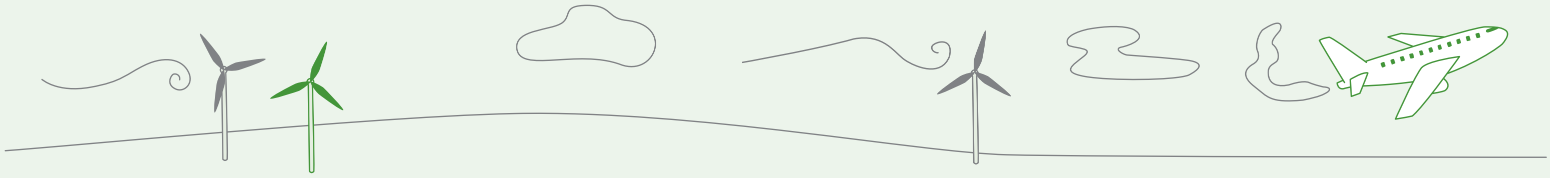

Transition to a low-carbon economy for New Zealand

April 2016

the ROYAL SOCIETY of NEW ZEALAND

TE APĀRANGI

A message from the President of the Royal Society of New Zealand

The Climate Agreement adopted at the UN Climate Change Conference in Paris in December 2015, and supported by 195 countries, gave us a timely reminder that all New Zealanders need to understand the need for meaningful action on climate change. New Zealand must contribute effectively to the global effort to avoid dangerous climate change. New Zealand is already experiencing, for example, more frequent floods, storms and droughts, scrub and forest fires causing damage to the environment and people's livelihoods.

The good news is that there are many opportunities to limit climate change by reducing our greenhouse gas emissions, the main cause of climate change or global warming as it is often called. New Zealand can also prepare for and adapt to living in a changing climate. While there is some uncertainty about the size and timing of changes, it is certain that it is happening and acting now to protect our environment, economy and culture will always be worthwhile.

To consider how to deal with climate change, New Zealand needs to have the evidence to hand, presented in a clear and understandable way, so people can see how they can and should contribute. Last year, the Royal Society of New Zealand established two expert panels: the first to present evidence on the impact of climate change on New Zealand, and the second to provide possible options New Zealand might take to reduce its greenhouse gas emissions.

This is the report of the second of these panels, the *Climate Change Mitigation Panel*, which investigated how New Zealand can reduce the impact of climate change (mitigation options) and assessed the technical and socio-economic options available to reduce New Zealand's greenhouse gas emissions, or remove them from the atmosphere (sequestration).

The report identifies the benefits of reducing greenhouse gas emissions; the interactions between technology, policy and behaviour; and considers factors either limiting the potential for action or providing opportunities for change. It also provides insights on which future technologies and practices might help, and on issues around implementation and adoption. Finally, the report proposes what further research, development and demonstration is needed.

I believe New Zealand has a significant opportunity to both prepare and adapt for the future while transitioning to a low-carbon economy. The risk of not acting to mitigate the adverse effects of climate change, or not protecting ourselves from these effects is vastly greater than the risk of over investing to protect ourselves and our environment.

Professor Richard Bedford QSO FRSNZ

President, Royal Society of New Zealand

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Key findings

Global increase in Greenhouse Gas emissions

- The climate is changing. Average temperatures are increasing due to human activity, particularly the historically high level of greenhouse gas (GHG) emissions.
- In order to limit temperature rise, and associated risks of accelerated sea level rise and more frequent extreme weather events for example, the world must reduce GHG emissions and work towards a low-carbon economy.
- Stabilising the world's climate requires net global emissions of GHGs to be reduced to zero before the end of the 21st century, especially carbon dioxide (CO_2) that is long-lived in the atmosphere.

New Zealand's GHGs increasing

- Our gross GHG emissions per capita are well above average for developed countries.
- Our annual gross and net GHG emissions continue to increase. (Net accounts for CO_2 removed by forests.)
- The main sources of CO_2 emissions are from heat and electricity supply, transport fuels, cement manufacture and forest harvesting.
- New Zealand also produces an unusually large portion of methane (CH_4) and nitrous oxide (N_2O) emissions due to the significant role of agriculture in our economy. This accounts for around half of our gross annual GHG emissions.

Understand the risks and trade-offs and take action

- All New Zealanders need to understand the risks of climate change, accept that we need to change the way we act, realise that trade-offs will need to be made, and become personally involved in implementing mitigation solutions.

Opportunities to reduce emissions

- There are good opportunities to reduce GHG emissions in all sectors and hence make the transition to a thriving low-carbon economy.
- Achieving a transition would rely on carefully planned policy interventions and behaviour changes at the individual, business, city and organisational levels.

Reducing fossil fuel use

- Around half of New Zealand's GHG emissions arise from the burning of coal, oil and gas for electricity generation, industrial heat processes, transport, and everyday activities in homes and commercial buildings.
- There are many opportunities to reduce fossil fuel dependence and hence CO_2 emissions across all of these sectors.

Increasing renewable electricity

- Increasing the share of renewable electricity generation to reach New Zealand's 90% target by 2025 is technically and economically possible.
- An even higher share is possible but would need a more flexible grid, energy storage, and back-up generation (possibly thermal-plant) to meet seasonal peaks, especially in dry years when hydroelectric power is constrained.

Smart energy for heat and electricity

- Renewable heat systems have good potential for buildings and industry. Distributed heat energy systems and a smart electricity grid incorporating small-scale, renewable electricity generation systems, demand-side management, and intelligent appliances could play a future role.

Low carbon transport

- New technologies and low-carbon travel choices can play a part, including more fuel-efficient vehicles;low-carbon fuels such as renewable electricity and biofuels; using buses, light rail, cycling and walking; and improving urban design to encourage their use.
- Journey avoidance and modal shifts for freight such as greater use of rail and sea t, will also assist.

Energy management in buildings and appliances

- GHG emissions can be reduced in the residential and commercial building sector through better energy management and improved minimum performance standards for appliances.
- Emissions reductions can also result from improving insulation levels; retro-fitting existing building stock; integrating renewable energy systems; and supporting innovative 'green building' designs.

Industrial energy use

- The present dependence on burning coal and natural gas for process heat can be displaced by bioenergy, geothermal, solar thermal and electro-thermal technologies.
- Energy efficiency initiatives can reduce GHG emissions significantly but may need further incentivising to meet the short investment time frame of business.
- Carbon dioxide capture and storage (CCS) could be an option in the long term and, if coupled with bioenergy (BECCS), would give negative GHG emissions.

Agriculture

- Increasing adoption of best practices can help reduce the present growth in emissions, but even if current research into additional mitigation technologies proves successful, strong reductions in absolute emissions would eventually involve trade-offs with current growth targets for livestock production and would rely on developing alternative low-emitting land-uses.
- Some measures to reduce emissions could also support water quality.

Forest planting and harvesting

- Significantly increasing the land area of plantation forests could offset up to a quarter of our total GHG emissions over the next two to three decades. However, there are only low levels of planting at this time so when current forest stands are harvested our net emissions (gross emissions less CO_2 removals) are likely to rise.
- Forest sinks can only be an interim solution because there is a limit to the area of available land.

Emissions trading

- The NZ Emissions Trading Scheme has been ineffective in reducing New Zealand's emissions. This has reflected low international carbon credit prices. Reform is needed to provide clear and stable investment signals.
- Emission pricing has an important role but to be most effective it needs to be embedded in a wider package of mitigation policies and actions.

Supporting low-carbon choices

- Policies, targets, regulations, infrastructure, and market settings should be developed systematically to support low-carbon choices by businesses, cities and households.
- An independent board or entity to provide evidence-based advice to Parliament and the public would be valuable.

More ambitious action needed now

- There is a clear case for immediate action. New research and technologies will continue to emerge but many mitigation options are already well-understood and achievable. Delaying actions would result in a greater amount of emissions overall, given that CO_2 emissions accumulate in the atmosphere for hundreds to thousands of years.
- Evidence for mitigation pathways for New Zealand is deficient. This has hampered the analysis conducted in this study and limits effective public engagement and debate about our future options.
- Investment in data gathering and deeper analysis will help refine early mitigation actions and support a transparent public debate about longer term desirable and feasible mitigation pathways.

Starting now

- We can start immediately by deploying low-risk mitigation actions whilst planning for and trialling more ambitious emission reductions options and system changes to commence the necessary transition to a low-carbon economy.

Extended summary

The problem

The climate is changing. Average temperatures are increasing due to human activity, which has driven increasingly high levels of greenhouse gas (GHG) emissions[1]. The 2015 Paris Climate Agreement adopted by 195 countries has the goal that the world will limit the increase in global temperature to well below 2 degrees Celsius (2 °C) above pre-industrial levels, and will pursue efforts to limit the increase to below 1.5 °C.

1 Climate change is largely attributable to emissions of carbon dioxide (CO_2) due to human activity. It is also exacerbated by nitrous oxide (N_2O) and the shorter-lived methane (CH_4). Other gases in the GHG family include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6) that are used as refrigerants, solvents etc. Even though they have grown since 1990, these other gases remain of little significance in New Zealand (~2% of total emissions) so were not covered in this study.

Global GHG emissions continue to rise and under current trends, the world is heading towards a global 3–4°C temperature rise. This will result in negative impacts on the global economy and significantly increase the risks from climate change through rising temperatures, accelerated sea level rise, changes in rainfall patterns, more frequent extreme weather events, and higher costs to adapt or protect ourselves and our infrastructure. We will need our economy to become more resilient. In order to limit temperature rise we must reduce GHG emissions and work towards a low-carbon economy.

The low-carbon economy for New Zealand, as defined in this study, is one that trends towards net zero emissions of carbon dioxide (CO_2), over the next few decades, while also reducing emissions of shorter-lived gases, mainly methane (CH_4). Reducing CO_2 is particularly important as it stays in the atmosphere for hundreds to thousands of years.

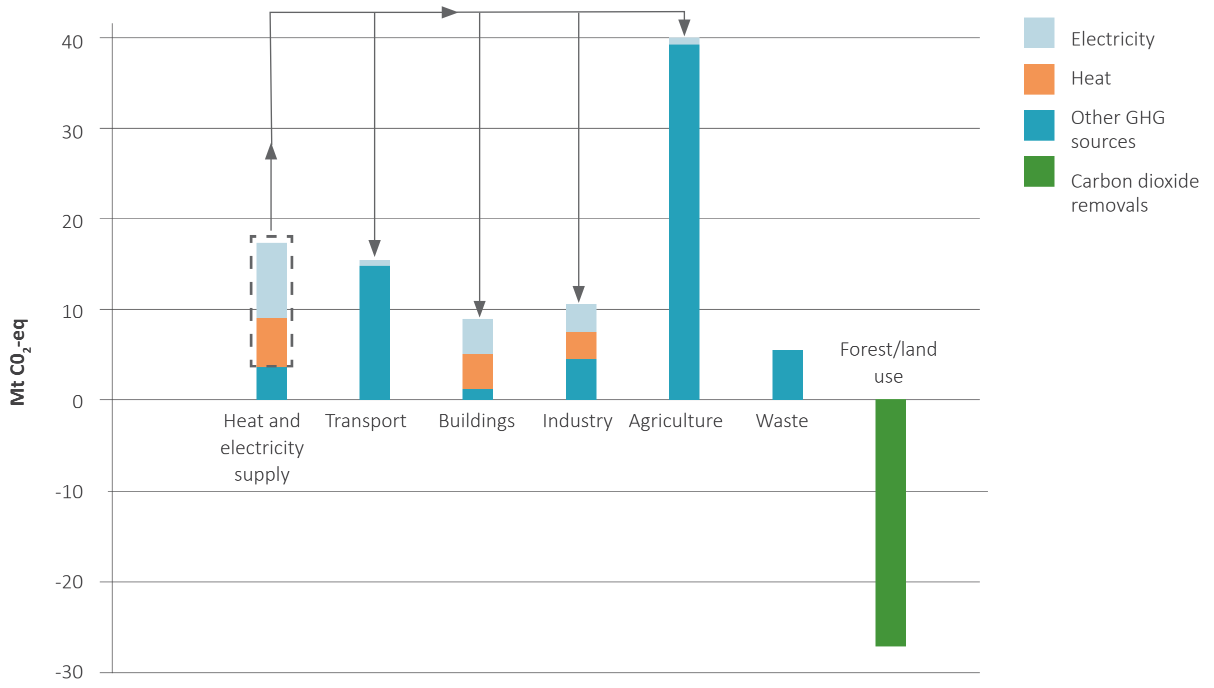
Prioritising CO_2 emission reductions in the near term is consistent with the authoritative assessment of the Intergovernmental Panel on Climate Change (IPCC) concerning the actions needed globally to stabilise the climate and to limit warming to well below 2°C.

This study provides a scientific analysis of the complex situation we find ourselves in and what we can best do about it. All New Zealanders need to understand the threats of climate change, accept that we need to change the way we act, realise there are trade-offs that will need to be made, and become personally involved in implementing mitigation solutions. Mitigation is where we take action to either reduce emissions, or support the removal of GHGs from the atmosphere.

We have the potential to make the transition to a low-carbon economy within several decades by taking mitigation actions. While this will have costs, it will also bring benefits and opportunities that need to be considered. This study is a first step to enable an open debate around options, choices and time frames.

There is very limited publicly available information on what we can and need to do, or the costs and policy options for their implementation now, or later, in individual sectors and across the economy. Such information is critical if we want to have a broad and inclusive debate involving all New Zealanders about how we best make the transition to a low-carbon economy, and the emissions reductions that could be achieved over time (commonly called emissions pathways). Addressing the information gaps so that we can have an informed debate is a very high priority.

Figure ES-1. 2013 Emissions by sector



Note: Annual greenhouse gas emissions and removals in New Zealand are shown from each sector in 2013, with emissions from the heat and electricity supply sector allocated to the transport, buildings, industry and agriculture end-user sectors to avoid double counting

Source: MfE, 2015a.

New Zealand's emissions and trends

New Zealand's annual gross GHG emissions are continuing to increase. Our net emissions, after taking into account removal of CO_2 from the atmosphere by our forests as they grow, have also risen. Neither gross nor net emissions are expected to decline significantly within at least the next two decades based on current policies.

The main sources of CO_2 emissions in New Zealand are heat and electricity supply, transport fuels, and industry. Buildings and industry are important users of the heat and electricity from fossil fuel combustion that produces a large share of these emissions (Figure ES-1) and thus are an important part of mitigation options.

New Zealand also produces an unusually large portion of methane (CH_4)and nitrous oxide (N_2O) emissions due to the significant role of agriculture in our economy. This accounts for around half of our total annual GHG emissions.

Emissions of CO_2 per capita are not as high as for many other developed countries but, in contrast to many, have increased slightly since 1990. However, because of our unusually large proportion of CH_4 and N_2O emissions, our annual emissions of total GHGs per capita are well above the average for developed countries, though they have fallen since 2005.

What can we do to reduce emissions, and in what order?

New Zealand can transition to a low-carbon economy over the next few decades if individuals, households, communities, cities, industries, commercial enterprises and land-users share aspirations and take action. Some mitigation options are well understood, for example reducing the use of fossil fuels. These options can be implemented or increased immediately, while others will take time to adopt and implement. In some cases, appropriate solutions remain the subject of intensive research.

There are good opportunities to reduce GHG emissions in all sectors in New Zealand in the short term. Some measures would save costs and bring additional benefits such as improved health, easier mobility and liveable cities. Other actions would become cost-effective if a substantial carbon price is imposed on GHG emissions.

In the medium to long term, there are additional mitigation opportunities, although there are many uncertainties over the scale and rate at which they will be implemented. In many instances the mitigation costs are unknown and further analysis is required due to limited publicly available information. This is measured in terms of dollars per tonne of CO_2 or per tonne of other GHGs when calculated to be equivalent or give similar impacts ($/t CO_2-equivalent).

