (2016). *A Culture of Growth: The Origins of the Modern Economy*. Princeton, NJ: Princeton University Press.
- Molina, M., Zaelke, D., Sarma, K. M., Andersen, S. O., Ramanathan, V., & Kaniaru, D. (2009). Reducing abrupt climate change risk using the Montreal Protocol and other regulatory actions to complement cuts in CO₂ emissions. *Proceedings of the National Academy of Sciences*, 106(49), 20616-20621.
- Monaghan, A. (2017). EasyJet says it could be flying electric planes within a decade. Retrieved from <https://www.theguardian.com/business/2017/sep/27/easyjet-electric-planes-wright-electric-flights>
- Monahan, J., & Powell, J. C. (2011). An embodied carbon and energy analysis of modern methods of construction in housing: A case study using a lifecycle assessment framework. *Energy and Buildings*, 43(1), 179-188.
- Monge, J., Parker, W., & Pizzirani, S. (2017). Identifying complementarities for the dairy and forestry industries in the Central North Island. *New Zealand Journal of Forestry*, 61(4), 16-23.
- Monge, J., Velarde, S., Yao, R., Pizzirani, S., & J. Parker, W. (2015). Identifying complementarities for the dairy and forestry industries in the central North Island. Rotorua: Scion.
- Monni, S., Pipatti, R., Lehtila, A., Savolainen, I., & Syri, S. (2006). Global climate change mitigation scenarios for solid waste management. Espoo: VTT Technical Research Centre of Finland.
- Monnin, P. (2018). Central banks and the transition to a low-carbon economy. Discussion note 2018/1. Zurich: Council on Economic Policies.
- Mooney, A. (2018). Church of England threatens climate change shares sell-off. *The Financial Times*. Retrieved from <https://www.ft.com/content/4407102a-82d6-11e8-96dd-fa565ec55929>
- Morgan, T. K. K. B. (2004). *A Tangata Whenua perspective on sustainability using the Mauri Model*. Paper presented at the International Conference on Sustainability Engineering and Science, Auckland. <http://www.thesustainabilitysociety.org.nz/conference/2004/Session5/36%20Morgan.pdf>
- MoT. (2011). Briefing to the incoming Minister of Transport: Policy challenges and upcoming decisions. Retrieved from <https://www.transport.govt.nz/assets/Uploads/About/Documents/BIM-2011-Policy-challenges-and-upcoming-decisions-REDACTED.pdf>
- MoT. (2014a). Future demand: How could or should our transport system evolve in order to support mobility in the future? Wellington: Ministry of Transport.
- MoT. (2014b). Ministry of Transport briefing to the incoming minister. Wellington: Ministry of Transport.
- MoT. (2015). 25 years of New Zealand travel: New Zealand household travel 1989–2014. Wellington: Ministry of Transport.
- MoT. (2016a). Annual fleet statistics 2016. Wellington: Ministry of Transport.

- MoT. (2016b). Regulatory impact statement: Road user charges exemptions and discounts for electric vehicles. Wellington: Ministry of Transport.
- MoT. (2016c). *Travel patterns: Household travel*. Retrieved from: <https://www.transport.govt.nz/resources/tmif/travelpatterns/tp002/>
- MoT. (2017a). About vehicle emissions. Retrieved from <http://www.transport.govt.nz/research/othertransportresearch/environmentalresearch/aboutvehicleemissions/>
- MoT. (2017b). Briefing to the incoming Minister of Transport. Wellington: Ministry of Transport.
- MoT. (2017c). Electric vehicles. Retrieved from <http://www.transport.govt.nz/ourwork/climatechange/electric-vehicles/>
- MoT. (2017d). Summary of GPS 2018 analysis. Wellington: Ministry of Transport.
- MoT. (2018a). Monthly electric and hybrid light vehicle tables. Retrieved from <http://www.transport.govt.nz/research/newzealandvehiclefleetstatistics/monthly-electric-and-hybrid-light-vehicle-registrations-2/>
- MoT. (2018b). Quarterly fleet statistics (data tables) - January to March 2018 update. Retrieved from <https://www.transport.govt.nz/resources/vehicle-fleet-statistics/quarterly-fleet-statistics-data-tables-january-to-march-2018-update/>
- MoT. (2018c). Regional Fuel Tax. Retrieved from <https://www.transport.govt.nz/land/regional-fuel-tax/>
- MoT. (2018d). Regulatory impact assessment: Regional fuel tax. Wellington: Ministry of Transport.
- MoT, NZTA, Auckland Council, Auckland Transport, The Treasury, & State Services Commission. (2017). Phase one report: The congestion question. Wellington: Ministry of Transport.
- Motor Industry Association. (2018). 1975 Onwards Registration Data Series. Retrieved from: <https://www.mia.org.nz/Sales-Data/Vehicle-Sales#oss>
- Motu. (2017). Shaping New Zealand's low emissions future. Retrieved from <https://motu.nz/our-work/environment-and-resources/emission-mitigation/shaping-new-zealands-low-emissions-future/>
- Moultak, M., Lutsey, N., & Hall, D. (2017). Transitioning to zero-emission heavy-duty freight vehicles. Washington DC: International Council on Clean Transportation.
- Movac. (2017). Is future of NZVIF...NZVIF2.0? Retrieved from <http://www.movac.co.nz/is-future-of-nzvif-nzvif2-0/>
- MPI. (2016). National exotic forest description 2016. Wellington: Ministry for Primary Industries.
- MPI. (2017a). Annual Report 2016/17. Wellington: Ministry for Primary Industries.
- MPI. (2017b). Briefing for incoming Ministers. Wellington: Ministry for Primary Industries.
- MPI. (2017c). Crown Forestry. Retrieved from <https://www.mpi.govt.nz/about-mpi/our-work/crown-forestry/>
- MPI. (2017d). Emissions trading scheme. Retrieved from <https://www.mpi.govt.nz/protection-and-response/environment-and-natural-resources/emissions-trading-scheme/>
- MPI. (2017e). National Environmental Standards for Plantation Forestry. Retrieved from <https://www.mpi.govt.nz/growing-and-harvesting/forestry/national-environmental-standards-for-plantation-forestry/>
- MPI. (2017f). National exotic forest description 2017. Wellington: Ministry for Primary Industries.
- MPI. (2017g). New Zealand: A policy perspective. Wellington: Ministry for Primary Industries.
- MPI. (2017h). Provisional estimates of tree stock sales and forest planting in 2016. Wellington: Ministry for Primary Industries.
- MPI. (2018a). Forestry in the emissions trading scheme. Retrieved from <https://www.mpi.govt.nz/growing-and-harvesting/forestry/forestry-in-the-emissions-trading-scheme/>
- MPI. (2018b). Terms of reference for the review of the Dairy Industry Restructuring Act 2001 and its impact on the dairy industry. Wellington: Ministry for Primary Industries.
- MRCagney. (2017). Autonomous vehicles: Research report. Retrieved from <http://mrcagney.com/uploads/case-studies/MRCAutonomousVehicles.pdf>
- MSI. (2011). Powering innovation: improving access to and uptake of R&D in the high value manufacturing and services sector. Wellington: Ministry of Science and Innovation.
- MWH. (2017). National waste disposal survey final report. Prepared for the Ministry of the Environment. Palmerston North: MWH.
- Myhre, G., Shindell, D., Bréon, F.-M., Collins, W., Fuglestedt, J., Huang, J., . . . Zhang, H. (2013). Anthropogenic and natural radiative forcing. In T. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, & P. Midgley (Eds.), *Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.
- NABERSNZ. (2017). The benefits of energy efficient buildings. Retrieved from www.nabersnz.govt.nz/news-and-resources/videos/the-benefits-of-energy-efficient-buildings/
- Nachmany, M., Fankhauser, S., Davidova, J., Kingsmill, N., Landesman, T., Roppongi, H., . . . Townshend, T. (2015). The 2015 global climate legislation study: A review of climate change legislation in 99

- countries. London: Grantham Research Institute on Climate Change and the Environment, GLOBE, Inter-Parliamentary Union.
- Nachmany, M., Fankhauser, S., Setzer, J., & Averchenkova, A. (2017). Global trends in climate change legislation and litigation. London: Grantham Research Institute on Climate Change and the Environment.
- Nana, G., Boshier, J., & Generosa, A. (2011). Preliminary analysis of the economic impact of the New Zealand bioenergy strategy. Wellington: BERL.
- National Infrastructure Commission. (2016). Smart power. London: National Infrastructure Commission.