Based on broad assumptions of future population, economic growth, business as usual (BAU) emissions, and the rate and scale of deployment of major low-carbon technologies and systems, most sectors have the technical potential to take steps toward reducing emissions and to eventually reach net zero emissions over several decades. This is referred to as 'moving along a low-carbon transition pathway'. The notable exception to this is agriculture.

Options exist to reduce the growth in emissions from the agriculture sector and there has been considerable investment in research to attempt to substantially increase the number of mitigation options available. Nonetheless, reducing absolute emissions substantially from this sector will be challenging even in the long term, unless there was a strategic decision to gradually reduce the reliance on animal protein production from meat and milk for the growth of New Zealand's economy.

Taking action

This study identifies a number of mitigation actions that New Zealand could take across each specific sector: heat supply, electricity supply, transport, building, industry, agriculture, forestry and other land use;possible actions by individuals, businesses, local and central government are also discussed.

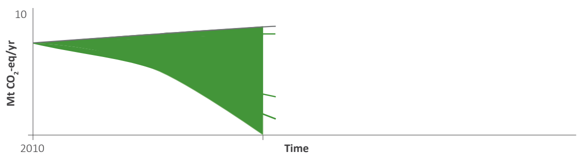
In doing this it was not always possible to make detailed evaluations of their social and economic impacts due to lack of available data. Further data gathering and analysis will be required to fully understand the trade-offs, risks and challenges from taking specific actions, as well as to identify the opportunities and quantify the additional benefits.

Figure ES-2. Potential emission reductions by New Zealand economy sectors over time

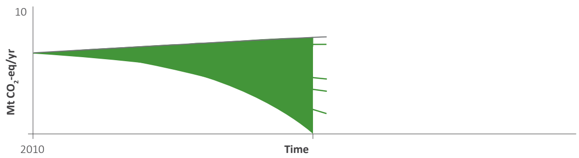
Figure ES-2 is an approximation based on expert opinion and simply serves to illustrate that all sectors can contribute to GHG emission reductions in New Zealand; achieving zero emissions will be more rapid in some sectors than others with the decarbonising of the electricity sector likely to happen first; and that achieving zero emissions for New Zealand's agricultural sector is unlikely this century unless there are trade-offs with current growth targets for livestock production and the development of alternative low GHG emitting land-uses. However, for the current farming systems, there is some potential for total agricultural emissions to be reduced over time compared with BAU.

Potential actions that New Zealand could take from the range of mitigation opportunities that exist in all sectors, are outlined in more detail in the sections below. They are also based on expert opinion, are approximations only, and purely indicative given the high uncertainties of factors such as future costs, trade-offs, technology deployment rates, policies and the absence of detailed data and analysis. Some mitigation options are ready for immediate deployment, while others will not come on stream until various times in the future.

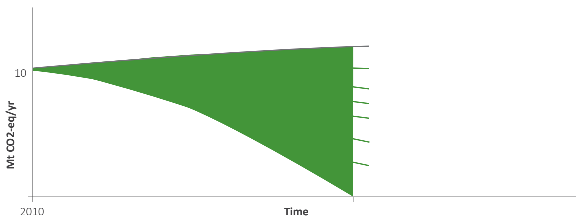
Electricity Supply



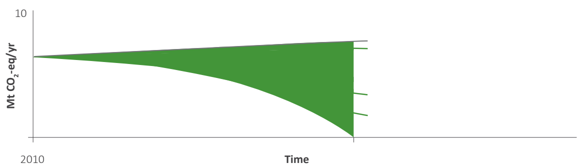
Heat Supply



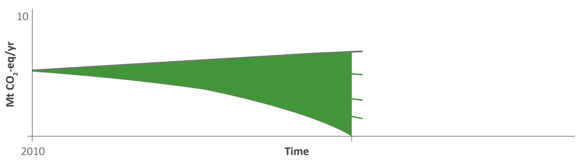
Passenger transport



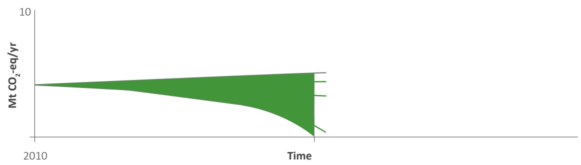
Freight transport



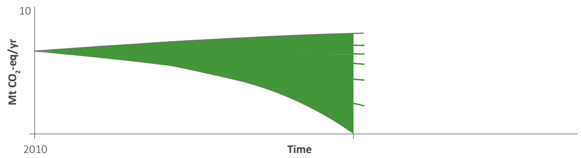
Industry



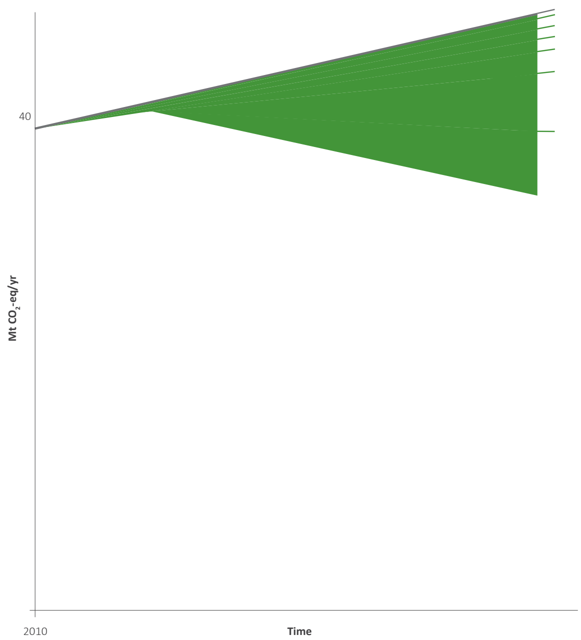
Commercial buildings



Residential buildings



Agriculture



Sectoral mitigation options

Note: The figures on the following pages are an approximation and indicative only given the high uncertainties on future costs, trade-offs, technology deployment rates, and in the absence of detailed data and analysis.

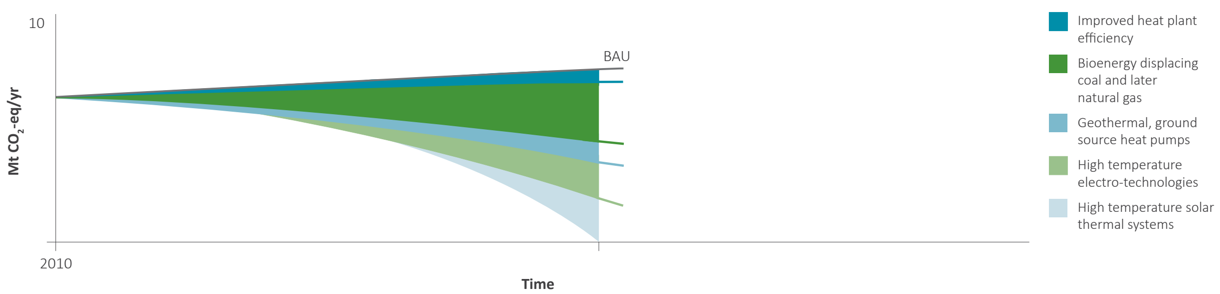
Heat supply

Cost effective options to reduce or avoid GHG emissions have not been fully realised to date. These options include the greater uptake of biomass, solar thermal, and geothermal resources to displace coal and natural gas in the heat sector. The technical mitigation potential for renewable heat is high and an increased carbon price ($ /t CO_2) would further encourage uptake.

Electricity has been the major focus of policy debate, and this has been a barrier to the development of low-carbon heat applications. There has been little recognition of the opportunities to reduce GHG emissions within the heat market despite heat accounting for around 28% of New Zealand's consumer energy use. Electricity equates to only 23% in energy terms.

Direct use of geothermal heat is growing, with many small and large-scale domestic and commercial applications that are economically viable where geothermal resources exist. In other locations, ground source heat pumps for heating and cooling of buildings have been recently installed. The wood energy heat market also has economic potential and as a result demand is growing for biomass-fired heat plant for a range of applications including swimming pools, greenhouses, schools, and hospitals. Where biomass resources exist locally there can be few barriers to greater uptake at all scales and bioenergy heat could become a significant contributor to achieving early mitigation targets.

Heat Supply
Zero emissions by medium to long term

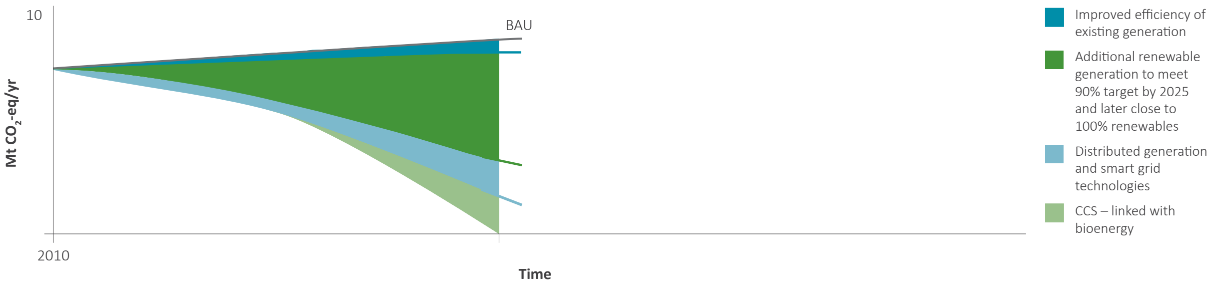


Electricity supply

Around 80% of New Zealand's electricity is generated from renewable sources, primarily hydropower. This can be further increased cost effectively to reach New Zealand's renewable electricity target of 90% by 2025. Eventually, it will be technically possible to reach close to 100% zero carbon generation (noting that geothermal power generation releases some CO_2 during brine extraction). This would possibly include coal-fired or gas-fired power plants linked with carbon dioxide capture and storage (CCS). Near zero carbon generation could be achieved without reducing the reliability of the supply system by making the power grid more flexible, improving efficiency of existing generators, integrating energy storage systems, utilising demand response, and retaining or installing back-up capacity (possibly thermal plant) to meet seasonal peak demand, especially in dry years.

If there is a high proportion of variable renewables in the mix of electricity generation, specifically designed equipment will be needed along with collaboration from stakeholders to ensure frequency fluctuations can be controlled to provide grid stability in the wholesale electricity market. Distributed generation systems and 'smart grids' using low-carbon generation technologies, smart appliances and electric vehicles (EVs) could become common as costs continue to decline and technology integration and electricity market issues are resolved.

Electricity Supply
Zero emissions by medium term



Transport

New Zealand's transport system is 99% dependent on fossil fuels and produces about 17% of our total GHG emissions. Annual emissions continue to increase but could be reduced by at least 60% by 2050 if appropriate policy measures are introduced, such as vehicle fuel efficiency standards and encouragement for people and organisations to use low and zero emissions vehicles.

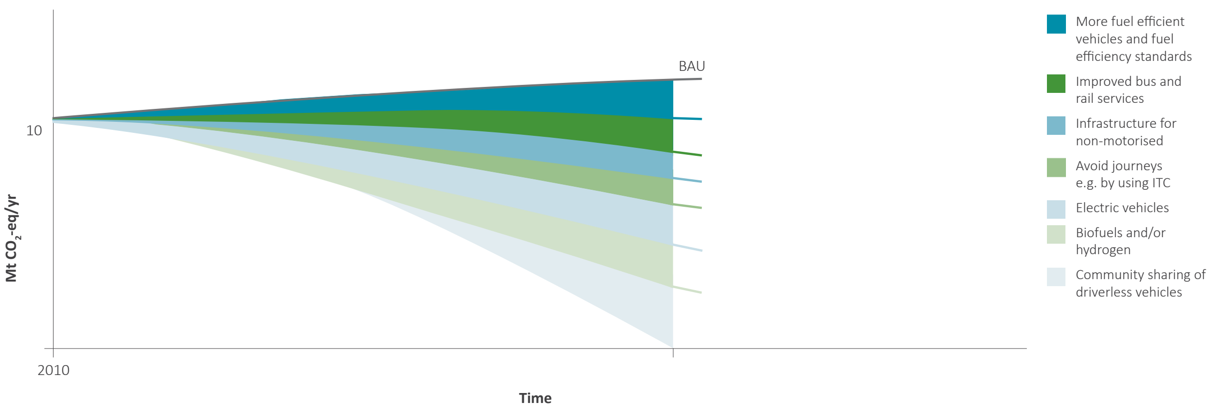
The current dependence on privately owned gasoline and diesel light duty vehicles for mobility can be reduced through urban design that would prioritise walking and cycling and give greater provision of comfortable and convenient bus and rail. The early adoption of electric vehicles (EVs) has begun but support may be required to accelerate deployment, including encouraging community-ownership, driverless designs, and smart-transport technologies.

The declining retail prices for EVs (including E-bikes, E-cycles and E-buses) and hydrogen fuel cell vehicles, coupled with the carbon price reaching a high level, could drive the large scale adoption of low-carbon mobility choices. To speed up development of EVs will require policy instruments and other incentives as, for example, used in Norway to incentivise private ownership of over 100,000 EVs in 2015.

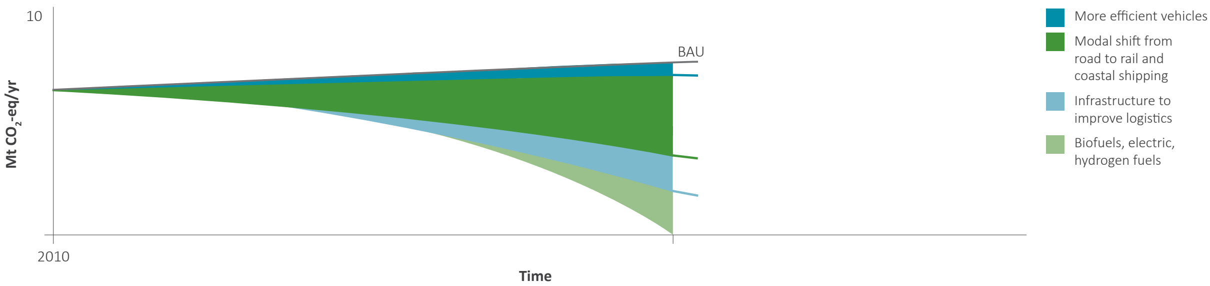
For freight movement, rail and coastal shipping have significantly lower emissions per tonne -kilometre than road transport. The transport of one tonne of freight by diesel-powered rail produces less than a third of the emissions than transport over the same journey by road. Emissions could be further reduced by additional rail electrification, given New Zealand's low-carbon electricity system.

Domestic biofuels based on by-products from food processing (such as ethanol produced from whey, biodiesel from tallow or used cooking oils, and biogas from organic wastes) avoid competition for land use and can be competitive with petroleum products. These are currently being utilised only at a small scale since the feedstocks are limited in volume. Large scale commercialisation of advanced biofuels produced from ligno-cellulosic plant matter could be used primarily for aviation, marine and heavy duty vehicle fuels but, based on existing processes and available feedstocks, remain costly. Viability will be enhanced with process technology improvements and high oil and carbon prices.

Passenger transport (domestic excluding international aviation)
Zero emissions by long term



Freight transport (domestic excluding international shipping)
Zero emissions by long term



Buildings

The buildings sector is indirectly responsible for around 20% of New Zealand's energy-related GHG emissions. These mostly arise from the consumption of fossil fuels to meet the demand for heating and cooking, as well as ther thermal share of electricity generation when used for appliances, heating, ventilation and cooling. Renewable heat and electricity systems integrated into the building fabric could provide energy services instead. New buildings can be designed to have a low energy demand and the total energy demand for heating, cooling and appliances can be met autonomously. Buildings can incorporate timber construction materials that store carbon over the medium to long term.

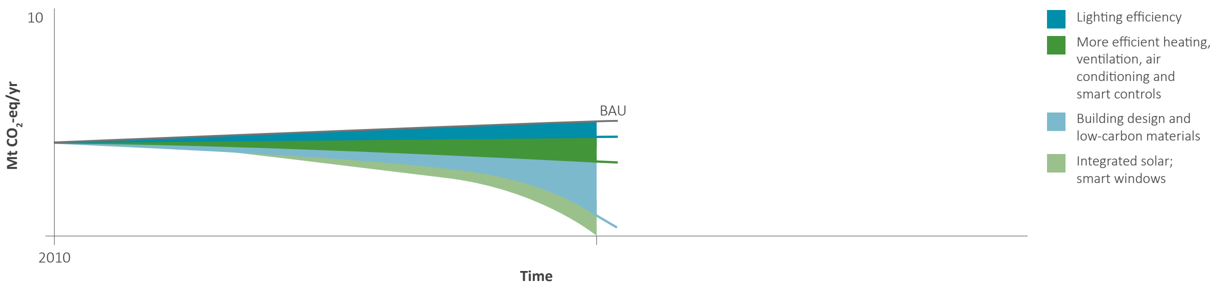
The majority of buildings that will exist in New Zealand by 2050 have already been built. Therefore improving the energy efficiency performance of the current building stock by retro-fitting is an important action. Energy efficiency benefits in building design and use are included in the NZ Building Code clause on Energy Efficiency but this is weak and gives only minimum requirements. Instruments such as *Greenstar Buildings* and the Green Building Council's *NABERSNZ*[2] rating can drive greater GHG emission reductions.

Instruments to help us do this are currently available, but for only a limited range of building types. Therefore, improving the energy efficiency performance of many buildings is partly constrained by their original design.

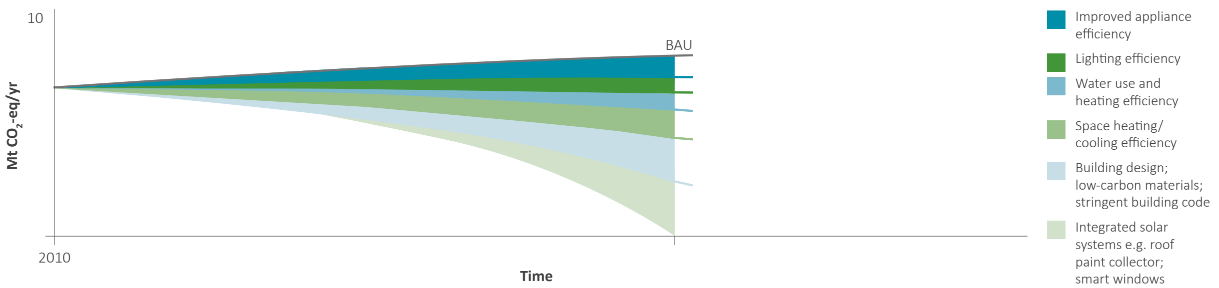
Appliances have a shorter life than buildings but often continue to consume energy 15 to 20 years after purchase. The application of minimum energy performance standards (MEPS) have helped remove the most energy inefficient appliances from the market. '*Doing better*' type labels such as *EnergyStar* can help encourage manufacturers to design, import and supply more efficient appliances.

While technological improvements are important, education and training for those designing, manufacturing, installing and using buildings are also key to reducing GHG emissions. There is limited up-to-date knowledge about how energy is used in buildings and this also needs to be addressed if this sector is to play a greater mitigation role.

Commercial buildings
Zero emissions by medium to long term



Residential buildings
Zero emissions by longer term



2 http://www.nzgbc.org.nz/

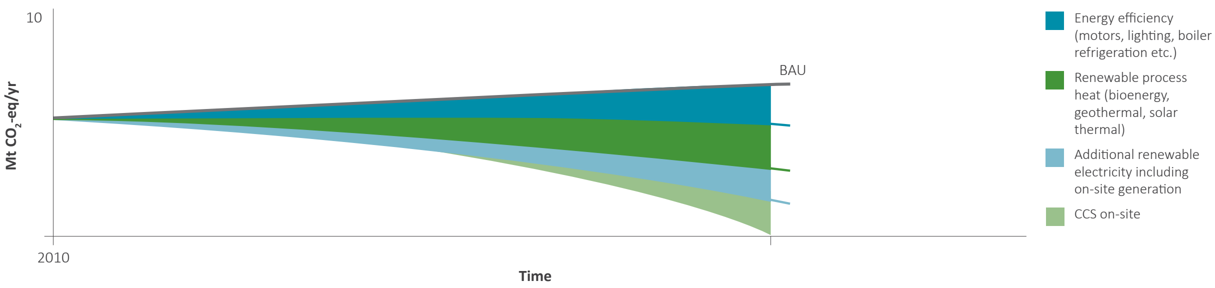
Industry

The industrial sector directly produces 6.3% of our gross emissions mainly from cement and steel manufacture and minor contributions from HFCs used for solvents and refrigerants. A similar amount of indirect emissions comes from the electricity consumed by industry plus fossil fuel combustion to raise process heat (with around 45% of that coming from coal). As outlined in the *'Heat supply'* section above, there are few technology barriers to the greater use of renewable heat energy, but there may be concerns by businesses over security of supply unless the biomass feedstock is produced on-site. Municipal sewage and landfill wastes can provide economic bioenergy opportunities and also reduce CH_4 emissions.

Industries that have large single point sources of emissions have the opportunity to consider CCS once the technology is proven but the cost-effectiveness will be based on the future carbon price as well as the availability of suitable CO^2 storage facilities close to the emitters. In addition, on-site bioenergy heat and power generation can potentially be linked with CCS (known as BECCS) that can physically remove CO^2 from the atmosphere. BECCS will be needed globally before the end of this century in order to constrain global temperature rise to below 2°C.

Industry

Zero emissions by longer term



Agriculture

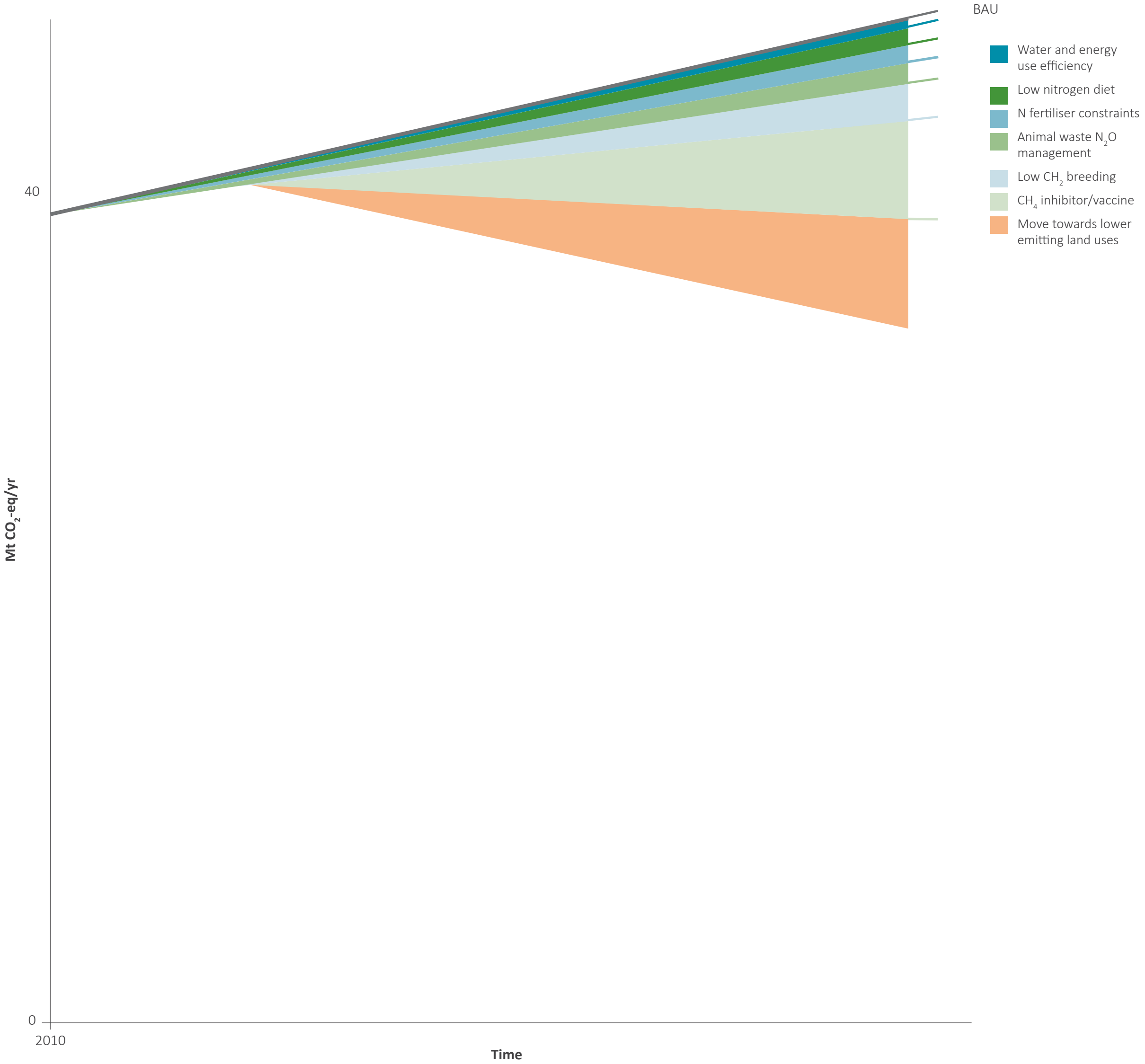
Direct emissions from agriculture make up almost half of New Zealand's gross GHG emissions. These are mainly CH_4 emissions from ruminant animals, N_2O from animal wastes, with CO_2 emissions related to energy demand on farms for electricity, greenhouse heating, crop drying, tractor fuels, water pumping etc. being relatively small.

On-farm GHG emissions per unit of farm product (emissions intensity) have fallen consistently over the past two decades owing to increased productivity per animal or per hectare. Nonetheless, absolute agricultural emissions have grown because of an increase in total production, mainly of dairy products in response to growing global demand. Further productivity gains are feasible and would reduce emissions intensity further, but absolute emissions are expected to rise in the longer term as the sector expands in response to continued global demand and in the absence of significant policy change or sustained depression of commodity prices.

While a range of mitigation options already exists within current farm systems, including utilising local renewable energy resources, they tend to focus on increasing adoption of best practices relating to increasing the productivity per animal and overall efficiency of farm systems. However, these mostly only produce small emission reductions over and above those that would have occurred under business as usual (BAU) in any case. Some mitigation options could have significant additional benefits such as improved water quality, particularly reductions in fertiliser use per animal or utilisation of lower nitrogen feeds, and reduced water use through precision irrigation.

Agriculture

Zero emissions not considered possible even in the long term especially for livestock based systems.



Research and investment in new agricultural mitigation technologies offer the potential for significant emission reductions in the medium to long term. However, even when such technologies are developed successfully and deployed widely, it appears that it will be very difficult to reduce absolute on-farm emissions below roughly 1990 levels based on projected production growth trends. Exploration of alternative land-uses, taking into account climate and carbon constraints as well as other economic, social and environmental objectives, would be needed if New Zealand wished to eventually reduce total agricultural emissions to well below 1990 levels in the next few decades.

Forests and other land-use

Planting new forests in unforested land is a practical method to remove large volumes of CO_2 from the atmosphere at a relatively low cost and thereby offset a portion of New Zealand's gross GHG emissions. Other mitigation actions include reducing deforestation, altering the species grown to faster growing species, and enhancing the carbon stocks of natural forests through improved management.

Since trees accumulate and store carbon over their life, forest sinks are an easily implemented means of offsetting future emissions of CO_2 from the combustion of fossil fuels and other GHGs. This is an effective strategy in the short to medium term whilst other sectors take time to deploy new, and possibly disruptive, low-carbon technologies.

Together, plantation forests and regenerating natural forests in New Zealand offset 29.1 Mt CO_2-eq per year, on average, over the period 1990-2013, equivalent to more than one third ofour annual gross GHG emissions. Around 600,000 ha of pasture and scrub land planted in fast-growing forests post-1989, (with the annual area planted peaking in the mid-1990s), played a significant role in reducing New Zealand's net GHG emissions under the Kyoto Protocol.

These 'Kyoto forests' averaged removals of 14.3 Mt CO_2 per year over the first Kyoto commitment period 2008-2012. Therefore, endeavouring to plant more forests in future would gain further CO_2 removals and, if planted into marginal hill country, also reduce erosion. Planting additional pasture or scrub land in forests (afforestation), or allowing native forests to regenerate naturally (reforestation) should be part of a strategy to achieving a low-carbon future and would allow New Zealand to reach its mitigation reduction target earlier. However, it should not be viewed as a means of avoiding implementation of GHG emission mitigation actions and there are limits from continuing afforestation due to the limited availability of suitable land. Hence the long-term mitigation potential from planting more forest stands is uncertain.

Reporting rules for forest and land use under the United Nations Framework Convention on Climate Change (UNFCCC) govern the estimates of carbon stock changes, whereas accounting rules as used in the NZ ETS define eligible mitigation actions.. Recent forest planting rates in New Zealand have been too small to significantly offset future CO^2 emissions. Our total net GHG emissions will increase as existing post-1989 forests mature and are harvested over the next decade under Kyoto accounting rules.

Planted forests can also support ecosystems by contributing to improved water quality and erosion control when planted on marginal land, and forest residues can provide a significant biomass feedstock.

Soil carbon contents vary with land use change between pasture and forests, but they are difficult to assess and are not always easily accounted for as a carbon sink or source. Soil carbon has shown different trends in grazed flat land and hill country, but there is insufficient evidence to demonstrate a significant overall trend of soil carbon storage in New Zealand's pastoral land, including from adding biochar (charcoal produced from plant matter and then stored in soil).

Behavioural and policy mitigation options

Reducing emissions and creating a low-carbon economy will involve changes in behaviour across all sectors of society, from families and communities to businesses and government, and will require a carefully developed programme to support these changes. The social and technological changes required are significant. Increasing people's knowledge and understanding of climate change is important, but is only part of the behaviour change solution.

Policies, infrastructure and social norms all need to align to make it easier for people and organisations to consistently make low-carbon choices. To be successful, behaviour change initiatives should be coordinated across sectors and domains; target social and material contexts, not just individuals; and communicate additional benefits. In performing its leadership role, the government could consider how to develop climate change policy most effectively by involving New Zealanders, our organisations, businesses and councils.

New Zealand has committed to a range of emissions targets for 2020, 2030 and 2050 but there is no publically available information as to how those targets are intended to be met, the relative contributions anticipated from different sectors, and the reliance on international carbon markets versus domestic abatement. It is important that actions and measures are put in place to ensure that the mitigation targets, as set, are ultimately reached.

Whether we achieve these goals or not will depend on how effective the policies are and on widespread acceptance of the need to change from BAU to a new low-carbon pathway. New procedures, strategies and action plans, and new institutions such as independent monitoring and advisory committees, may help ensure climate change policy-making is effective. Businesses prefer a stable regulatory environment, so clear and consistent messaging regarding low-carbon expectations is critical. Public debate could be better informed by providing information about the strengths and weaknesses of the different policy options.

The current policy approach aims to meet emission reduction targets by relying on the New Zealand Emission Trading Scheme (ETS) where it is cost effective to do so relative to purchasing carbon credits from a range of overseas sources. This approach allows emissions prices to create market drivers for making trade-offs. As a result, our Kyoto target to be below 1990 emission levels on average over the first commitment period from 2008 to 2012 was largely met through CO_2 removals via forest sinks and from purchasing international emissions trading units. Some of these units have had low credibility internationally and, since 2015, the NZ ETS no longer involves international units.

The effectiveness of the NZ ETS in reducing actual domestic emissions has been limited, although it has served to raise the awareness of the need for GHG accounting and the importance of reducing emissions.

Few regulatory measures that are common overseas to reduce GHGs exist in New Zealand, such as motor vehicle fuel efficiency standards, mandatory biofuel requirements, green taxes, or renewable and energy efficiency portfolio standards. New policy provisions are needed alongside the ETS to support change in areas in which the market acts imperfectly to add to the few climate policy measures in place that include supporting research and providing consumers with information.