- Natural Resources Canada. (2018). Electricity facts Retrieved from www.nrcan.gc.ca/energy/facts/electricity/20068
- Neal, T. (2018). Government outlines Southern Sky initiatives. Retrieved from <https://www.radionz.co.nz/news/political/363246/government-outlines-southern-sky-initiatives>
- NERI. (2017). Energy research strategy for New Zealand: The key issues. Te Horo: National Energy Research Institute.
- NETL. (2018). What is the carbon cycle? Retrieved from <https://www.netl.doe.gov/research/coal/carbon-storage/carbon-storage-faqs/what-is-the-carbon-cycle>
- Neumann, C., & Achimescu, A. (2018). Supporting the circular economy transition. Amsterdam: Oliver Wyman, Marsh & McLennan Companies.
- New Climate Economy. (2014). Better growth, better climate. Retrieved from <https://newclimateeconomy.report/2014/overview/>
- New York City against BP plc, Chevron Corporation, ConocoPhillips, Exxon Mobil Corporation, Royal Dutch Shell plc. Case No. 18 cv 182 (United States District Court 2018).
- New Zealand Council for Infrastructure Development. (2016). NZCID Submission to the Productivity Commission on the Better Urban Planning draft report. Wellington: New Zealand Productivity Commission.
- New Zealand Council of Trade Unions. (2017). Just transition: A working people's response to climate change. Wellington: New Zealand Council of Trade Unions.
- New Zealand Emissions Trading Register. (2018). Holding & transaction summary. Retrieved from <https://www.emissionsregister.govt.nz/Common/ViewPublicReport.aspx?rt=32363df9-4b5b-4be6-bdf7-df3d08d3d2d9>
- New Zealand Geothermal Association. (2018). Geothermal Emissions. Retrieved from <http://nzgeothermal.org.nz/emissions/>
- New Zealand Government. (2008). National Policy Statement on Electricity Transmission 2008. Wellington: New Zealand Government.
- New Zealand Government. (2009). Resource Management (National Environmental Standards for Electricity Transmission Activities) Regulations 2009. Wellington: New Zealand Government.
- New Zealand Government. (2011a). The Climate Change Response (2050 Emissions Target) Notice 2011. *New Zealand Gazette*, 41, 1.
- New Zealand Government. (2011b). National Policy Statement for Renewable Electricity Generation 2011. Wellington: New Zealand Government.
- New Zealand Government. (2015). Submission to the Ad-Hoc Working Group on the Durban Platform for Enhanced Action (ADP). New Zealand's Intended Nationally Determined Contribution. Wellington: New Zealand Government.
- New Zealand Government. (2016). National interest analysis: The Paris Agreement. Wellington: New Zealand Government.
- New Zealand Government. (2017a). Draft Government policy statement on land transport 2018/19 – 2027/28. Retrieved from <http://www.transport.govt.nz/assets/Uploads/Our-Work/Documents/MOT-GPS-2018-web.pdf>
- New Zealand Government. (2017b). National Policy Statement for Freshwater Management 2014. Wellington: New Zealand Government.
- New Zealand Government. (2017c). New Zealand submission under the Paris Agreement: New Zealand's nationally determined contribution. Wellington: New Zealand Government.
- New Zealand Government. (2018a). Fiscal Strategy Report. Retrieved from <https://www.budget.govt.nz/budget/pdfs/fsr/b18-fsr.pdf>
- New Zealand Government. (2018b). Government Policy Statement on Land Transport 2018/19-2027/28. Wellington: Ministry of Transport.
- New Zealand Herald. (2016). Genesis extends life of Huntly station to 2022. Retrieved from http://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11630125
- New Zealand Labour Party, & Green Party of Aotearoa New Zealand. (2017). Confidence and supply agreement. Wellington: New Zealand Labour Party and Green Party of Aotearoa New Zealand.
- New Zealand Labour Party, & New Zealand First. (2017). Coalition agreement between the New Zealand Labour Party & New Zealand First Party. Wellington: New Zealand Labour Party & New Zealand First.

- New Zealand Law Commission. (2001). Māori custom and values in New Zealand law. Study paper 9. Wellington: New Zealand Law Commission.
- New Zealand Parliament. (2014). Climate change agreements. Retrieved from <https://www.parliament.nz/en/pb/research-papers/document/00PLEcoC5121/climate-change-agreements>
- New Zealand Shipping Federation. (n.d.). Emissions: Low sulphur fuel: A fact sheet. Retrieved from <http://nzsf.org.nz/media/emissions-low-sulphur-fuel-a-fact-sheet>
- Nichols, B., & Kockelman, K. (2015). Urban form and life-cycle energy consumption: Case studies at the city scale. *The Journal of Transport and Land Use*, 8(3), 115-129.
- NIWA. (2017). Greenhouse gas measurements. Retrieved from <https://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/gases>
- Nolan, P. (2007). Lifting families' incomes. *Policy Quarterly*, 3(2), 22-29.
- Norman, J., Maclean, H., & Kennedy, C. (2006). Comparing high and low residential density: Life-cycle analysis of energy use and greenhouse gas emissions. *Journal of Urban Planning & Development*, 132(1), 10-21.
- Norton, D., & Pannell, J. (2018). Desk-top assessment of native vegetation on New Zealand sheep and beef farms. Christchurch and Auckland: School of Forestry, University of Canterbury & Institute of Applied Ecology, Auckland University of Technology.
- Nunns, P. (2014). Population-weighted densities in New Zealand and Australian cities: A new comparative dataset - MRCagney working paper. Auckland: MRCagney Pty Ltd.
- Nyborg, K., Anderies, J. M., Dannenberg, A., Lindahl, T., Schill, C., Schlüter, M., . . . de Zeeuw, A. (2016). Social norms as solutions. *Science*, 354(6308), 42-43.
- NZ Product Accelerator. (2018). NZ Product Accelerator - About us. Retrieved from <http://www.nzproductaccelerator.co.nz/en/about-us.html>
- NZ Super Fund. (2015). NZ institutional investors establish 'Corporate Governance Forum', release best practice guidelines for NZ listed companies [Press release]. Retrieved from <https://www.nzsuperfund.co.nz/news-media/nz-institutional-investors-establish-%E2%80%98corporate-governance-forum%E2%80%99-release-best-practice>
- NZ Super Fund. (2017). Invested in New Zealand and the world. Annual report 2017. Wellington: New Zealand Super Fund.
- NZ Super Fund. (2018). Exclusions. Retrieved from <https://www.nzsuperfund.co.nz/how-we-invest-responsible-investment/exclusions>
- NZAGRC. (2012). Impacts of global climate change on New Zealand agriculture. Palmerston North: New Zealand Agricultural Greenhouse Gas Research Centre.
- NZAGRC. (2017). Highlights 2017. Palmerston North: New Zealand Agricultural Greenhouse Gas Research Centre.
- NZAGRC, & PGgRC. (2016). What we are doing. Palmerston North: NZAGRC & PGgRC.
- NZAS. (2017). NZAS. Retrieved from <https://www.nzas.co.nz/>
- NZCFG. (2016, 30 April). Submission to the Ministry for the Environment on the NZ ETS Review Consultation Part Two. Retrieved from http://www.mfe.govt.nz/sites/default/files/media/NZETS_reviewstage2%20-%20New%20Zealand%20Carbon%20Farming%20Group%2000069.pdf
- NZGBC. (2017). About Home Star. Retrieved from <https://www.nzgbc.org.nz/homestar>
- NZIER. (2013). Appraising transport strategies that induce land use changes: Estimating benefits of long-term land use change from standard transport model outputs. Wellington: NZIER.
- NZIER. (2018). Economic impact analysis of 2050 emissions targets: A dynamic computable general equilibrium analysis. Wellington: New Zealand Institute of Economic Research.
- NZPC. (2013). Towards better local regulation. Wellington: New Zealand Productivity Commission.
- NZPC. (2014a). Boosting productivity in the services sector: Final report. Wellington: New Zealand Productivity Commission.
- NZPC. (2014b). Regulatory institutions and practices: Final report. Wellington: New Zealand Productivity Commission.
- NZPC. (2015). Using land for housing: Final report. Wellington: New Zealand Productivity Commission.
- NZPC. (2017a). Better urban planning: Final report. Wellington: New Zealand Productivity Commission.
- NZPC. (2017b). New models of tertiary education: Final report. Wellington: New Zealand Productivity Commission.
- NZTA. (2013). How does public transport benefit New Zealanders. Retrieved from <https://www.nzta.govt.nz/assets/resources/public-transport-information-pack/docs/public-transport-information-pack-no-1.pdf>
- NZTA. (2014). Funding assistance rates review update - The far story. Retrieved from <https://nzta.govt.nz/assets/planning-and-investment/docs/far-final-decisions-201410.pdf>

- NZTA. (2017). NZ Transport Agency and National Land Transport Fund annual report: For the year ended 30 June 2017. Wellington: New Zealand Transport Agency.
- NZTA. (2018). EVRoam. Retrieved from <https://www.nzta.govt.nz/planning-and-investment/planning/transport-planning/planning-for-electric-vehicles/evroam>
- NZTA. (n.d). 2015–18 NLTP revenue and investment flows. Retrieved from <https://nzta.govt.nz/assets/planning-and-investment/docs/nltp-2015-18-revenue-and-investment-flows.pdf>
- NZTA. (n.d.). Roads of national significance (RoNS). Retrieved from <https://nzta.govt.nz/roads-and-rail/state-highway-projects/roads-of-national-significance-rons/>
- NZX. (2017a). Environmental, social and governance: NZX guidance note. Wellington: New Zealand Stock Exchange.
- NZX. (2017b). NZX Corporate Governance Code. Wellington: New Zealand Stock Exchange.
- Ocko, I. B., Hamburg, S. P., Jacob, D. J., Keith, D. W., Keohane, N. O., Oppenheimer, M., . . . Pacala, S. W. (2017). Unmask temporal trade-offs in climate policy debates. *Science*, 356(6337), 492-493.
- ODT. (2017, 13 December 2017). It'll cost more to dump your rubbish. *Otago Daily Times*. Retrieved from <https://www.odt.co.nz/news/dunedin/dcc/itll-cost-more-dump-your-rubbish>
- OECD. (2012a). Financing climate change action. Paris: OECD.
- OECD. (2012b). G20/OECD policy note on pension fund financing for green infrastructure and initiatives. Paris: OECD.
- OECD. (2014). Institutional investors and long-term investment: Project report May 2014. Paris: OECD.
- OECD. (2015a). Aligning policies for a low-carbon economy. Paris: OECD.
- OECD. (2015b). Green bonds: Mobilising the debt capital markets for a low-carbon transition. Paris: OECD.
- OECD. (2015c). Green investment banks: Policy perspectives. Paris: OECD.
- OECD. (2015d). Shifting risks and the search for yield in financial markets. OECD Business and finance outlook 2015. Paris: OECD.
- OECD. (2016a). Green investment banks: Scaling up private investment in low-carbon, climate-resilient infrastructure. Paris: OECD.
- OECD. (2016b). OECD environmental performance reviews: France 2016. Paris: OECD.
- OECD. (2016c). OECD science, technology and innovation outlook 2016: Megatrends affecting science, technology and innovation. Paris: OECD.
- OECD. (2016d). Effective carbon rates. Pricing CO₂ through taxes and emissions trading systems. Paris: OECD.
- OECD. (2017a). Back to work: New Zealand – improving the re-employment prospects of displaced workers. Paris: OECD.
- OECD. (2017b). How's life? 2017 Measuring well-being. Paris: OECD Publishing.
- OECD. (2017c). Investing in climate, investing in growth. Paris: OECD.
- OECD. (2017d). Mobilising bond markets for a low-carbon transition. Paris: OECD.
- OECD. (2017e). OECD environmental performance reviews: New Zealand. Paris: OECD.
- OECD. (2017f). Private finance for climate action: Estimating the effects of public interventions. Paris: OECD.
- OECD. (2018a). *Greenhouse gas emissions by source*. Retrieved from: https://stats.oecd.org/Index.aspx?DataSetCode=AIR_GHG#
- OECD. (2018b). *Gross domestic spending on R&D. Total, % of GDP, 2015*. Retrieved from: <https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm>
- OECD. (2018c). OECD-FAO agricultural outlook 2016-2025. Retrieved from http://stats.oecd.org/index.aspx?datasetcode=high_aglink_2016
- OECD. (2018d). OECD-IEA fossil fuel support and other analysis: New Zealand. Retrieved from http://stats.oecd.org/Index.aspx?DataSetCode=FFS_NZL
- Office of the Auditor-General. (2016). Energy sector: Results of the 2014/15 audits. Wellington: Office of the Auditor General.
- Office of the Auditor-General. (2017). Managing the assets that distribute electricity. Wellington: Office of the Auditor General.
- Office of the Minister for Climate Change. (2017). The 100 day plan for climate change. Cabinet Paper. Wellington: Office of the Minister for Climate Change.
- Office of the Minister for Climate Change Issues. (2015). New Zealand's intended contribution to the new global climate change agreement. Cabinet Paper. Wellington: Office of the Minister for Climate Change Issues.
- Office of the Minister for Climate Change Issues. (2016). Paris climate change agreement: Report back to Cabinet and approval for Signature. Cabinet Paper. Wellington: Office of the Minister for Climate Change Issues.
- Oldfield, P. (2012). Embodied carbon and high-rise. Retrieved from <http://www.ctbuh.org/LinkClick.aspx?fileticket=vSmq5tNl40E%3D&tabid=3999&language=en-US>
- Orkuveita Reykjavíkur. (2018). The CarbFix project. Retrieved from <https://www.or.is/carbfix>

- Ostrom, E. (2007). Challenges and growth: the development of the interdisciplinary field of institutional analysis. *Journal of Institutional Economics*, 3(3), 239-264.
- Ottmar, E., Jan Christoph, S., Michael, J., & Christoph, B. (2018). Reports of coal's terminal decline may be exaggerated. *Environmental Research Letters*, 13(2), 024019.
- OVERSEER. (2017). Benefits of using OVERSEER. Retrieved from <https://www.overseer.org.nz/benefits-of-using-overseer>
- Palmer, G. (2015). New Zealand's defective law on climate change. Public lecture delivered at Victoria University of Wellington, 16 February 2015. Wellington: Faculty of Law and Centre for Public Law, Victoria University of Wellington.
- Palmerston North City Council. (2017). Palmerston North City Council biogas projects. Retrieved from <https://www.bioenergy.org.nz/documents/events/WtE-PhilBurt-Palmerston-North-City-Council.pdf>
- Papandreou, A. A. (2015). The Great Recession and the transition to a low-carbon economy. FESSUD Working Paper No. 88. Leeds: FESSUD.
- Para Kore. (2018). What is Para Kore? Retrieved from <http://parakore.maori.nz/para-kore/what-is-para-kore/>
- Patel, S. (n.d.). Climate finance: Engaging the private sector. Washington D.C.: International Finance Corporation.
- Patterson, J. J., Thaler, T., Hoffmann, M., Hughes, S., Oels, A., Chu, E., . . . Jordan, A. (2018). Political feasibility of 1.5°C societal transformations: the role of social justice. *Current Opinion in Environmental Sustainability*, 31, 1-9.
- Pawson, E. (2014). Cars and the motor industry: Demise of the car-assembly and component industries. Retrieved from <https://teara.govt.nz/en/cars-and-the-motor-industry/page-4>
- PCE. (2010). Some biofuels are better than others: Thinking strategically about biofuels. Wellington: Parliamentary Commissioner for the Environment.
- PCE. (2013). Water quality in New Zealand: Land use and nutrient pollution. Wellington: Parliamentary Commissioner for the Environment.
- PCE. (2016). Climate change and agriculture: Understanding the biological greenhouse gases. Wellington: Parliamentary Commissioner for the Environment.
- PCE. (2017). Stepping stones to Paris and beyond: Climate change, progress, and predictability. Wellington: Parliamentary Commissioner for the Environment.
- PCE. (2018). A Zero Carbon Act for New Zealand: Revisiting Stepping stones to Paris and beyond. Wellington: Parliamentary Commissioner for the Environment.
- Peden, R. (2008a). Farming in the economy - A sunset industry? 1984 to the present, Te Ara - the Encyclopedia of New Zealand. Retrieved from <https://teara.govt.nz/en/farming-in-the-economy/page-8>
- Peden, R. (2008b). Farming in the economy - Horticulture and viticulture, Te Ara - the encyclopedia of New Zealand. Retrieved from <https://teara.govt.nz/en/farming-in-the-economy/page-9>
- Perry, M. J. (2012). Even with baggage fees, the 'miracle of flight' remains a real bargain; average 2011 airfare was 40% below 1980 average. Retrieved from <http://www.aei.org/publication/even-with-baggage-fees-the-miracle-of-flight-remains-a-real-bargain-average-2011-airfare-was-40-below-1980-average/>
- Persson, U. M., Johansson, D. J. A., Cederberg, C., Hedenus, F., & Bryngelsson, D. (2015). Climate metrics and the carbon footprint of livestock products: Where's the beef? *Environmental Research Letters*, 10(3).