Global context

The globe has warmed by around 1 °C since pre-industrial times and this is already having impacts including more extreme weather events, ocean acidification and sea level rise. To succeed in limiting global warming to below 2 °C, the world needs to reduce current annual global GHG emissions by 40-70% below 2010 levels in the next 30 to 40 years and with net emissions of long-lived GHGs (especially CO_2) approaching zero before the end of this century. This will require significant actions by all countries including phasing out the use of fossil fuels (unless linked with CCS) and the greater use of biomass and bioenergy to actively remove CO_2 from the atmosphere, thereby ultimately reaching net zero emissions of CO_2.

The 2015 Paris Agreement was a significant step forward to achieving a low-carbon future and reflects a growing global concern for climate action. The growing global movement, as expressed outside of the negotiation rooms by businesses, cities, financiers, bankers, and other institutions, has continued. Setting emissions targets will require nations to make ethical judgements while considering the economic, social and environmental consequences. However, the intended targets to reduce GHG emissions, which nations set for themselves prior to the Paris meeting and then submitted to the UNFCCC[3], when accumulated, imply higher costs in the long term as they would then require extremely rapid and much more costly reductions beyond 2030 to limit warming to below 2°C. Therefore, the Agreement enables and encourages countries to strengthen their nationally determined contributions (NDCs) before they ratify the Agreement in the next few years and to prepare and maintain even more ambitious targets by 2020 and onwards.

In the global context, all nations are expected to take responsibility for what are likely to be increasingly stringent expectations of emissions reductions. New Zealand has signed the Paris Agreement and already made some commitments to emissions reduction, indicating its intention to make the transition to a low-carbon economy and be a part of the world's endeavours to decarbonise, as driven by the d post-Agreement negotiations.

3 http://newsroom.unfccc.int/

Knowledge gaps

Publicly available data for producing emission and mitigation pathways for New Zealand are extremely limited and this has hampered the analysis conducted in this study. This included limited available data on the costs and potentials of climate change mitigation options. These are needed for analysing GHG mitigation options in most New Zealand sectors. Due to the time and resource constraints of this study, it was not possible to undertake scenario modelling, life cycle assessments, nor sensitivity analyses of major uncertainties such as future energy costs, carbon prices, rate of uptake of low-carbon technologies and systems, behavioural change, policy interventions etc.

Models, tools and analytical methods developed and used overseas for other emission reduction pathways could be employed for assessing New Zealand's climate change mitigation options, but need time and resources to adapt them to suit local conditions. Investment in data gathering and analysis, possibly involving international collaboration, could help refine early mitigation actions and thereby enable a transparent public debate to be had about desirable and feasible mitigation pathways.

Detailed integrated assessment modelling would help test the wide range of assumptions being used to evaluate possible pathways to reach a low-carbon economy. Even so, great uncertainties would remain since the rate of uptake of disruptive technologies is not possible to predict with any degree of accuracy in a scenario modelling study. For example, *airbnb*, and Uber taxi services have become common far more quickly than many people predicted and no global or national scenarios produced only 15 to 20 years ago included the present impacts of the internet and social media on people's lifestyles.

Accumulating more scientific knowledge takes time, but meanwhile our GHGs continue to increase. The need to obtain more scientific knowledge should not be a reason to delay mitigation actions, especially if a lack of action would mean deeper cuts in GHG emissions in the future that would be harder to achieve. Long-lived GHGs such as CO_2 accumulate in the atmosphere so reducing or capturing emissions as soon as possible is preferable to waiting for future advancements.

In summary

Many mitigation options are already well-understood and achievable. New Zealand's current target is to reduce emissions to 30% below 2005 levels by 2030. If we want to achieve this target through increased contributions from domestic actions rather than relying on reductions off-shore and purchasing the related carbon credits, this will require immediate attention.

Accumulating more scientific knowledge takes time, but meanwhile our GHGs continue to increase. The need to obtain more scientific knowledge should not be a reason to delay mitigation actions, especially if a lack of action would mean deeper cuts in GHG emissions in the future that would be harder to achieve. Long-lived GHGs such as CO2 accumulate in the atmosphere so reducing or capturing emissions as soon as possible is preferable to waiting for future advancements.

Section 1: Introduction

GHG emitting human activities over the past two centuries, including from the combustion of large amounts of fossil fuels and deforestation, have resulted in changes to the climate. This is starting to have widespread impacts on human and natural systems including water supplies and food production (IPCC, 2014a).

The Intergovernmental Panel on Climate Change succinctly summarised current knowledge on climate change in four headline statements (IPCC, 2014a):

- Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases (GHGs) are the highest in history. Recent climate changes have had widespread impacts on human and natural systems.
- Continued emission of GHGs will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in GHG emissions which, together with adaptation, can limit climate change risks.
- Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change. Substantial emission reductions over the next few decades can reduce climate risks in the 21st century and beyond; increase prospects for effective adaptation; reduce the costs and challenges of mitigation in the longer term; and contribute to climate-resilient pathways for sustainable development.
- Many adaptation and mitigation options can help reduce the risks from climate change impacts, but no single option is sufficient by itself. Effective implementation depends on policies and cooperation at all scales and can be enhanced through integrated responses that link adaptation and mitigation with other societal objectives.

These global challenges and opportunities provide the context for this report. All indications are that, if the world wishes to limit warming to below 2°C, we must change our current development trajectories as soon as possible and without impacting on future well-being. A rapid gain in momentum is needed if the world is to reach zero-carbon emissions before the end of this century.

New Zealand has the opportunity to reduce its GHG emissions by undertaking climate change mitigation actions. These can start immediately and continue over the next few decades. There are costs and risks involved, but there are also various co-benefits that can be identified from a transition to a low-carbon economy. The Royal Society of New Zealand's emerging issues report in 2014, *'Facing the Future – Towards a Green Economy for New Zealand'* provided a broad overview of the potential benefits, including this summary statement on climate change:

'Lowering greenhouse gas emissions will require changes in patterns of production and consumption, but need not reduce well-being.'

This current study provides a detailed assessment of the numerous mitigation actions that exist to lower our GHG emissions over the next few decades but starting now.

Definitions

Adaptation involves responding to and coping with climate change as it occurs.

Carbon dioxide equivalent (CO_2 -eq) is a standard unit for measuring carbon footprints, expressing the impact of each different greenhouse gas in terms of the amount of CO_2 that would create the same amount of warming.

Carbon sequestration is the capture and storage of carbon by either natural or artificial processes.

Climate-smart agriculture is an approach to managing cropland, livestock, forests and fisheries to increase productivity, enhance resilience and reduce GHG emissions per unit of food produced.

Global warming is the increasing temperature of the earth's climate system and its related effects.

Greenhouse gases (GHG) produced from anthropogenic activities include primarily carbon dioxide, but also methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride.

Low-carbon economy is one that tracks towards reaching net zero GHG emissions, primarily of long-lived CO_2 that makes up three quarters of global GHG emissions.

Mitigation involves a human intervention to reduce the sources or enhance the sinks of GHG emissions, such as through the planting of forests.

The Royal Society of New Zealand's 2016 publication '*Climate Change Implications for New Zealand*' stated that:

"New Zealand's climate is changing. The Australasian region continues to show long-term trends toward higher surface air and sea surface temperatures, more hot extremes and fewer cold extremes, and changed rainfall patterns. Warming is projected to continue through the 21st century along with other changes in climate. Without adaptation, further changes in climate, atmospheric carbon dioxide (CO_2), and ocean acidity are projected to have substantial impacts on water resources, coastal ecosystems, infrastructure, health, agriculture, and biodiversity".

Adaptation, as a response to the actual or potential impacts of climate change, is not discussed in detail in this report. However, it is well understood that, along with taking mitigation measures, it is imperative for our cities, communities, households, and businesses to become more resilient to the inevitable effects of anthropogenic climate change and the unprecedented rate of change, including changing weather patterns, sea level rise, and ocean acidification. Mitigation and adaptation are both essential if we are to reduce overall risks.

Mitigation will not be straightforward. Almost all our everyday activities, from household routines to business and government operations, produce GHGs. Almost half of New Zealand's emissions consist of CO_2 released to the atmosphere during the combustion of coal, natural gas, or oil products (with small amounts arising from geothermal projects and other sources) This supplies us with heat and around 20% of our electricity supply (Section 5.1), together with transport services (Section 5.2). Most heat and electricity is used in our buildings (Section 5.3) and industry (Section 5.4). Smaller volumes of GHG arise from forest clearing and during cement manufacture. Our agricultural sector directly emits mainly methane (CH_4) and nitrous oxide (N_2O) that, together, contribute almost half of our total GHGs (Section 5.5). A portion of our GHG emissions is offset in those land use practices which absorb carbon dioxide into our forests (Section 5.6).

This study reviewed the latest scientific knowledge on climate change mitigation opportunities in New Zealand. It considered what social changes are needed to help us take up these opportunities. It attempted to identify the options available to reduce our GHG emissions and hence do our part in addressing the global challenge of climate change. While people, communities and companies are already taking actions of their own, government actions to make a concerted effort to reduce our GHG emissions will involve political choices from the options available.

On a per capita basis, New Zealanders were the seventh highest net emitters in OECD countries in 2012; 13.26 tonnes of CO_2-eq per capita, if CO_2 removals through land use change and forests are included. For our gross emissions that exclude forest removals, in 2012 we were the fifth highest OECD emitter (17.37 tonnes CO_2-eq per capita) after Australia, Canada, Luxemburg and USA (CAIT, 2015; Section 3.1).

To reduce or eliminate GHG emissions, New Zealand needs to develop a greater understanding of what activities produce GHGs, how we might alter our usual processes and routines, and what new low-carbon technologies we might adopt. The information presented in this report aims to help policymakers make decisions and enable families, businesses and organisations to determine what actions they could take to reduce their ‘carbon footprint’.

A low-carbon future could come at a cost, but also offers significant economic, social and health benefits for New Zealand, particularly if we take actions and collaborations across all sectors. If the world fails to significantly reduce GHG emissions, this will increase the risks and costs of consequential damage and adaptation. At the international level, New Zealand’s previous Minister of Climate Change, the Hon. Tim Groser stated:

“While New Zealand’s emissions are small on a global scale, we are keen to make a fair and ambitious contribution to the international effort to reduce greenhouse gas emissions and avoid the most harmful effects of climate change”[4].

Climate change mitigation involves fundamentally changing our dependence on fossil fuels over the next few decades and modifying some existing consumption patterns. New Zealand has options for mitigation in all sectors, particularly when combining low-carbon technologies that have good economic and market potential[5] with good practices, policy and regulatory changes. However, there are many uncertainties regarding the future rate of uptake of particular options, including how rapidly disruptive technologies may be deployed and what fluctuations there may be in future international and local prices for carbon, oil, gas, coal and our exported food commodities.

The mitigation challenges come with potential benefits for New Zealand but the problem for both individuals and the government is to make investment and regulatory decisions under uncertainty.

- We could invest in mitigation actions in the near future which would possibly maximise co-benefits and hence be more cost-effective than waiting for high carbon prices to materialise.
- We could wait until other countries have acted, which could be argued to be a cheaper option since New Zealand is a technology-taker. However, this option also carries the high risks of loss of international status as well as the inevitable impacts of climate change being felt in the global economy.

In the longer term, investing early in mitigation globally is likely to reduce the cost of adaptation, achieve greater resilience, and reduce the risk of runaway climate change. The whole issue of risk management, adaptive planning and balancing the energy portfolio, in light of New Zealand’s specific circumstances now and in the future, requires additional analysis.

- Behaviour and culture have a considerable influence on mitigation of GHG emissions. The challenge is to find low-carbon development pathways that New Zealanders are willing to adopt and that allow continued socio-economic prosperity whilst supporting a healthy, functioning environment. There is already a strong and growing interest in mitigation actions across New Zealand communities[6], businesses[7] and local governments[8]. Collaborative approaches between local and central government, businesses and civil society will help enable a successful transition to a low-carbon economy.

4 Minister Tim Groser, https://www.beehive.govt.nz/release/climate-change-target-announced

5 The *technical potential* of a technology or system ignores any cost constraints but considers current practical limits to uptake based on climate, engineering, or competition for resources such as land. It can increase over time when technologies using an available resource become operational in future years after the socio-economic conditions change, given certain economic and operating conditions.

The *market or economic potential* for utilising an energy resource is based on current market prices and any policies and measures in place. It is based on private discount rates and all barriers and hidden costs are included.

The *socio-economic or realisable potential* is when uptake of an energy technology is viable or close to becoming viable under current market conditions but with some projects not being implemented due to market barriers, externalities and social costs.

6 See for example http://parihaka.maori.nz/taiepa-tiketike/

7 Sustainable Business Council (http://www.sbc.org.nz)

8 Local Government New Zealand (http://www.lgnz.co.nz/new-zealand-local-government-leaders-join-global-community-to-address-climate-change)

1.1 Report framework

This report identifies that New Zealand has good potential to shift towards a low-carbon economy in innovative ways. These could have positive repercussions including the development of new climate technologies and services for export to the global market. The report covers the global context for GHG emissions and climate change mitigation potentials (Section 2) before outlining emission trends, current actions and policy settings in New Zealand (Section 3). Behavioural issues relating to mitigation are then discussed along with the policy framework and options for policy processes, although the report does not attempt to prescribe policy measures (Section 4). Evaluations of GHG reduction potentials and co-benefits are then given for each of the sectors covered: heat and power supply, passenger and freight transport, commercial and residential buildings, industry, agriculture, forests and other land use (Section 5). Plausible integrated emission reduction pathways are discussed, based on the sectoral assessments (Section 6). Critical knowledge gaps are identified throughout the report. Public and private research investments to fill these gaps could help support and accelerate the pursuit of mitigation development pathways.

No new research was commissioned for this report. The study authors relied largely on key analyses of climate change mitigation recently published in New Zealand[9], and on international studies including the 5th Assessment Mitigation Report of the Intergovernmental Panel on Climate Change (IPCC, 2013; IPCC, 2014a; IPCC, 2014b). The material was assessed and synthesised with regard to the specific New Zealand context and aims to provide science-based information in an accessible manner for the New Zealand public and policy makers.

This scientific assessment on its own cannot determine what New Zealand's future emissions should be in 'doing our fair share', given the relatively small absolute quantity of national emissions and our unusual emissions profile. Deciding on how much and how quickly our emissions should be reduced invariably relies not only on a technical analysis of abatement options and costs, but also on ethical judgements (such as considerations of what is 'right' when contrasted with what results in lowest costs). Emissions abatement options are also based on conjectures about the implications if New Zealand fails to do what others would have considered its fair share and the potential indirect economic, social and environmental consequences of our actions. This report makes no judgement on those matters, but limits itself to presenting the current scientific knowledge to better inform a public discussion.

- The transition to a low-carbon economy will need to extend far beyond technical solutions and will require political will and political leadership to alter aspects of New Zealand's regulatory, economic and infrastructural frameworks. Such a transition can only succeed if it is a collaborative approach that gains broad support from a majority of the population and key stakeholders including public and private sector decision-makers.
- Gaining the opportunities as offered by the transition to a low-carbon economy for New Zealand will require a much improved information base to better manage risks. Currently, the publically available evidence for mitigation pathways for New Zealand is extremely limited and the analysis conducted in this study was constrained as a result. Investment in data gathering and more detailed analysis, possibly involving international collaboration, will help refine early mitigation actions. Improved data availability will also give supporting evidence for a transparent public debate to be undertaken about desirable and feasible mitigation pathways.

9 Examples include the work of Motu (http://www.motu.org.nz/our-work/environment-and-resources/emission-mitigation/) and Business NZ Energy Council (http://www.bec.org.nz/projects/bec2050).

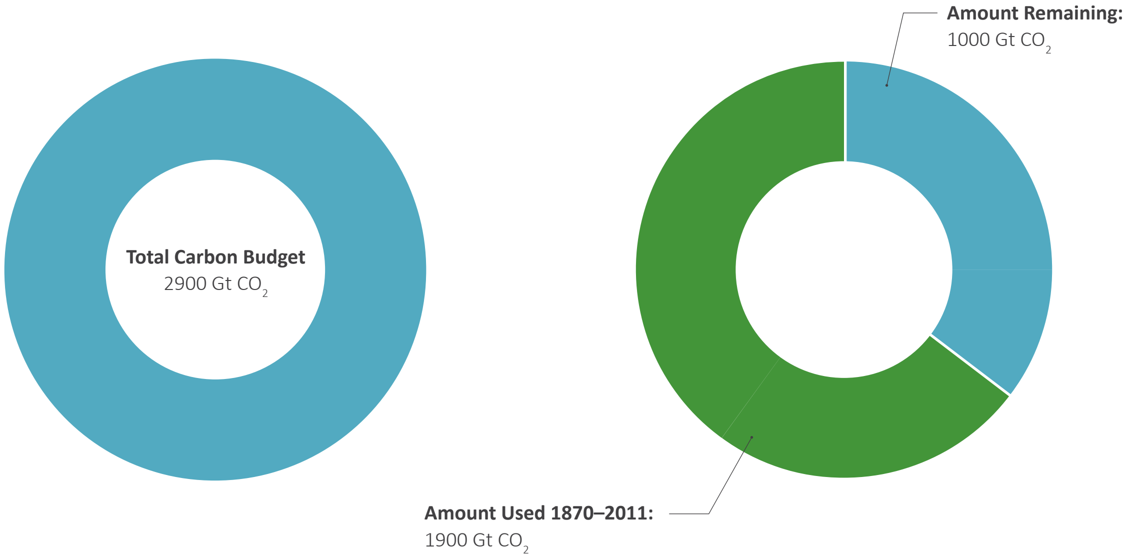
Section 2: Global context

The 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has made it clear that human influence has already impacted on the Earth's climate system. The IPCC calculated that if the world is to stay below the 2oC level, then only 2,900 Gt (billion tonnes) of CO_2 in total can be emitted to the atmosphere. Around two thirds of this total carbon budget has already been released from the combustion of fossil fuels and through deforestation over the past 150 years. If under business-as-usual the world continues to burn coal, oil and gas and does not slow deforestation, then the remaining one third of the total CO_2 budget will be released in less than 15–20 years.

Key messages

- Global GHG emissions continue to rise in spite of all the new technologies being used, policies being implemented, or changes made to the way we act worldwide to reduce energy demand.
- The world is currently heading towards a 3–4 °C temperature rise that will significantly increase the likelihood of accelerated sea level rise, more frequent extreme weather events, and higher costs to adapt or protect ourselves.
- To succeed in limiting global warming to below 2°C the world needs to reduce current annual global GHG emissions by 40–70% below 1990 levels by 2050. This will require significant action including phasing out a major portion of CO_2 emissions from the use of fossil fuels over the next few decades and implementing stringent mitigation policies.
- The 2015 Paris Climate Agreement was a significant step forward, but the initial targets which nations set to reduce GHG emissions will be insufficient to limit warming to below 2°C. Hence, the Agreement enables and encourages countries to strengthen their nationally determined contributions (NDCs) and target before they ratify it in the next few years and every five years subsequently.
- Setting emissions targets like the NDCs will require nations to make ethical judgements while considering economic, social and environmental consequences.

Figure 2.1 Around 1,900 Gt CO_2 of the total budget of 2,900 Gt CO_2 of anthropogenic CO_2 emissions that can be emitted into the atmosphere in order to keep below the agreed 2°C temperature rise target, has already been released.



Source: IPCC (2013).

In order to avoid increasing the unmanageable risks from climate change, world citizens and businesses will have to move away from fossil fuel dependence under BAU. IPCC scenarios show that to have a likely chance of limiting the increase in global mean temperature to below 2°C, means lowering global annual GHG emissions by 40 to 70 % below 2010 levels by 2050, and to near-zero before 2100 (IPCC, 2014b)[10]. A critical component of mitigation actions is to reduce the emissions of long-lived CO_2 to, or even below, zero before the end of this century.

Reducing emissions of non-CO_2 gases is also an important element of mitigation strategies. It is not imperative that short-lived GHGs such as CH_4 are reduced to zero although all GHG emissions and other forcing agents such as black carbon will affect the rate and magnitude of climate change over the next few decades, (IPCC, 2014a). Debate is continuing on the best metrics for trading off actions on different gases based on prioritising these actions, value judgements, and, most critically, depending on climate policy objectives (IPCC, 2009; Harmsen *et al.,* 2016).

Calculations of the economic costs of mitigation vary widely due to different assumptions made about key future uncertainties. Several of the more ambitious scenarios show the projected global BAU consumption growth of between 1.6 to 3% per year would be reduced by around 0.06 percentage points per year if effective climate policies were implemented promptly by most countries (IPCC, 2014b). This slight slowing of the consumption growth rate will deliver overall economic benefits resulting from reduced climate change impacts as well as from any resulting co-benefits such as improved health.

This report endeavours to address the potential to instigate a broad range of technological developments and changes in behaviour from the New Zealand perspective in order to equitably contribute to reducing climate risks through reducing global GHG emissions. However, achieving the necessary emission reductions may also need to involve major changes at the national level (Box 2.1).

10 http://www.ipcc.ch/pdf/ar5/pr_wg3/20140413_pr_pc_wg3_en.pdf

Feasible mitigation policies, practices and technologies with high-potential for low-carbon policy options are outlined in the UNFCCC (2015a) report '*Climate Action Now*' that aims to support policymakers in implementing current and future mitigation actions in the pre-2020 period. The report highlights effective approaches to rapidly reduce GHG emissions that could be considered in New Zealand. Key messages include:

- Enhanced action is urgently needed as current pre-2020 emission reduction pledges fall short of the 2°C – compatible emissions trajectory.
- Solutions to limit warming to 2°C exist with a wide range of policies, measures and actions already in place that can be replicated by other countries wishing to increase the ambition of their mitigation efforts.
- Leadership and willingness to act are required to overcome financial, technological and capacity-related barriers to mitigation action. Cooperative initiatives are essential to mobilize climate action across a range of stakeholders and need to be further promoted.
- Co-benefits can be gained in other economic, social and environmental areas.

2.1 Co-benefits

Climate mitigation options can intersect with other societal goals, create the possibility of resulting co-benefits, and hence strengthen the rationale for undertaking climate actions (IPCC, 2014a). Co-benefits vary with the specific circumstances but can include improved human health and livelihoods, greater food security, increased business viability, new business opportunities, enhanced biodiversity, better local air and water quality, greater energy access and security, and more equitable sustainable development.

IPCC mitigation scenarios showed reduced costs for achieving air quality and energy security objectives with additional benefits for human health, ecosystem impacts, sufficiency of resources for energy supply systems to meet national demands, and their resilience to price volatility and supply disruptions. However, depending on the specific circumstances, there could be a wide range of other possible side-effects and spillovers resulting from mitigation measures, such as on biodiversity conservation, water availability, food security, efficiency of the taxation system, employment, and income distribution, that have not been well quantified (IPCC 2014b). Section 5 covers mitigation options for specific sectors, including discussions on co-benefits.

Box 2.1

The following statements from the IPCC Synthesis Report (2014a), concerning climate change mitigation measures to reduce GHG emissions at the global level, relate to actions that can be taken at the national level.

"Mitigation options are available in every major sector. Mitigation can be more cost-effective if using an integrated approach that combines measures to reduce energy use and the GHG intensity of end-use sectors, decarbonise energy supply, reduce net emissions, and enhance carbon sinks in land-based sectors".

"Adaptation and mitigation responses are underpinned by common enabling factors. These include effective institutions and governance, innovation and investments in environmentally sound technologies and infrastructure, sustainable livelihoods and behavioural and lifestyle choices".

"There are many opportunities to link mitigation, adaptation and the pursuit of other societal objectives through integrated responses (high confidence). Effective adaptation and mitigation responses will depend on policies and measures across multiple scales: international, regional, national and sub-national".

2.2 UNFCCC 21st Conference of Parties, Paris, December 2015

During 2015, for the first time ever, 195 national governments met and pledged to reduce or control their national GHG emissions between 2020 and 2030[11]. Their collective aim is to limit the future mean global annual temperature rise to well below 2°C above the pre-industrial level, and thereby constrain future impacts of climate change on current and future generations, as well as on ecosystems.

Each country was asked to produce an *Intended Nationally Determined Contribution* (INDC), outlining its intended mitigation actions. However, based on the latest IPCC science assessment (IPCC, 2014a), the Paris Agreement recognised that the INDCs, as submitted by countries prior to the Paris 21st Conference of Parties, are collectively inadequate to meet the desired goal of below 2°C. Many of the INDCs have conditions imposed, such as no action occurring without finance being forthcoming, or support for technology transfer, or, in New Zealand's case, international acceptance of carbon markets and forest sinks. New Zealand has now signed the Paris Agreement on 22 April 2016, so the next step is to ratify it.

The total emission reductions, as pledged in the INDCs, will together result in annual total GHG emissions increasing through to the period 2025 to 2030 before possibly peaking soon after. This implies that parties will need to strengthen their mitigation targets over following decades so that GHG emissions will rapidly decline at unprecedented rates over the following decades (Box 2.2 and Figure 2.2). Given the overall goal to optimise the social, environmental, and economic values of living with a GHG emission constraint in an uncertain world, a thorough understanding of the trade-offs and complexities is needed.

Given the financing constraints of concern for many developing countries and the complexities of the negotiations, the Paris Agreement was a major step forward. The range of INDC emission reductions submitted would limit the on-going increase in annual global emissions to 2.7–3°C[12] This is below that based on pledges made in 2010 at COP 16 in Cancun, Mexico. However, much more needs to be achieved beyond 2030 if the world is to limit the increase in mean global temperature to below 2°C (or achieve the more ambitious 1.5°C target)[13].

This will entail reducing net CO_2 emissions to zero, including the removal of CO_2 directly from the atmosphere or seeking other forms of geo-engineering, and accepting the costs and risks entailed. In essence, continuing with the current rate of reduction of global carbon intensity by 1.3% per year on average, as occurred from 2000–2014, will result in emitting the remaining 1000 Gt CO_2 allowed to avoid exceeding 2 °C (Figure. 2.1) by around 2036[14]. This decarbonisation rate will have to be increased five-fold, on average, for every year until 2100 to avoid exceeding the 2 °C level (PWC, 2015).

11 This was the outcome negotiated by the 195 countries that attended the UNFCCC 21st Conference of Parties held in Paris, France in December 2015. The proposed text, yet to be ratified, can be found at http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

12 Synthesis report on the aggregate effects on INDCs (though this presents emission levels rather than making judgements on temperature outcomes) http://unfccc.int/focus/indc_portal/items/9240.php

13 *Towards a Workable and Effective Climate Regime* http://www.voxeu.org/sites/default/files/image/FromMay2014/Climate%20change%20book%20for%20web.pdf

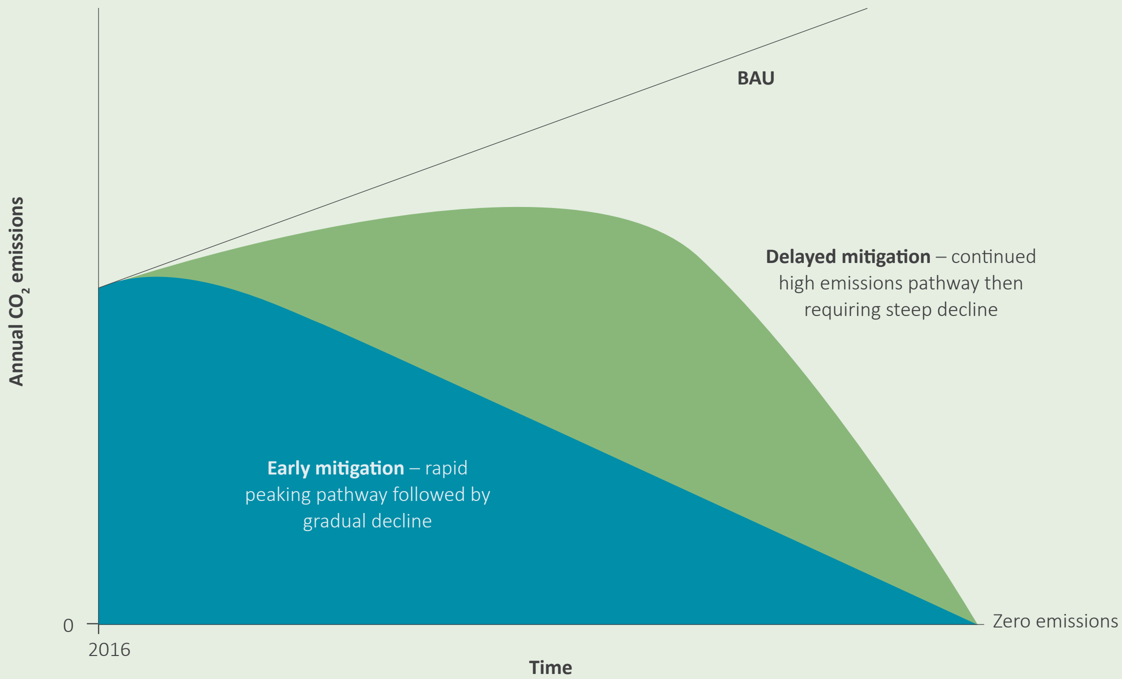
14 To avoid exceeding 1.5°C, only around 500 Gt CO_2 can be emitted which is likely to be rapidly used up given many major developing countries only intend to peak their GHG emissions by 2030 at the earliest.

Box 2.2

Delaying CO_2 mitigation actions can result in higher overall societal costs and greater emissions to the atmosphere that cannot be compensated for by a more rapid reduction in the future.

Climate change is related mainly to cumulative emissions of CO_2, a gas with a relatively long-life, as a fraction of today's emissions will remain in the atmosphere for between hundreds and thousands of years. This implies an unequivocal need for net annual global CO_2 emissions to ultimately decline to zero[15] if climate change is to be halted at any level. Both the time by when emissions decline to zero, and the pathway below the business as usual trajectory (BAU) taken to achieve this, will influence how much warming occurs.

A delayed mitigation pathway that continues with high annual CO_2 emissions for several years, followed by a rapid decline in the future to reach zero emissions, will contribute more warming than would an early mitigation pathway, with earlier peaking of emissions followed by a more gradual reduction over time, to reach zero emissions that same year.[16] In other words, a near-term delay in reducing annual CO_2 emissions cannot be compensated for by more rapid reductions undertaken later unless the delayed mitigation pathway becomes so steep that zero emissions are achieved sooner.[17] Hence, urgent mitigation actions at the global, national, local and personal levels would avoid higher future costs from more extreme weather impacts and adaptation.