- Peters, G. P. (2018a). Beyond carbon budgets. *Nature Geoscience*, 11(6), 378-380.
- Peters, H. W. (2018b). Funding for Taranaki hydrogen infrastructure. Retrieved from <https://www.beehive.govt.nz/release/funding-taranaki-hydrogen-infrastructure>
- Philip, M. (2011). Multi-storey media and arts building Retrieved from <http://architecturenow.co.nz/articles/nmit/>
- Pickford, M. (2013). State highway investment in New Zealand: The decline and fall of economic efficiency. *Policy Quarterly*, 9(3), 28-35.
- Pierrehumbert, R. T. (2014). Short-lived climate pollution. *Annual Review of Earth and Planetary Sciences*, 42(1), 341-379.
- PMR, & ICAP. (2016). *Emissions trading in practice: a handbook on design and implementation*. Washington, DC: Partnership for Market Readiness (PMR), International Carbon Action Partnership (ICAP) and The World Bank.
- Polkinghorne, J. (2011). *Factors affecting household demand for energy*. (Bachelor of Commerce (Honours) in Economics), University of Auckland. Retrieved from <http://www.greatauckland.org.nz/wp-content/uploads/2014/09/JP-Dissertation-14.01.11.pdf>
- Polkinghorne, J. (2016). Petrol stations in the city centre. Retrieved from <https://www.greatauckland.org.nz/2016/12/12/petrol-stations-in-the-city-centre/>
- Power Project Limited. (2008). Development of marine energy in New Zealand: A report prepared for the Electricity Commission, Energy Efficiency and Conservation Authority and Greater Wellington Regional Council. Wellington: Power Project Limited.

- Powerco. (2018). Innovative electricity choice for remote customers. Retrieved from <https://www.powerco.co.nz/news/innovative-electricity-choice-for-remote-consumers/>
- Pratt, K., & Lenaghan, M. (2015). The carbon impacts of the circular economy: Summary report. Edinburgh: Zero Waste Scotland.
- PRI. (2016). French Energy Transition Law: Global investor briefing. London: Principles for Responsible Investment (PRI) Initiative.
- Prskawetz, A., Fent, T., Barthel, W., Crespo-Cuaresma, J., Lindh, T., Malmberg, B., & Halvarsson, M. (2007). The relationship between demographic change and economic growth in the EU. Vienna: Vienna Institute of Demography, Austrian Academy of Sciences.
- Pullar-Strecker, T. (2016). NZ's 15,000 motor mechanics get ready for the electric vehicle era. *Stuff*. Retrieved from <https://www.stuff.co.nz/business/industries/82255599/nzs-15000-motor-mechanics-get-ready-for-the-electric-vehicle-era>
- PwC. (2013). Growing the productive base of Māori freehold land. Wellington: Ministry for Primary Industries.
- PwC. (2014). Growing the productive base of Māori freehold land - further evidence and analysis. Wellington: Ministry for Primary Industries.
- PwC. (2017). Innovation for the earth: Harnessing technological breakthroughs for people and the planet. Davos: World Economic Forum, PricewaterhouseCoopers LLP.
- Pyle, E. (2016). Case study on the development of the wind industry in New Zealand. Report for APEC. Wellington: New Zealand Wind Energy Association.
- Raftery, A. E., Zimmer, A., Frierson, D. M. W., Startz, R., & Liu, P. (2017). Less than 2°C warming by 2100 unlikely. *Nature Climate Change*, 7, 637.
- Rajamani, L. (2016). The 2015 Paris Agreement: Interplay between hard, soft and non-obligations. *Journal of Environmental Law*, 28(2), 337-358.
- Rausch, S., Metcalf, G. E., & Reilly, J. M. (2011). Distributional impacts of carbon pricing: A general equilibrium approach with micro-data for households. NBER Working Paper No. 17087. Cambridge MA: National Bureau of Economic Research.
- RBNZ. (2018). Stress testing. Retrieved from <https://www.rbnz.govt.nz/financial-stability/stress-testing>
- Reid, C. (2012). A new sort of duty? The significance of "outcome" duties in the Climate Change and Child Poverty Acts. *Public law*, 748-766.
- Reisinger, A. (2017a). Agricultural emissions: Their role in climate change. Paper presented at the New Zealand Agricultural Greenhouse Gas Mitigation Conference 2017, Palmerston North. <http://www.nzagrc.org.nz/agricultural-emissions-their-role-in-climate-change-past-present-and-future.html>
- Reisinger, A. (2017b). Mitigation in the land sector: Challenges and choices. Presentation at E-Mission Possible Roundtable, 8 December 2017. Wellington: New Zealand Agricultural Greenhouse Gas Research Centre.
- Reisinger, A., Clark, H., Journeaux, P., Clark, D., & Lambert, G. (2017). On-farm options to reduce agricultural GHG emissions in New Zealand. Palmerston North: New Zealand Agricultural Greenhouse Gas Research Centre.
- Reisinger, A., Clark, H., Lambert, C., Lambert, G., Rollo, M., Melville, P., . . . Forbes, R. (2016). Modelling agriculture's contribution to New Zealand's contribution to the post-2020 agreement. Retrieved from Wellington: <http://www.nzagrc.org.nz/knowledge/listing/312/modelling-agricultures-contribution-to-new-zealands-contribution-to-the-post-2020-agreement.html>
- Reisinger, A., Havlik, P., Riahi, K., van Vliet, O., Obersteiner, M., & Herrero, M. (2013). Implications of alternative metrics for global mitigation costs and greenhouse gas emissions from agriculture. *Climatic Change*, 117(4), 677-690.
- Reisinger, A., & Stroombergen, A. (2011). Economic and policy implications of alternative metrics to account for emissions of non-CO₂ greenhouse gases. Wellington: New Zealand Agricultural Greenhouse Gas Research Centre, Infometrics.
- Rentschler, J. E. (2013). Oil price volatility - its risk on economic growth and development. Retrieved from <http://blogs.worldbank.org/developmenttalk/oil-price-volatility-its-risk-economic-growth-and-development>
- Rhodes, A., Gazis, E., & Gross, R. (2017). Is the UK facing an electricity security crisis? London: Energy Futures Lab, Imperial College.
- Rifkin, J. (2011). *The third industrial revolution: How lateral power is transforming energy, the economy, and the world*. New York: St Martin's Press.
- Rio Tinto. (2018). Rio Tinto and Alcoa announce world's first carbon-free aluminium smelting process [Press release]. Retrieved from https://www.riotinto.com/documents/180511_Rio_Tinto_announces_worlds_first_carbon_free_aluminium.pdf
- Rive, V. (2011). New Zealand Climate Change Regulation. In A. Cameron (Ed.), *Climate Change Law and Policy in New Zealand*. Wellington: LexisNexis NZ.

- Rive, V., & Harker, J. (2017). Climate change. In Justice O'Regan (Ed.), *The laws of New Zealand*. Wellington: Lexis Nexis.
- Robert, C., & Jin, M. (2010). Effects of built environments on vehicle miles traveled: Evidence from 370 US urbanized areas. *Environment and Planning A: Economy and Space*, 42(2), 400-418.
- Robinson Institute. (2018). Superconducting power systems. Retrieved from <https://www.victoria.ac.nz/robinson/research/electric-power-systems>
- Rodrik, D. (2015). *Economics rules: The rights and wrongs of the dismal science*. New York: W. W. Norton.
- Rogelj, J., Meinshausen, M., Schaeffer, M., Knutti, R., & Riahi, K. (2015a). Impact of short-lived non-CO₂ mitigation on carbon budgets for stabilizing global warming. *Environmental Research Letters*, 10(7), 075001.
- Rogelj, J., Schaeffer, M., Meinshausen, M., Knutti, R., Alcamo, J., Riahi, K., & Hare, W. (2015b). Zero emission targets as long-term global goals for climate protection. *Environmental Research Letters*, 10, 105007.
- Rogelj, J., Schaeffer, M., Meinshausen, M., Shindell, D., Hare, W., Klimont, Z., . . . Schellnhuber, H. J. (2014). Disentangling the effects of CO₂ and short-lived climate forcer mitigation. *Proceedings of the National Academy of Sciences*, 111(46), 16325-16330.