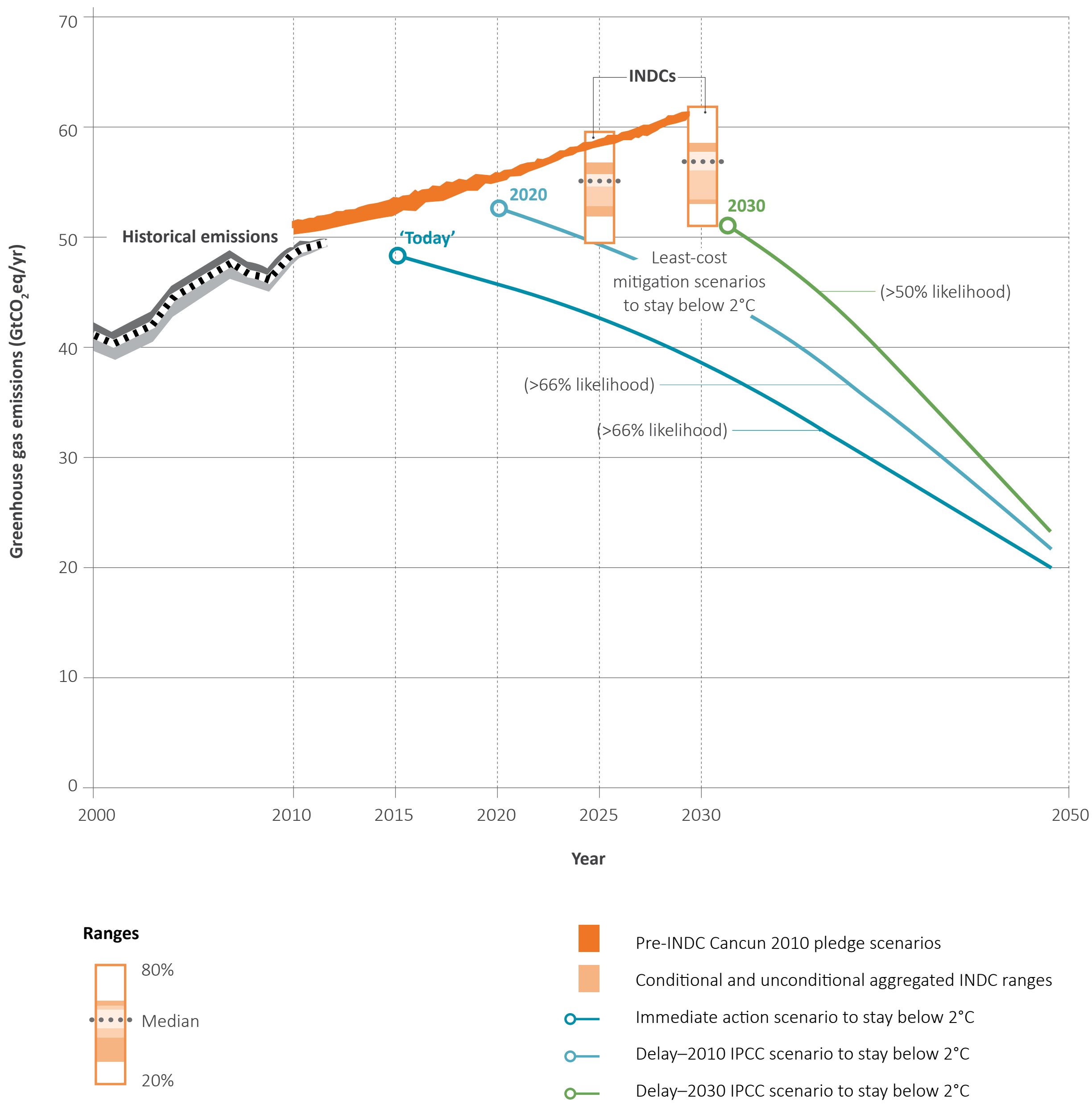
Two possible emission pathways to reach zero annual CO^2 emissions at the same point of time in the future. The delayed mitigation pathway results in around double the total CO^2 emissions over the period, and hence greater warming, than the early mitigation pathway, even though they both end up with zero emissions at the same time.

15 Note that many mitigation scenarios also highlight the need to reach *below zero* CO_2 emissions before the end of this century by, for example, pulling CO_2 out of the atmosphere through bioenergy linked with CCS (IPCC, 2014b),

16 The total area beneath each of the two pathway curves depicts the total emissions over time, the rapid peaking option having around half of the total emissions of the later peaking continued high emissions pathway.

17 Note that this does not apply to the same degree to other GHGs with a much shorter lifetime than CO_2 such as methane (Section 5.5).

Figure 2.2 Based on the submitted INDCs, the projected global GHG emission reduction ranges in 2025 and 2030 (orange boxes) have medians lower than the national pledges made at COP 16 in Cancun in 2010 (orange line), but are still insufficient to keep the temperature rise below 2°C target without a subsequent steep and rapid emission reduction (shown by the simplified blue and green pathways based on IPCC least cost scenarios).



Source: Based on UNFCCC, 2015a.

Decision 1.CO/21 set conditions to the adoption of the Paris climate Agreement (2015) that consists of 29 Articles of which Articles 2 and 4 have direct impact on New Zealand's policies and actions (Box 2.3).

Box 2.3: The Paris Agreement

The following statements, extracted from the Paris Agreement with minor editing, are compiled here to show the impact that the Agreement is likely to have on New Zealand's policies and actions.

- This Agreement aims to strengthen the global response to the threat of climate change by holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change. (Article 2, 1a).
- In order to achieve this long-term temperature goal, Parties aim to reach global peaking of GHG emissions as soon as possible and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty. (Article 4, 1).
- Requests those Parties whose INDC contains a time frame up to 2030 to communicate or update by 2020 these contributions and to do so every five years. (Decision 1./CP21, 24; Article 4, 9).
- Each Party shall prepare, communicate and maintain successive Nationally Determined Contributions (NDCs) that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions. (Article 4, 2).
- Each Party's successive NDC will represent a progression beyond the Party's then current NDC and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities in the light of different national circumstances. (Article 4, 3).
- Invites Parties to communicate by 2020 their mid-century, long-term low GHG emission development strategies (in accordance with Article 4, 19) and requests the secretariat to publish on the UNFCCC website the Parties' low GHG emission development strategies as communicated. (Decision 1./CP21, 36).
- All Parties should strive to formulate and communicate long-term low GHG emission development strategies, mindful of Article 2 taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances. (Article 4, 19).
- Decides to convene a facilitative dialogue among Parties in 2018 to take stock of the collective efforts of Parties in relation to progress towards the long-term goal (Article 4, 1) and to inform the preparation of NDCs (Decision 1./CP21, 20).
- In communicating their NDCs, all Parties shall provide the information necessary for clarity, transparency and understanding in accordance with Decision 1./CP.21 and any relevant decisions of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement. (Article 4, 8).

Fossil fuel subsidy reforms were not included in the Paris Agreement but, nevertheless, are gaining international traction to remove both consumption and production subsidies. IEA analysis has identified the 'absurd situation' of opposite forces at work in the global energy economy: where subsidies for the use of fossil fuels are employed, globally they equate to an average of around US$110 /t C emitted whereas the carbon price in Europe to avoid emissions is approximately US$10 /t C[18]. At present, the G7 countries[19] plus Australia invest around forty times more in fossil fuel subsidies (approximately US$ 80 billion/yr) than their total contribution to the Green Climate Fund (GCF)[20] (Turnbull, 2015). New Zealand presented a *Friends of Fossil Fuel Subsidy Reform* communiqué[21] from 40 countries at the Paris COP 21 and also participated in an APEC peer review process of fossil fuel subsidy reform in March 2015. It concluded that none of the four production subsidies or two consumption subsidies currently in place in New Zealand were 'inefficient subsidies that encourage wasteful consumption of fossil fuels'[22].

The GCF was established in 2009 with the aim for richer countries to help support poorer countries meet their mitigation and adaptation goals by committing US$100 billion per year by 2020. Before Paris, the GCF had funded its initial projects selected, but had only received commitments of around US$10 billion. Therefore, 'financing' was a key discussion point in the Paris negotiations, especially given that many of the INDCs are conditional on support from the GCF. Together INDCs will require a cumulative investment from 2015 until 2030 of around US$13.5 trillion to support low carbon technologies, energy efficiency (IEA, 2015a) and adaptation actions.

Not explicitly covered in the Paris Agreement, although discussed at length during the negotiations and at various side-events, were emissions from international aviation and shipping. Steady progress has been made by the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO)). Further work is being undertaken which, no doubt, will have impacts for New Zealand given our isolation, increasing tourism numbers (Section 4.6), and high-volume exports.

The Paris Agreement was opened for signature by Parties from 22 April 2016 with ratification any time after they sign[23]. An INDC will become a *Nationally Determined Contribution* (NDC) when the party ratifies. Strengthening an INDC before ratification is explicitly encouraged. The NDCs will cover the period 2021–30, with most parties having specified either 2025 or 2030 as their target year. The Agreement will come into force when 55 parties comprising at least 55% of total global annual emissions have ratified. Under the Agreement, countries are obliged to declare, communicate and maintain targets although modalities of the compliance mechanism have yet to be negotiated. The Paris Agreement is therefore not so much a conclusion as the beginning of a new phase of international efforts that will engage New Zealand and other parties in cooperation and negotiation for a long time into the future.

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18 https://www.iisd.org/GSI/news/fossil-fuel-subsidy-reform-big-climate-talks-and-agreement

19 The Group of 7 (G7) is a group consisting of Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

20 New Zealand has contributed NZ$3 million to the GCF, far less than the approximately NZ$80 million NZ has invested to subsidise oil and gas exploration. The New Zealand contribution to the GCF equates to around US$0.37/capita compared with the UK contribution of US$18.47/capita and the US of US$9.41/capita. However, New Zealand has also committed NZ$50 M/yr for 4 years to support South Pacific countries. Together that equates to around US$7.40/capita.

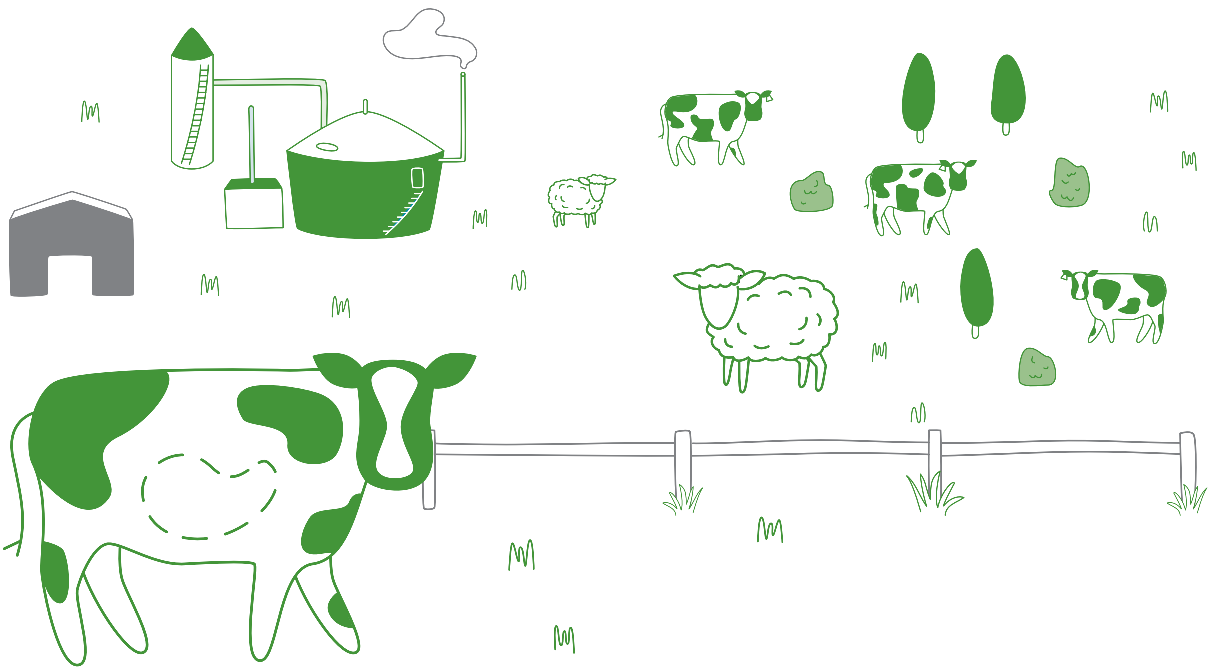
21 http://fffsr.org/communique/

22 http://www.mbie.govt.nz/info-services/sectors-industries/energy/international-relationships/pdf-document-library/peer-review-fossil-fuel-subsidy-reforms-nz.pdf

23 Parties that don't sign before 21 April 2017 will not have the option of the "sign then later ratify" process and can only accede (having the same legal effect as ratifying).

Section 3: New Zealand's emissions and trends

New Zealand's total annual greenhouse gas emissions are projected to continue to steadily increase under business-as-usual over the next one to two decades. On a per capita basis, our emissions are well above the global average. Around half the total emissions consist of CO_2 from fossil fuel combustion with the other half being mainly methane and nitrous oxide from agriculture. Both energy intensity and emission intensity per unit of GDP have followed the global trend and declined since 1990.



Key messages

- New Zealand's net and gross emissions are increasing.
- New Zealand produces an unusually large portion of CH_4 and N_2O emissions due to the significant role of agriculture in our economy.
- Emissions of CO_2 per capita are not high compared to other developed countries but have increased since 1990. Emissions of all GHGs per capita, however, are above the average for developed countries even though they have declined since 2005.
- Since 2008 New Zealand has its own emissions trading scheme, the NZ ETS, but its effectiveness to reduce GHG emissions to date has been limited.
- New Zealand has relied on buying international emissions trading units to meet emission reduction targets, as well as reducing domestic GHG emissions and removing CO_2 through forests. Some of the trading units have historically had low credibility internationally. Currently the NZ ETS does not involve international units, but the government has indicated an intention to make use of them in the future.
- Other measures include supporting research and providing consumers with information.
- Few regulatory measures relating to reducing GHG emissions that are common overseas exist in New Zealand, such as motor vehicle fuel efficiency standards, mandatory biofuel requirements, or regulated priority for the use of renewable energy for heat and electricity supply.

3.1 Historical trends

New Zealand's gross emissions have been on an upward trend and are projected to continue to increase (MƒE, 2015e). Between 1990 and 2013[24], gross emissions increased by 21.3% (14.4 Mt CO_2-eq) from 66.7 Mt CO_2-eq to 81.0 Mt CO_2-eq[25]. Net emissions, when CO_2 removals from forests are included, have increased by an even greater 42.4%, from 38.0 to 54.2 Mt CO_2-eq.

Net emissions are significantly lower than gross emissions because New Zealand on average has been converting some low-quality pasture and scrub land (which was mostly natural forests prior to arrival of the first human settlers) back into forests (mostly plantation forests for harvesting but some areas also into permanent forests).

On average, growing forests[26] have offset 29.1 Mt CO_2-eq which equates to more than one third of New Zealand's annual average gross emissions during 1990–2013 (Section 5.6).

Most of the growth in gross GHG emissions from 1990 to 2013 came from fossil-fuel combustion (7.7 Mt CO_2-eq, equating to a 31.9% increase), agriculture (4.8 Mt CO_2-eq, an increase of 14.1%), and industrial processes and product use (1.8 Mt CO_2-eq, an increase of 54.8%) (Figure. 3.1). Most of the increase in fossil fuel-related emissions arose from an increase in transport emissions, with a smaller increase in emissions from electricity and heat generation (Sections 5.1 and 5.2). The direct emissions from industry arise from processes such as cement manufacture and product use (Section 5.4). Emissions from waste were almost constant and relatively low with policy mechanisms in place. Even though they are relatively high per capita on an international basis, and there may be further mitigation opportunities, they were not considered further in this report.

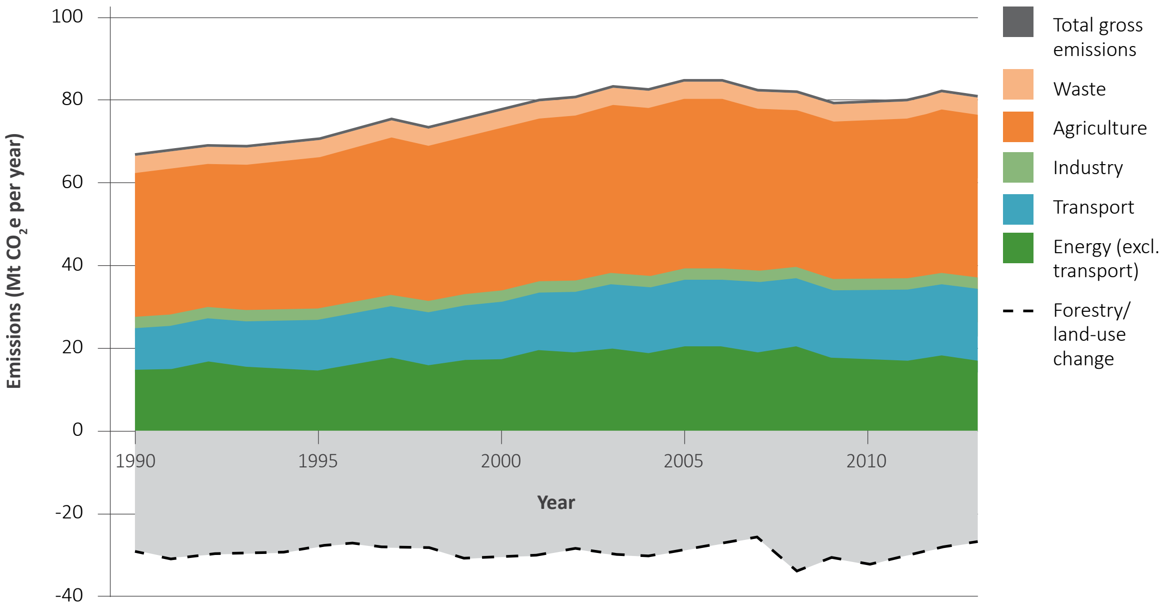
Emissions of synthetic gases (HFCs, PFCs and SF_6), used mostly in refrigeration and as solvents for cleaning processes, showed a significant increase but make only a very small contribution to total overall emissions so were also not further assessed here even though there are viable alternatives for HFCs under negotiation in the Montreal Protocol that could be considered. Removals of atmospheric CO_2 by growing forests showed cyclical variations between 1990 and 2013, but no consistent long-term trend (Section 5.6). Removals by forests in 2013 of 26.8 Mt CO_2e were 6.6% less than those in 1990.

24 All emissions data are from the New Zealand national GHG emissions inventory, published annually by the Ministry for the Environment. The inventory is usually released in April covering emissions up to the end of the prior 16 months. Hence this report, which used the inventory published in April 2015, refers to emissions up to the end of the calendar year 2013 (http://www.mƒe.govt.nz/publications/climate-change/new-zealands-greenhouse-gas-inventory-1990-2013).

25 Comparisons of the emissions of different gases rely on a metric to translate emissions of CH_4 and N_2O (which have different molecular weights, warming effects, and lifetimes in the atmosphere) into'CO_2-equivalent' emissions. Such a common metric enables the different warming impacts from the various GHGs to be added and contributions from different sectors, which may emit different gases, to be compared. The most commonly used metric is the Global Warming Potential (GWP). GWPs compare the amount of heat trapped in the atmosphere by the emission of 1 kg of a GHG other than CO_2 to the heat trapped by the emission of 1 kg of CO_2. In this report, we use the 100 year GWP metric, as used in New Zealand's reporting under the UNFCCC, which gives a weighting of 25 to CH_4 and 298 to N_2O. Note that there is an active debate in New Zealand and internationally about alternative metrics to compare non-CO_2 gases with CO_2, given the very different properties of different gases which mean that any 'equivalence' with CO_2 applies only in some respects but not in others. Other metrics would assign less weight to gases with a relatively short atmospheric lifetime such as CH_4, and some would assign a lower weight in the near term but increase this weight steadily over the next several decades. The choice of metric clearly is very important for NZ, given that an unusually large fraction of our total emissions (48%) comes from agriculture in the form of CH_4 and N_2O. The most appropriate metric depends on value judgements and policy objectives. For this report, we will not enter into this discussion but instead adopt the metric that is used for reporting under the UNFCCC, namely the 100-year GWP.

26 'Kyoto' forests removed 14.3 Mt CO_2 per year on average from 2008 to 2012 (http://www.mƒe.govt.nz/climate-change/reporting-greenhouse-gas-emissions/nzs-net-position-under-kyoto-protocol/update-net). Primarily, only forests regenerated or planted into pasture or crop land after 1990 qualify as a carbon sink under the rules of the Kyoto Protocol. Net emissions reported in the GHG Inventory under UNFCCC accounting rules include all emissions and removals from land-use activities. Existing forests are largely factored out under a BAU accounting approach called a 'reference level', and New Zealand has elected to not include other land use categories.

Figure 3.1 Gross GHG emissions in New Zealand from all sectors and removals by forests, 1990–2013.

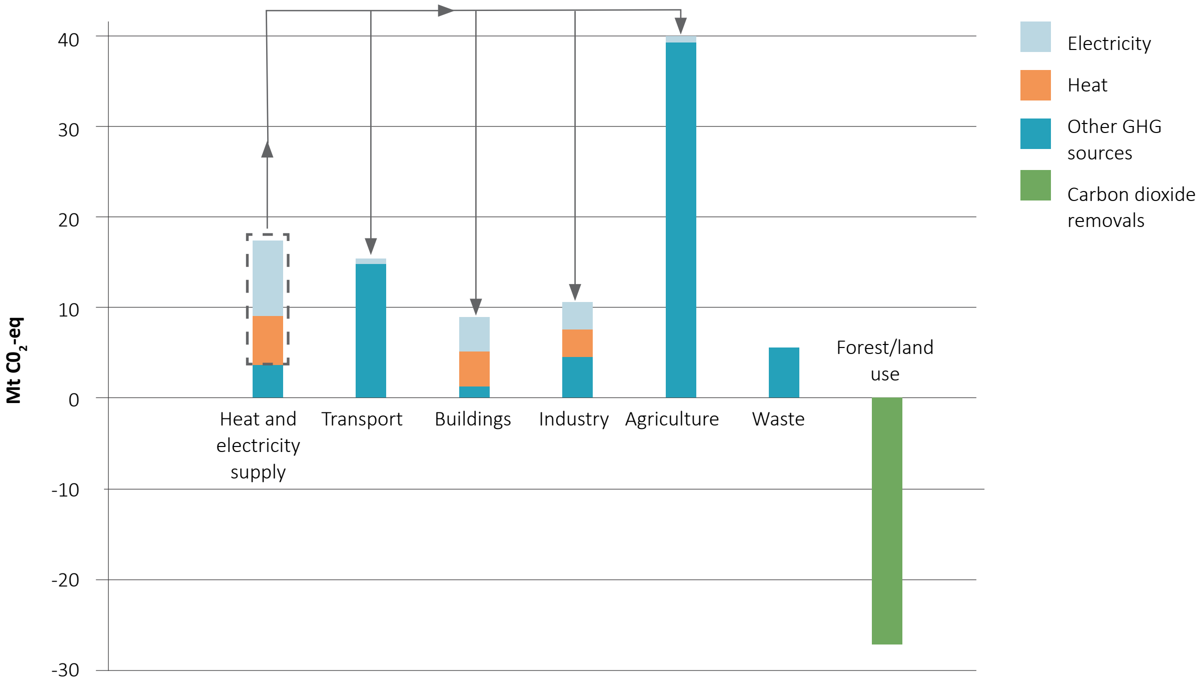


Source: M*f*E (2015a).

Emissions from electricity and heat generation can be allocated to the end-use sectors that use the heat or electricity (Figure 3.2). Buildings are important consumers of electricity and fossil fuels are commonly used for heating. Hence, the sector offers important abatement opportunities, even though their direct emissions are very small (Section 5.3).

Industry is also a significant user of heat and power (Section 5.4). This report considers emissions both from a production perspective (i.e. opportunities to generate electricity and heat with lower carbon emissions) as well as a consumption perspective (i.e. reducing the demand for electricity and heat).

Figure 3.2 Greenhouse gas emissions from each sector in 2013 showing allocations of emissions from the heat and electricity sector to the end-user sectors (transport, buildings, industry and agriculture).

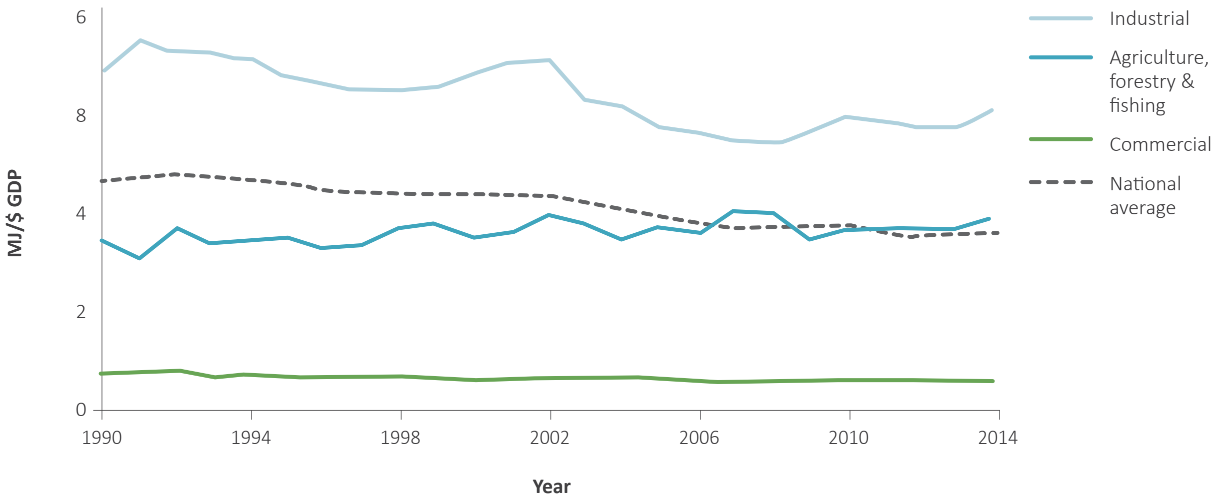


Source: MfE (2015a).

Global energy intensity (GJ/unit of GDP) is projected to fall three times faster out to 2030 than in the past decade (IEA, 2015a). As New Zealanders have also used energy more wisely and efficiently since 1990, particularly industry, our national energy intensity (MJ/$ GDP) has steadily declined (Figure. 3.3). However, this has been insufficient to fully offset the country's growth in GDP over this period, so our total annual energy demand continues to grow as do our GHG emissions.

However, the growth rate is slower than it would have been without energy efficiency measures being implemented across all sectors. Business NZ Energy Council (BEC, 2015) projected that the current energy intensity reduction of 1.7% per year will continue through to 2050 in its *Kayak* scenario. In the *Waka* scenario with heightened environmental awareness, energy intensity will decline faster by 2050 reaching 2.0% per year.

Figure 3.3 Energy intensity (MJ/$ GDP) of NZ sectors 1990-2014.



Source: MBIE (2015).

Two other metrics often used in national accounting and international comparisons (Section 3.4) are a) GHG emissions per capita and b) GHG emissions per unit of GDP (Figure 3.4).

a. Although New Zealand's population has grown by around 30% since 1990 and total GHG emissions have increased, our per capita CO_2-eq emissions fell by 7%, from 19.6 tCO_2-eq / capita in 1990 to 18.2 tCO_2-eq /capita in 2013[27]. This is higher than the approximately 15 tCO_2e per capita emissions across the average of high income countries and much higher than the average in upper middle income countries, which doubled from just over 4 tCO_2eq per capita in 1990 to 8 tCO_2eq in 2011. However, excluding agricultural non-CO_2 gases, so looking at just CO_2, per capita emissions increased slightly during this period, from 7.45 t CO_2/capita in 1990 to 7.78 tCO_2/capita in 2013. This is near the lower end of the 6 to 17 tCO_2/capita range in high income countries due to New Zealand's high shares of renewable electricity (section 5.1) but is above the estimated global average of 4.6 tCO_2/capita (excluding emissions from land-use change).

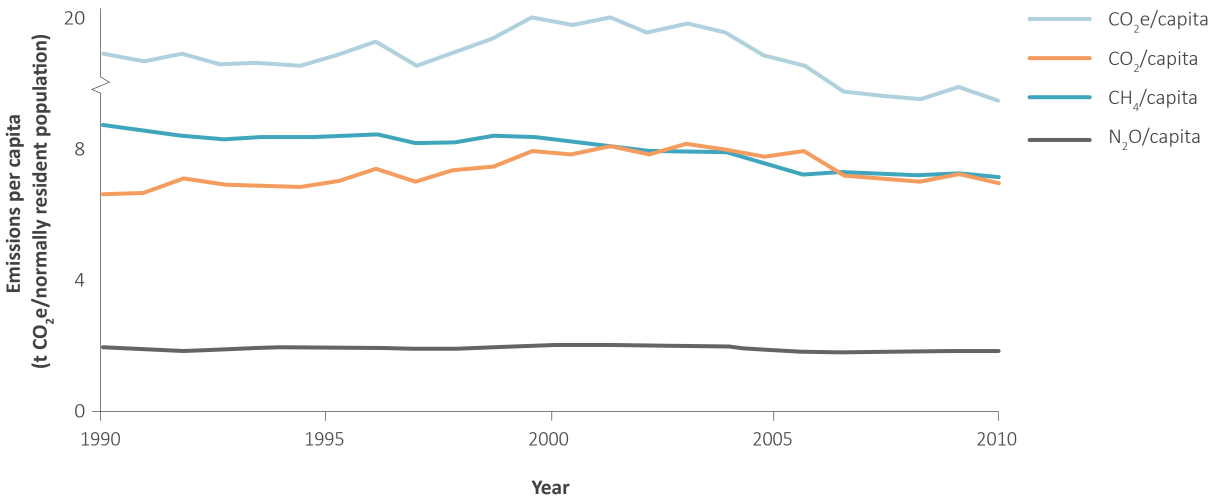
b. Emission intensity per unit of GDP has fallen in New Zealand, by 25% from 0.82 kg CO_2-eq /$GDP in 1990 to 0.55 kg CO_2-eq /$GDP in 2013 (MBIE, 2015). This is a trend of almost all economies around the world (excluding short-term variations related to economic shocks or natural disasters). In New Zealand, it is partly overall energy efficiency improvements that saved 36 PJ of energy demand between 2001 and 2011 (MBIE, 2015). Business NZ Energy Council (BEC, 2015) projected the present emissions intensity of 0.18 kg CO_2 / $ GDP will drop to 0.07 kg CO_2/ $GDP by 2050 in its *Kayak* scenario and down to 0.05 kg CO_2/ $ GDP in the *Waka* scenario.

Given New Zealand's unusual emissions profile with a very high fraction of emissions of CH_4 and N_2O from agriculture, it is also worthwhile to compare trends in individual gases and sectors. Nominal CH_4 emissions per capita declined by 18%, from 9.8 tCO_2eq/capita in 1990 to 8.0 tCO_2eq/capita in 2013, with a much lower fall of 4.8% in N_2O emissions per capita (from 2.1 to 2.0 tCO_2eq/capita) (Figure. 3.4).

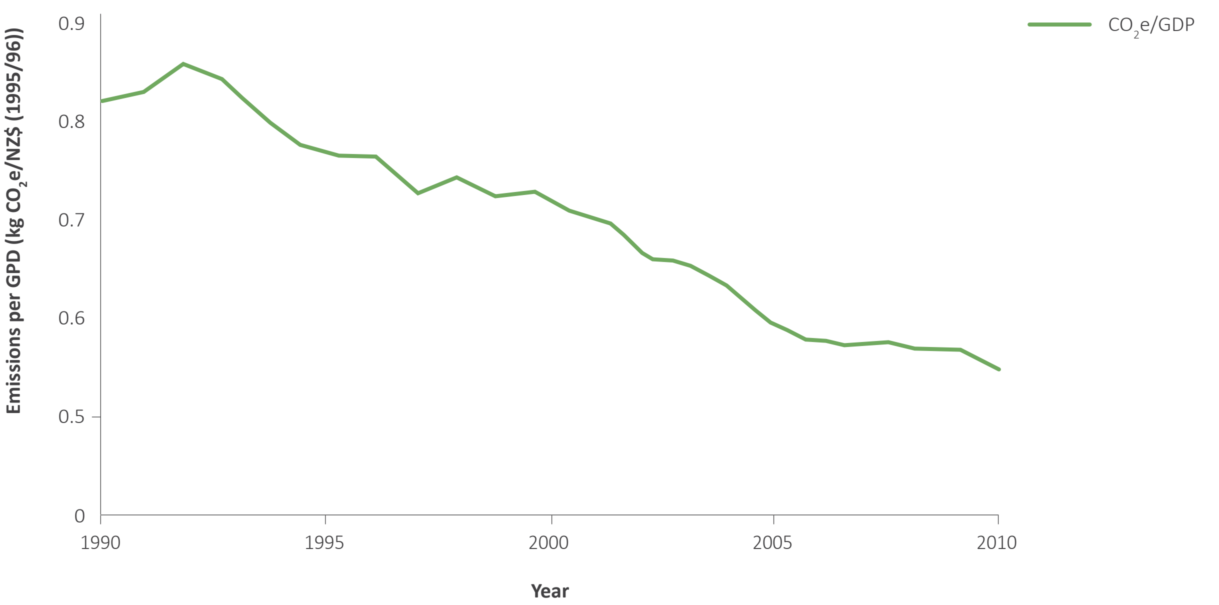
27 CAIT (2015) gives 17.37 t CO_2-eq / capita for New Zealand in 2012

Figure 3.4 Trends in emissions per resident capita (for total CO2-eq and individual gases) and emissions per unit of GDP..