- Rollinson, S. (2010). Changing dynamics of environmental politics in Britain: A case study of the UK climate change act. *POLIS Journal*, 3, 1-38.
- Romera, B. M. (2016). The Paris Agreement and the regulation of international bunker fuels. *Review of European Community & International Environmental Law*, 25(2), 215-227.
- Ross, V. (2018). Solar flair for farming in South Australia. Retrieved from <https://solarmagazine.com/solar-flair-for-farming-in-south-australia/>
- Rotherham, F. (2018, 3 August 2018). Callaghan 2.0 - the new strategy. *The National Business Review*, 3 August 2018, 24.
- Rotmans, J., Kemp, R., & van Asselt, M. (2001). More evolution than revolution: Transition management in public policy. *Foresight*, 3(1), 15-31.
- Rotorua Lakes Council. (2015). Wood first policy. Retrieved from https://www.rotorualakescouncil.nz/our-council/PoliciesandBylaws/Policies/Documents/2017/Council_Policies/Wood_First_Policy.pdf
- RSNZ. (2016). Transition to a low-carbon economy for New Zealand. Wellington: The Royal Society of New Zealand.
- Russell McVeagh. (2017). Green bonds. Retrieved from <https://www.russellmcveagh.com/insights/august-2017/green-bonds>
- Rutter, J., & Knighton, W. (2012). Legislated policy targets: Commitment device, political gesture or constitutional outrage. London: Institute for Government.
- Ryan-Collins, J., & van Lerven, F. (2017). Central banks, climate change and the transition to a low-carbon economy. London: New Economics Foundation.
- Salmond, A. (2017a, 14 December 2017). Forestry plan not out of the woods. Retrieved from <https://www.newsroom.co.nz/2017/12/13/68180/anne-salmond-plan-to-revive-forestry-service-not-out-of-the-woods>
- Salmond, A. (2017b). Forestry plan not out of the woods. Retrieved from <https://www.newsroom.co.nz/2017/12/13/68180/anne-salmond-plan-to-revive-forestry-service-not-out-of-the-woods>
- Sargent, E. (2018). New Zealand's birthrate hits a new low. *Stuff*. Retrieved from <https://www.stuff.co.nz/life-style/parenting/pregnancy/birth/101562144/new-zealands-birthrate-hits-a-new-low>
- Saunois, M., Jackson, R. B., Bousquet, P., Poulter, B., & Canadell, J. G. (2016). The growing role of methane in anthropogenic climate change. *Environmental Research Letters*, 11(12), 120207.
- Schatzki, T. (2003). Options, uncertainty and sunk costs: An empirical analysis of land use change. *Journal of Environmental Economics and Management*, 46(1), 86-105.
- Schein, E. H. (2010). *Organizational culture and leadership*. San Francisco CA: John Wiley & Sons.
- Schoenberger, M. M., Bentrup, G., & Patel-Weynand, T. (Eds.). (2017). *Agroforestry: Enhancing resiliency in U.S. agricultural landscapes under changing conditions*. Washington, DC: U.S. Department of Agriculture Forest Service.
- Schumpeter, J. A. (1939). *Business cycles: A theoretical, historical and statistical analysis of the capitalist process*. New York: McGraw-Hill.
- Schumpeter, J. A. (1942/2003). *Capitalism, socialism & democracy*. London: Routledge.
- Schwartz, J. D. (2014). Soil as carbon storehouse: New weapon in climate fight. Retrieved from https://e360.yale.edu/features/soil_as_carbon_storehouse_new_weapon_in_climate_fight
- Scion. (2018). New Zealand biofuels roadmap: Summary report. Rotorua: Scion.
- Scott, G. (1995). New Zealand's fiscal responsibility act. *Agenda: A Journal of Policy Analysis and Reform*, 2(1), 3-16.

- Scott, G. (1996). Budget execution and reporting. Presentation to the Fiscal Management Seminar, organised by The World Bank, The International Monetary Fund and the Russian Ministry of Finance. Moscow: Graham Scott (NZ) Ltd.
- Scott, R. A., Currie, G. V., & Tivendale, K. J. (2012). Company cars and fringe benefit tax – understanding the impacts on strategic transport targets. Wellington: New Zealand Transport Agency.
- Shammin, M. R., & Bullard, C. W. (2009). Impact of cap-and-trade policies for reducing greenhouse gas emissions on U.S. households. *Ecological Economics*, 68(8), 2432-2438.
- ShareChat. (2018). Treasury seeks financial gurus to advise on \$100m green investment fund by July. Retrieved from <http://www.sharechat.co.nz/article/7fd18c02/treasury-seeks-financial-gurus-to-advise-on-100m-green-investment-fund-by-july.html>
- Shaw, C., Randal, E., Keall, M., & Woodward, A. (2018). Health consequences of transport patterns in New Zealand's largest cities. *The New Zealand Medical Journal*, 131(1472), 64-72.
- Shindell, D., Borgford-Parnell, N., Brauer, M., Haines, A., Kuylenstierna, J. C. I., Leonard, S. A., . . . Srivastava, L. (2017). A climate policy pathway for near- and long-term benefits. *Science*, 356(6337), 493-494.
- Shindell, D., Kuylenstierna, J. C. I., Vignati, E., van Dingenen, R., Amann, M., Klimont, Z., . . . Fowler, D. (2012). Simultaneously mitigating near-term climate change and improving human health and food security. *Science*, 335(6065), 183-189.
- Shine, K. P., Berntsen, T. K., Fuglestvedt, J. S., Skeie, R. B., & Stuber, N. (2007). Comparing the climate effect of emissions of short- and long-lived climate agents. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 365(1856), 1903-1914.
- Shine, K. P., Fuglestvedt, J. S., Hailemariam, K., & Stuber, N. (2005). Alternatives to the global warming potential for comparing climate impacts of emissions of greenhouse gases. *Climatic Change*, 68(3), 281-302.
- Shoemaker, J. K., Schrag, D. P., Molina, M. J., & Ramanathan, V. (2013). What role for short-lived climate pollutants in mitigation policy? *Science*, 342(6164), 1323-1324.
- Silk, K. (2017). Financing the transition to a greener New Zealand. Retrieved from <http://pureadvantage.org/news/2017/10/10/financing-transition-greener-new-zealand/>
- Silvestri, S., & Omri, M. (2008). A method for the remote sensing identification of uncontrolled landfills: Formulation and validation. *International Journal of Remote Sensing*, 29(4), 975-989.
- Simmons, G., Robertson, B. C., Whittaker, H., Slooten, E., McCormack, F., Bremner, G., . . . Dawson, S. M. (2017). New Zealand's fisheries quota management system: On an undeserved pedestal. Retrieved from <https://theconversation.com/new-zealands-fisheries-quota-management-system-on-an-undeserved-pedestal-82210>
- Simmons, G., & Young, P. (2016). Climate cheats. Wellington: The Morgan Foundation.
- Sims, R. (2018). What's the point of looking for more gas? Retrieved from <https://pureadvantage.org/news/2018/03/09/whats-the-point-of-looking-for-more-gas/>
- Sjöström, M., & Östblom, G. (2010). Decoupling waste generation from economic growth — A CGE analysis of the Swedish case. *Ecological Economics*, 69(7), 1545-1552.
- Skiba, U., Jones, S. K., Dragosits, U., Drewer, J., Fowler, D., Rees, R. M., . . . Manning, A. J. (2012). UK emissions of the greenhouse gas nitrous oxide. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 367(1593), 1175-1185.
- Skodvin, T. (1999). Making climate change negotiable: The development of the Global Warming Potential index. CICERO Working Paper 1999:9. Oslo: Center for International Climate and Environmental Research.
- Skodvin, T., & Fuglestvedt, J. (1997). A comprehensive approach to climate change: Political and scientific considerations. *Ambio*, 26(6), 351-358.
- Slezak, M. (2018). Super fund REST being sued for not having a plan for climate change. Retrieved from <http://www.abc.net.au/news/2018-07-25/super-fund-rest-sued-for-not-doing-enough-on-climate-change/10029744>
- Slooten, E., Simmons, G., Dawson, S. M., Bremner, G., Thrush, S. F., Whittaker, H., . . . Zeller, D. (2017). Evidence of bias in assessment of fisheries management impacts. *Proceedings of the National Academy of Sciences*, 114(25), E4901-E4902.
- Smil, V. (2017). *Energy and civilisation: A history*. Cambridge MA: MIT Press.
- Smith, A. M. C. (2018). The fiscal impact of the Trans-Tasman Travel Arrangement: Have the costs become too high? *Australian Tax Forum*, 33(2), 1-36.
- Smith, K. (2006). Public policy framework for the New Zealand Innovation System, Ministry of Economic Development Occasional Paper 06/06. Wellington: NZ Ministry of Economic Development.
- Smith, S. M., Lowe, J. A., Bowerman, N. H. A., Gohar, L. K., Huntingford, C., & Allen, M. R. (2012). Equivalence of greenhouse-gas emissions for peak temperature limits. *Nature Climate Change*, 2(7), 535-538.

- SMMT. (2018). Average vehicle age. Retrieved from <https://www.smmt.co.uk/industry-topics/sustainability/average-vehicle-age/>
- Staffell, I., Dodds, P., Scamman, D., Abad, A., Mac Dowell, N., Ward, K., . . . Ekins, P. (2017). The role of hydrogen and fuel cells in future energy systems. London, UK: H2FC SUPERGEN.
- State Services Commission. (1996). *New Zealand's state sector reform: A decade of change*. Wellington: State Services Commission.
- State Services Commission. (2014). *Statutory Crown Entities: A guide for Ministers*. Wellington: New Zealand Government.
- Statistics Norway. (2015). Registered vehicles, 2015. Retrieved from <https://www.ssb.no/en/transport-og-reiseliv/statistikker/bilreg/aar/2016-03-30>
- Stats NZ. (2008). Housing indicators. Retrieved from http://archive.stats.govt.nz/browse_for_stats/people_and_communities/housing/housing-indicators.aspx
- Stats NZ. (2017a). Group: Agriculture - AGR, Table: Variable by Total New Zealand (Annual-Jun).
- Stats NZ. (2017b). Group: Agriculture - AGR, Table: Variable by Total New Zealand (Annual-Jun). Retrieved from <http://archive.stats.govt.nz/infoshare/SelectVariables.aspx?pxID=a7d04370-2094-4604-abdc-a863bb7b1091>
- Stats NZ. (2017c). Group: Population estimates - DPE, Table: Estimated Resident Population by Age and Sex (1991+) (Annual-Jun). Wellington: Statistics New Zealand.
- Stats NZ. (2017d). National accounts. Retrieved from <http://www.stats.govt.nz/infoshare/SelectVariables.aspx?pxID=a44abb67-161f-4510-84b0-e20ca6d85a9f>
- Stats NZ. (2018a). Building consents. Retrieved from <http://archive.stats.govt.nz/infoshare/SelectVariables.aspx?pxID=80677538-1d8f-4876-bd80-526896e74e17>
- Stats NZ. (2018b). LEED quarterly tables. Retrieved from http://archive.stats.govt.nz/tools_and_services/nzdotstat/tables-by-subject/leed-quarterly-tables.aspx
- Stats NZ. (2018c). New Zealand: An urban/rural profile. Historical context. Retrieved from http://archive.stats.govt.nz/browse_for_stats/Maps_and_geography/Geographic-areas/urban-rural-profile/historical-context.aspx
- Stats NZ. (2018d). Table: Estimated Resident Population by Age and Sex (1991+) (Annual-Jun). Retrieved from: <http://archive.stats.govt.nz/infoshare/SelectVariables.aspx?pxID=b315b7be-8cf2-4eb1-87b2-877a74634149>
- Stats NZ. (2018e). Table: Series, GDP(P), Chain volume, Actual, Total (Annual-Mar). Retrieved from: <http://archive.stats.govt.nz/infoshare/SelectVariables.aspx?pxID=8dab6d38-fac7-4a8b-bf46-e57a1e6c7941>
- Stephan, A., Crawford, R. H., & de Myttenaere, K. (2013). Multi-scale life cycle energy analysis of a low-density suburban neighbourhood in Melbourne, Australia. *Building and Environment*, 68, 35-49.
- Stern, N. (2007). *The economics of climate change: The Stern review*. Cambridge: Cambridge University Press.
- Stern, N. (2015). *Why are we waiting? The logic, urgency, and promise of tackling climate change*. London: MIT Press.
- Stevenson, T., Batstone, S., Reeve, D., Poynton, M., & Comendant, C. (2018). Transition to zero net emissions by 2050: Moving to a very low-emissions electricity system in New Zealand. Wellington: New Zealand Productivity Commission.
- Stiglitz, J. (2013). Sharing the burden of saving the planet: Global social justice for sustainable development. In M. Kaldor & J. Stiglitz (Eds.), *The quest for security: Protection without protectionism and the challenge of global governance* (pp. 161-190). New York, United States: Columbia University Press.
- Stiglitz, J., & Stern, N. (2017). Report of the high-level commission on carbon prices. Paris: Carbon Pricing Leadership Coalition.
- Stips, A., Macias, D., Coughlan, C., Garcia-Gorrioz, E., & Liang, X. S. (2016). On the causal structure between CO₂ and global temperature. *Nature Scientific Reports*, 6, 21691.
- Storey, B., Noy, I., Townsend, W., Kerr, S., Salmon, R., Middleton, D., . . . James, V. (2017). Insurance, housing and climate adaptation: Current knowledge and future research. Motu Note #27. Wellington: Motu Economic and Public Policy Research.
- Stringleman, H., & Scrimgeour, F. (2008). Dairying and dairy products - Dairying in the 2000s, Te Ara - the encyclopedia of New Zealand. Retrieved from <http://www.TeAra.govt.nz/en/dairying-and-dairy-products/page-10>
- Stroombergen, A. (2010). The international effects of climate change on agricultural commodity prices, and the wider effects on New Zealand. Wellington: Motu Economic and Public Policy Research.

- Suckling, I. (2018). *New Zealand Biofuels Roadmap*. Wellington: Scion and Bioenergy Association of New Zealand.
- Sustainable Business Network. (2018). *The circular economy opportunity for New Zealand and how business can realise it*. Auckland: Sustainable Business Network.
- Sustainable Living Education Trust. (2018). *Future living skills*. Retrieved from <https://sustainableliving.org.nz/>
- Swannix, J.-M. (2017). Government to review building code. *Newshub*. Retrieved from <http://www.newshub.co.nz/home/money/2017/11/government-to-review-building-code.html>
- Tanaka, K., & O'Neill, B. C. (2018). The Paris Agreement zero-emissions goal is not always consistent with the 1.5 °C and 2 °C temperature targets. *Nature Climate Change*, 8(4), 319-324.
- Tanaka, K., Peters, G. P., & Fuglestedt, J. S. (2010). Multicomponent climate policy: Why do emission metrics matter? *Carbon Management*, 1(2), 191-197.
- Tate, K.R., Giltrap, D.J., Claydon, J.J., Newsome, P.F., Atkinson, A.E., Taylor, M.D. & Lee, R. (1997). Organic carbon stocks in New Zealand's terrestrial ecosystems. *Journal of the Royal Society of New Zealand*, 27(3), 315-335.
- Tax Working Group. (2018). *The future of tax: Submissions background paper*. Wellington: New Zealand Government.
- Taylor, G. (2017). Why New Zealand needs a Climate Commission. Retrieved from <https://www.westpac.co.nz/rednews/lifestyle/why-new-zealand-needs-a-climate-commission/>
- TCFD. (2017). *Final report: Recommendations of the Task Force on Climate-related Financial Disclosures*. New York: Task Force on Climate-related Financial Disclosures.
- TDB Advisory. (2017). *Iwi investment report 2017*. Wellington: TDB Advisory Limited.
- Te Ātiawa o Te Waka-a-Māui. (2014). *Iwi environmental management plan*. Picton: Te Ātiawa o Te Waka-a-Māui.
- Te Uru Rākau. (2018a). *A better ETS for forestry: Proposed amendments to the Climate Change Response Act 2002*. Wellington: Te Uru Rākau.
- Te Uru Rākau. (2018b). *Te Uru Rākau*. Retrieved from <https://www.mpi.govt.nz/teururakau/>
- Technopolis Group. (2016). *Regulatory barriers for the circular economy: Lessons from ten case studies*. Brighton: Technopolis Group.
- The Dominion Post. (2009). Flashback to LPG. Retrieved from <http://www.stuff.co.nz/business/487977/Flashback-to-LPG>
- The Guardian. (2016). *World's first large-scale tidal energy farm launches in Scotland*. Retrieved from <https://www.theguardian.com/uk-news/2016/sep/12/worlds-first-large-scale-tidal-energy-farm-launches-scotland>
- The Korea Bizwire. (2017). *South Korean Government to impose landfill levy to promote recycling*. Retrieved from <http://koreabizwire.com/south-korean-government-to-impose-landfill-levy-to-promote-recycling/85330>
- The Treasury. (2005). *A guide to the Public Finance Act*. Wellington: The Treasury.
- The Treasury. (2008). *Innovation and productivity: Using bright ideas to work smarter*. New Zealand Treasury Productivity Paper 08/05. Wellington: The Treasury.
- The Treasury. (2015a). *An introduction to New Zealand's fiscal policy framework*. Wellington: The Treasury.
- The Treasury. (2015b). *Official Information Act request: Reference 20150294*. Retrieved from <http://www.treasury.govt.nz/downloads/pdfs/oia/oia-20150294.pdf>
- The Treasury. (2016a). *Notes from No. 1 The Terrace - Climate*. Wellington: The Treasury.
- the Treasury. (2016b). *Official Information Act request: Reference 20160305*. Retrieved from <https://treasury.govt.nz/sites/default/files/2017-11/oia-20160305.pdf>
- The Treasury. (2018a). *Changes to the Overseas Investment Screening Regime for Forestry and other profits à prendre: Questions and Answers*. Wellington: The Treasury.
- The Treasury. (2018b). *Forestry registration rights in the Overseas Investment screening regime*. Retrieved from <https://treasury.govt.nz/publications/information-release/forestry-registration-rights-overseas-investment-screening-regime>
- The University of Auckland. (n.d.). *Going wireless*. Retrieved from <https://www.auckland.ac.nz/en/for/the-media/ourstories/going-wireless.html>
- Thompson, M. (2016). *The fifth carbon budget: A balanced path to a necessary goal*. Retrieved from <https://www.theccc.org.uk/2016/03/31/the-fifth-carbon-budget-a-balanced-path-to-a-necessary-goal/>
- Thompson, M. (2017). *Five reflections on Dieter Helm's Cost of Energy Review*. Retrieved from <https://www.theccc.org.uk/2017/10/31/five-reflections-dieter-helms-cost-energy-review/>
- Thomson v The Minister for Climate Change Issues, No. CIV 2015-485-919, [2017] NZHC 733 (High Court of New Zealand 2017).
- Tietenberg, T. H. (1985). *Emissions trading: An exercise in reforming pollution policy*. Washington D.C.: Resources for the Future.

- Timperley, J. (2017). COP23: Key outcomes agreed at the UN climate talks in Bonn. Retrieved from <https://www.carbonbrief.org/cop23-key-outcomes-agreed-un-climate-talks-bonn>
- Transfield Worley. (2011). CCS in New Zealand: Can carbon capture and storage deliver value to New Zealand as we head towards a low carbon future? . Wellington: NZCCS Partnership.
- Transport & Environment. (2017). Roadmap to climate-friendly land freight and buses in Europe. Brussels: Transport & Environment.
- Transport & Environment. (2018). US truck fuel efficiency standards: costs and benefits compared. Brussels: Transport and Environment.
- Transport and Industrial Relations Committee. (2017). Inquiry into the future of New Zealand's mobility: Report of the Transport and Industrial Relations Committee. Wellington: New Zealand Parliament.
- Transportation Research Board. (2009). Driving and the built environment. The effects of compact development on motorized travel, energy use, and CO₂ emissions. Washington, D.C.: National Research Council of the Research Academies.
- Transpower. (2018a). Security of supply annual assessment 2018. Wellington: Transpower.
- Transpower. (2018b). Te Mauri Hiko: Energy futures. Wellington: Transpower.
- Tunakino Forestry. (2016). Submission on the NZ ETS Review discussion document. Retrieved from http://www.mfe.govt.nz/sites/default/files/media/NZETS_reviewstage2%20-%20Tunakino%20Forestry%20Limited%2003002.pdf
- UK Department for Transport. (2017). Freight carbon review 2017: Moving Britain ahead. London: Department for Transport.
- UK Government. (2013). The Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013. London: UK Government.
- UK Government. (2017a). Digest of UK energy statistics. Retrieved from www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes
- UK Government. (2017b). Green finance. Retrieved from <https://www.gov.uk/guidance/green-finance>
- UK Treasury. (2013). Infrastructure carbon review. Retrieved from <https://www.gov.uk/government/publications/infrastructure-carbon-review>
- Umwelt Bundesamt. (2017). Indicator: Greenhouse gas emissions. Retrieved from <https://www.umweltbundesamt.de/en/indicator-greenhouse-gas-emissions>
- UN DESA. (2018). World population prospects 2017 - Total population, both sexes. Retrieved from: <https://esa.un.org/unpd/wpp/Download/Standard/Population/>
- UN PAGE. (2016). The People's Bank of China issued the "Guidelines for Establishing the Green Financial System". Retrieved from <http://www.un-page.org/people%E2%80%99s-bank-china-issued-%E2%80%9Cguidelines-establishing-green-financial-system%E2%80%9D>
- UNDP. (2018). Public guarantees. Retrieved from <http://www.undp.org/content/sdfinance/en/home/solutions/public-guarantees.html>
- UNEP. (2014). Demystifying private climate finance. Geneva: UNEP Finance Initiative.
- UNEP. (2017a). The emissions gap report 2017: A UN Environment synthesis report. Nairobi: United Nations Environment Programme.
- UNEP (2017b). Global review of sustainable public procurement. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/20919/GlobalReview_Sust_Procurement.pdf?sequence=1&isAllowed=y
- UNFCCC. (1992). United Nations Framework Convention on Climate Change. New York: United Nations.
- UNFCCC. (2008). Kyoto Protocol reference manual: On accounting of emissions and assigned amount. New York: United Nations.
- UNFCCC. (2015a). Methodological tool: Emissions from solid waste disposal sites. Version 06.0.1: CDM Executive Board.
- UNFCCC. (2015b). The Paris Agreement. United Nations Framework Convention on Climate Change. New York: United Nations.
- UNFCCC. (2016). High-level climate champions launch 2050 pathways platform. Retrieved from <https://unfccc.int/news/high-level-climate-champions-launch-2050-pathways-platform>
- UNFCCC. (2017). Koronivia joint work on agriculture. New York: United Nations Framework Convention on Climate Change.
- UNFCCC. (2018a). Communication of long-term strategies. Retrieved from <https://unfccc.int/process/the-paris-agreement/long-term-strategies>
- UNFCCC. (2018b). The Paris Agreement. Retrieved from http://unfccc.int/paris_agreement/items/9485.php
- University of Canterbury. (2017). Resilient seismic design in multi-story wood buildings. Retrieved from <http://www.canterbury.ac.nz/engineering/schools/cnre/research-groups-and-partnerships/timber/research/>

- Upton, S. (2016). Managing biological sources and sinks in the context of New Zealand's response to climate change. NZ Resource Management Law Association Conference, Nelson, 22 September 2016. Nelson: NZ Resource Management Law Association.
- US Department of Energy. (2017). U.S. energy and employment report. January 2017. Washington D.C.: United States Department of Energy.
- US EPA. (2016). Tire-Derived Fuel. Retrieved from <https://archive.epa.gov/epawaste/conserve/materials/tires/web/html/tdf.html>
- US EPA. (2017a). Methane emissions. Retrieved from <https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane>
- US EPA. (2017b). Nitrous oxide emissions. Retrieved from <https://www.epa.gov/ghgemissions/overview-greenhouse-gases#nitrous-oxide>
- US EPA. (2018a). Basic information about landfill gas. Retrieved from <https://www.epa.gov/lmop/basic-information-about-landfill-gas>
- US EPA. (2018b). Light-duty automotive technology, carbon dioxide Emissions, and fuel economy trends: 1975 through 2017: Trends report. Washington DC: United States Environmental Protection Agency.
- USDA Foreign Agricultural Service. (2017). Brazil biofuels annual 2017. Retrieved from https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Sao%20Paulo%20AT_O_Brazil_9-15-2017.pdf
- Vale, R. (2017). The Hockerton Housing Project: A case study of the use of concrete. In E. K. Petrovic, B. Vale, & M. P. Zari (Eds.), *Materials for a healthy, ecological and sustainable built environment: Principles for evaluation* (pp. 309-319). Cambridge: Woodhead Publishing.
- Vallejo, L., Moarif, S., & Halimanyaja, A. (2017). Enhancing mitigation and finance reporting: Building on current experience to meet the Paris Agreement requirements. Climate Change Expert Group Paper No. 2017(6). Paris: OECD and International Energy Agency.
- van den Wall Bake, J. D., Junginger, M., Faaij, A., Poot, T., & Walter, A. (2009). Explaining the experience curve: Cost reductions of Brazilian ethanol from sugarcane. *Biomass and Bioenergy*, 33(4), 644-658.
- van Vuuren, D. P., Stehfest, E., Gernaat, D. E. H. J., van den Berg, M., Bijl, D. L., de Boer, H. S., . . . van Sluisveld, M. A. E. (2018). Alternative pathways to the 1.5°C target reduce the need for negative emission technologies. *Nature Climate Change*, 8(5), 391-397.
- Vector. (2018a). Electricity asset management plan. Auckland: Vector.
- Vector. (2018b). EV network integration green paper. Auckland: Vector.
- Vector. (2018c). Tesla Powerwall 2 battery. Retrieved from <https://www.vector.co.nz/personal/batteries>
- Vitalis, V. (2007). Agricultural subsidy reform and its implications for sustainable development: the New Zealand experience. *Environmental Sciences*, 4(1), 21-40.
- Vivid Economics. (2017a). Net zero in New Zealand: Scenarios to achieve domestic emissions neutrality in the second half of the century. Summary report. London: Vivid Economics.
- Vivid Economics. (2017b). Net zero in New Zealand: Technical report. London: Vivid Economics.
- Waisman, H., Spencer, T., & Colombier, M. (2016). Long-term low emissions development strategies and the Paris Agreement: Why, what and how? IDDRI Policy Brief No 06/16. Paris: Institute for Sustainable Development and International Relations.
- Waitangi Tribunal. (2011). Ko Aotearoa tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity. Te taumata tuatahi [Wai 262]. Wellington: Waitangi Tribunal.
- Wakeman, S., & Conway, P. (2017). Innovation and the performance of New Zealand firms. Staff Working Paper 2017/2. Wellington: New Zealand Productivity Commission.
- Wallis, I., & Lupton, D. (2013). The costs of congestion reappraised. NZ Transport Agency research report 489. Wellington: New Zealand Transport Agency.
- Wang, L., & Chen, L. (2018). The impact of new transportation modes on population distribution in Jing-Jin-Ji region of China. *Scientific Data*, 5, 170204.
- Wang, Q., Hubacek, K., Feng, K., Wei, Y.-M., & Liang, Q.-M. (2016). Distributional effects of carbon taxation. *Applied Energy*, 184(C), 1123-1131.
- Wang, T., Harvey, J., & Kendall, A. (2014). Reducing greenhouse gas emissions through strategic management of highway pavement roughness. *Environmental Research Letters*, 9(3), 1-10.
- Warne, K. (2017). Troubled waters. *New Zealand Geographic*. Retrieved from <https://www.nzgeo.com/stories/troubled-waters/>
- Waste Not Consulting. (2009). Household sector waste to landfill in New Zealand. Wellington: Ministry for the Environment.
- Water New Zealand. (2018). NZ WWTP inventory. Retrieved from <https://www.waternz.org.nz/WWTPInventory>
- Watt, M. S., Kirschbaum, M. U. F., Paul, T. S. H., Tait, A., Pearce, H. G., Brockerhoff, E. G., . . . Kriticos, D. J. (2008). The effects of climate change on New Zealand's planted forests: Impacts, risks and opportunities. Rotorua: Scion.

- Watts, N., Amann, M., Ayeb-Karlsson, S., Belesova, K., Bouley, T., Boykoff, M., . . . Costello, A. (2018). The Lancet Countdown on health and climate change: From 25 years of inaction to a global transformation for public health. *The Lancet*, 391(10120), 581-630.
- Weeks, T. (2017). Examining the UK Climate Change Act 2008. Research Note. September 2017. Wellington: New Zealand Productivity Commission.
- Weitzman, M. L. (1974). Prices vs quantities. *Review of Economic Studies*, 41(4), 15.
- Wellington Region. (2017). Wellington Region waste management and minimisation plan. Wellington: The Councils of the Wellington Region.
- Wesseling, J. H., Farla, J. C. M., Sperling, D., & Hekkert, M. P. (2014). Car manufacturers' changing political strategies on the ZEV mandate. *Transportation Research Part D: Transport and Environment*, 33, 196-209.
- Westpac NZ. (2018). Climate change impact report. Auckland: Westpac NZ.
- Whitehead, J. (2005). Speech: The challenges of a growing economy. Retrieved from <https://treasury.govt.nz/publications/speech/challenges-growing-economy>
- Whitney, A., & Bodnar, P. (2018). Beyond direct access: How national green banks can build country ownership of climate finance. Insight brief March 2018. Colorado: Rocky Mountain Institute.
- Willis, R. (1994). Ten years of change in New Zealand manufacturing employment. *Labour, Employment and Work in New Zealand, 1994*, 344-355.
- Wilson, D., Chowdhury, T., Elliott, T., Elliott, L., & Hogg, D. (2017). The New Zealand Waste Disposal Levy: Potential impacts of adjustments to the current levy rate and structure. Final report. Auckland: Eunomia.
- Wilson, Z. (2017, 21 December 2017). Shane Jones wants to work with Whanganui landowners in tree planting programme. *The Whanganui Chronicle*. Retrieved from http://www.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=11963146
- Winter, C. (2017). Sir Bob Jones plans to build world's tallest wooden office tower in Wellington. Retrieved from <https://www.stuff.co.nz/business/95526075/sir-bob-jones-plans-to-build-worlds-tallest-wooden-office-tower-in-wellington>
- WMO. (2016). Provisional WMO statement on the status of the global climate in 2016. Retrieved from <https://public.wmo.int/en/media/press-release/provisional-wmo-statement-status-of-global-climate-2016>
- World Aluminium. (2017). Results of the 2016 anode effect survey: Report on the aluminium industry's global perfluorocarbon gases emissions. London: International Aluminium Institute.
- World Bank. (2014). Fundacion Chile Incubator: Chile case study. Washington, DC: The World Bank.
- World Bank. (2015). Decarbonizing development: Three steps to a zero-carbon future. Washington DC: World Bank Group.
- World Bank. (2017). World Bank Group announcements at One Planet Summit [Press release]. Retrieved from http://www.worldbank.org/en/news/press-release/2017/12/12/world-bank-group-announcements-at-one-planet-summit?CID=ECR_FB_worldbank_EN_EXT_OnePlanet
- WSP and Parsons Brinckerhoff. (2016). Wiri to Westfield: The case for investment. Wellington: KiwiRail.
- XRB. (2018). Why report? Retrieved from <http://www.xrb.govt.nz/reporting-requirements/why-report/>
- Xu, Y. Y., & Ramanathan, V. (2017). Well below 2°C: Mitigation strategies for avoiding dangerous to catastrophic climate changes. *Proceedings of the National Academy of Sciences of the United States of America*, 114(39), 10315-10323.
- Yang, Z., & Bandivadekar, A. (2017). 2017 Global update: Light-duty vehicle greenhouse gas and fuel economy standards. Washington DC: International Council on Clean Transportation.
- Yao, R., Harrison, D. R., & Harnett, M. (2017). The broader benefits provided by New Zealand's planted forests. *New Zealand Journal of Forestry*, 61(4), 7-15.
- Yarrow, G. (2018). ETNZ release on flawed report on NZ energy; The International Energy Authority's 2017 Review of New Zealand [Press release]. Retrieved from <https://news.fuseworksmmedia.com/888c69e1-be73-470a-b98f-520e7b9c8c86>
- Young, P., & Simmons, G. (2016). Cook the books - climate cheats III: when the going gets tough, change the rules. Wellington: The Morgan Foundation.
- Z Energy. (2017). Future moves: the future of mobility. Wellington: Z Energy.
- Zenghelis, D. (2016). Decarbonisation: Innovation and the economics of climate change. In M. Jacobs & M. Mazzucato (Eds.), *Redefining capitalism: Economics and policy for sustainable and inclusive growth* (pp. 172-190). Chichester: Wiley Blackwell.
- Zhang, X., Myhrvold, N. P., Hausfather, Z., & Caldeira, K. (2016). Climate benefits of natural gas as a bridge fuel and potential delay of near-zero energy systems. *Applied Energy*, 167, 317-322.
- Zheng, G. (2013). The effect of Auckland's Metropolitan Urban Limit on land prices. Wellington: New Zealand Productivity Commission.

Zwick, S. (2013). Understanding carbon accounting under the UN Framework Convention. Retrieved from https://www.forest-trends.org/ecosystem_marketplace/understanding-carbon-accounting-under-the-un-framework-convention/