Trends in emissions per capita (normally resident population)

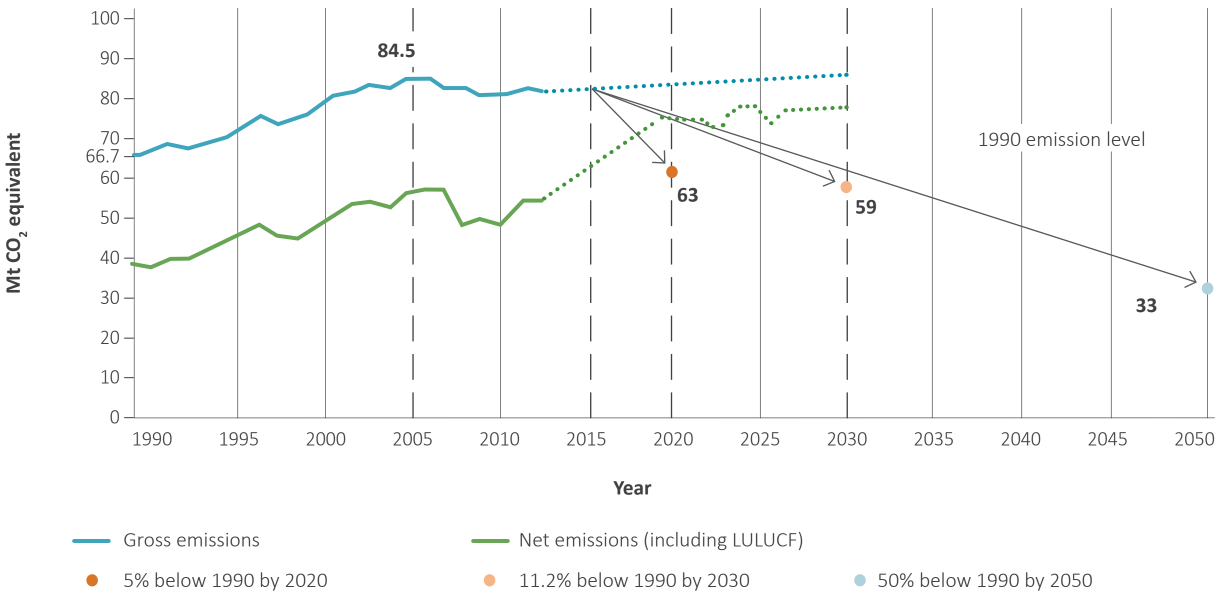


Trends in emissions per unit of GDP



Source: MfE (2015a); Statistics New Zealand.

Figure 3.5 New Zealand's gross and net emissions from 1990 to 2013, future projections and national emission reduction targets for 2020, 2030 and 2050.



Note: The 2020 conditional target range of 10–20% below 1990 is not shown.

Source: Based on MƒE (2015e).

3.2 Targets and policies

New Zealand's main approach to addressing GHG emissions currently consists of its emissions trading scheme (NZ ETS) (MƒE, 2013). While designed in principle to cover all sectors and all gases, the scheme, currently, places no obligations on biological emissions from agriculture; it only requires agricultural processors to report on emissions (Section 4.7).

New Zealand's greenhouse gas emission targets

New Zealand has four national targets:[28]

1. ***by 2020:* unconditional target** of 5% below 1990 levels by 2020, announced in August 2013 in lieu of joining the Kyoto Protocol second commitment period;[29]
2. ***by 2020:* conditional target range** of 10–20% below 1990 levels by 2020, assuming there was a comprehensive global agreement, announced in 2009, at the 15th UNFCCC Conference of the Parties;[30]
3. ***by 2030:* provisional target** of 30% below 2005 levels by 2030, equivalent to 11.2% below 1990 levels, but subject to international agreement on accounting for the land sector and confirmation of access to carbon markets. This was New Zealand's intended nationally determined contribution (INDC) advised for the Paris COP in 2015 (MƒE, 2015b);
4. ***by 2050:* aspirational long-term target** of 50% below 1990 levels by 2050 (Figure 3.5).[31]

28 http://www.mƒe.govt.nz/climate-change/reducing-greenhouse-gas-emissions/emissions-reduction-targets

29 T Groser, press release, 'New Zealand commits to 2020 climate change target' 16 August 2013.

30 The agreement assumed the world will set a pathway to limit temperature rise to not more than 2°C; developed countries make comparable efforts to those of New Zealand; advanced and major emitting developing countries will take action fully commensurate with their respective capabilities; there is an effective set of rules for LULUCF; there is full recourse to the international carbon market. Source: N Smith, N Groser, press release '2020 target balances economy & environment' 10 August 2009.

31 Climate Change Response (2050 Emissions Target) Notice 2011, NZ Gazette p 987, 31 March 2011, pursuant to s 224 of the Climate Change Response Act 2002.

The 2030 INDC target may be adjusted with the provisional target probably being finalised in the near term as an NDC and the conditional 2020 target range perhaps being regarded as superseded. All New Zealand's targets are stated to be 'responsibility targets' which can be met either by domestic emission reductions, including forest sinks, or by the Government or other actors purchasing emission credits abroad.

Infometrics (2015) and Landcare (2015) modelled the impacts of a potential New Zealand emissions target and showed heavy reliance on purchasing international carbon credits assuming they are available. The models were unable to simulate achievement of the target modelled without purchase of international carbon credits; the required price was too high. The studies assumed a decadal emissions reduction target of 260 Mt (equivalent to 10% below 1990 levels by 2030) with a global carbon price that reaches \$50/tonne. Agricultural non-CO_2 emissions were included in New Zealand's responsibilities but were excluded from carbon pricing. Under these assumptions, about four-fifths of the target would be met from international carbon credits, and only one-fifth of the target would be met by the abatement of emissions in New Zealand. Based on these assumptions, the cost of purchasing international carbon credits to offset the share of annual projected emissions would equate to approximately \$1.3 billion per year.

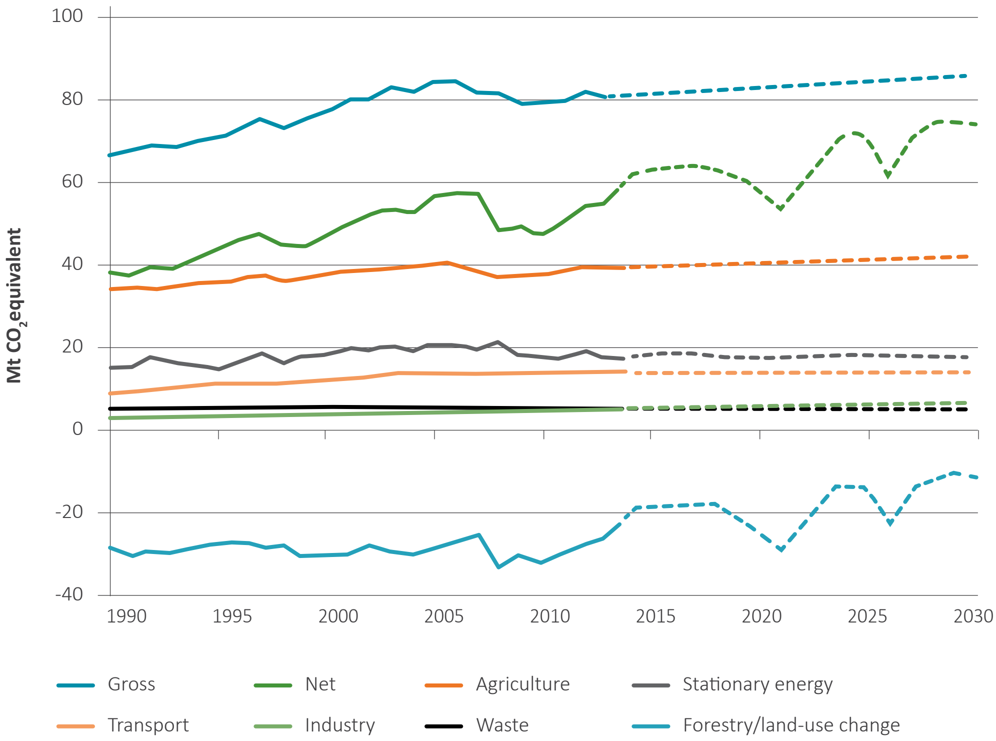
The INDC of 2015 made access to international credits one of the conditions for the commitment. The Ministry for the Environment in its NZ Emission Trading Scheme Review Discussion Document of 2015 suggests the ETS is likely to accept international carbon credits in the future. Credits will be subject to new rules that will aim to ensure that units have environmental integrity and represent genuine reductions (Section 4.7).

3.3 Future trends

New Zealand's 6th National Communication (NC6) to the UNFCCC (MƒE, 2013) provided New Zealand's future emissions projections out to 2030 and trends across the economy. These projections were updated in the Second Biennial Report to the UNFCCC (MƒE, 2015e). Underpinning all future projections are the assumptions that New Zealand's population will rise to 5.2 million by 2030 and GDP will rise by 40% relative to 2015. The NC6 projections assumed an effective carbon price of only \$5 /t CO_2eq, which limits the effect of any price-based climate policies on emissions. Such a price assumption was not consistent with global scenarios that would succeed in limiting global GHG emissions to limit the global average temperature increase to 2°C relative to pre-industrial levels. The amended projections (MƒE, 2015e) assumed a carbon price rising in 2030 to the current \$25 fixed price option under the ETS. This is consistent with UNFCCC guidelines that require the 'with measures' scenario to apply current policies. By comparison, the two Business Energy Council (BEC, 2015) scenarios for New Zealand's energy future, assumed carbon prices of \$60/t CO_2 (*Kayak)* and \$115/t CO_2 (*Waka*) in 2050 (BEC, 2015). Such carbon price levels are more consistent with carbon prices coming out of international modelling studies (Clarke et al, 2014).

Based on New Zealand's second biennial update report to the UNFCCC (MƒE, 2015e) that supersedes the NC6, gross emissions are now estimated to increase to 29% above 1990 levels by 2030 in the absence of additional policy measures beyond those currently in place (Figure. 3.6). Notably, a significant decline in removals from forestry is expected over this period due to harvesting cycles resulting in net emissions increasing by 96% above net emissions in 1990. In absolute terms, using the same conversion factors for non-CO_2 gases into CO_2-equivalents as used in the most recent annual emissions inventory, gross emissions would increase by 2030 to 86.0 Mt CO_2e and net emissions to 74.6 Mt CO_2e.

Figure 3.6 Historical and projected future GHG emissions in New Zealand from all sectors, 1990 to 2030.



Source: MfE (2015e).

Since no official data are available for projected GHG emissions beyond 2030, possibly due to large uncertainties from future disruptive technologies, it has been challenging to assess the mitigation options, emissions pathways and policy options for New Zealand that could meet the gazetted 2050 goal or any longer term target.

This report therefore used long-term sector-specific projections where available, inferred future emissions levels based on other longer-term forecasts, or employed plausible assumptions based on expert judgement where justified and deemed necessary to provide useful order-of-magnitude information given this knowledge gap.

3.4 New Zealand's emissions and trends in a global context

New Zealand's overall GHG emissions are relatively small at around 0.15% of total global emissions, (reflecting our small economy and our population at about 0.06% of the global total). The 48% share of total emissions from direct agricultural emissions is the highest of all developed countries, being significantly higher than Ireland (31%), France (18%) and Australia (16%). In most developed countries agriculture constitutes less than 10% of total emissions. New Zealand's emissions profile makes it more like many small developing countries with strong agricultural sectors such as Uruguay (75%), Ethiopia (52%) or Argentina (34%), although there are differences in the structure of the agriculture sector between New Zealand and some of these countries. The largest emitters in the developing world all tend to have a lower share of agriculture emissions than New Zealand, (e.g. Brazil, 30%; India, 20%; China, 9%) mostly because of their rapidly growing (and often highly fossil-fuel dependent) energy sector and despite the importance of food security for those countries. New Zealand's unusual emissions profile, along with the large fraction of emissions that are effectively exported through agricultural products, creates a challenge in how best to conceptualise its role and opportunities in contributing to global mitigation efforts (see Box 3.1).

Our geographical remoteness and economic reliance on exports of agricultural products and long-haul tourism imply that international perceptions of New Zealand as a source of products and services could play a role in shaping New Zealand's future emission reductions (Section 4.6).

To limit the rise in global average temperatures to no more than 2°C, aggregate emission reductions across high income countries would need to amount to typically 80% or more below 2010 levels by 2050 in order to give developing countries more breathing space to achieve sustainable development as they also decarbonise their economies (Clarke *et al.,* 2014). New Zealand's long-term goal of reducing emissions by 50% relative to 1990 levels by 2050 is significantly less ambitious. This could reflect New Zealand's emissions profile, but no formal analyses of how the target was derived have been released, nor what the government would expect the relative emission reduction shares of different sectors of the economy to be if such a target were in fact achieved.

New Zealand can choose to make greater emission reductions than other developed countries or it can choose not to try and match what they aspire to. Such a choice inevitably (explicitly or implicitly) involves value judgements and other assumptions such as the attitudes of our trading partners. For this reason, this study aimed to evaluate what options exist for reductions in GHG emissions, as low as possible and as soon as feasible, for each sector of the economy and across the economy as a whole. A range of transparent assumptions were made about the cost and availability of current and future technologies and the rate of behavioural change.

The long-term goal assumed for New Zealand is to reduce net emissions of long-lived CO_2 to zero or below, consistent with findings by the IPCC and endorsed by the Paris Climate Agreement[32]. A separate mitigation goal could be considered for short-lived gases, in particular for methane, since these emissions do not have to decline to zero in order for the climate to stabilise and the GHG metrics currently used for methane, other short-lived gases, and black carbon are being reviewed (Harmsen *et al.,* 2016; see footnote 25 above).

32 It is not a given that each individual country would have to achieve this, as long as excess emissions in one group of countries is balanced by active carbon removals in another group of countries; but without a transparent case for New Zealand taking a different role in the long term, we take a goal of carbon neutrality as a given for the purpose of this report.

Box 3.1: Export component of emissions

Under reporting and accounting rules adopted by the UNFCCC, emissions are generally counted where they actually occur into the atmosphere. For some countries with large export components, this can result in a relatively higher emissions burden compared to countries with high levels of imports, especially of emissions intensive products. Examples include steel, cement and aluminium in the construction sector, or ruminant livestock products and rice in agriculture.

In a consumption-based approach, emissions assigned to high income countries would, on average, increase, while those assigned to upper and lower middle income countries would decrease, reflecting the fact that high income countries increasingly outsource production overseas, where labour is generally cheaper. However, most studies have only explored implications of different accounting approaches on CO_2 emissions, not for non-CO_2 emissions.

Since New Zealand exports more than 90% of its total livestock production, an alternative consumption-based perspective would assign livestock emissions to the countries where livestock products (mainly meat and milk) are consumed rather than to New Zealand. On the other hand, in a consumption based approach, New Zealand would become liable for emissions arising in other countries for products that it imports (such as cars, machinery, clothing, and electronics). An existing study (Peters *et al.*, 2011) indicates that New Zealand's CO_2 emissions based on a consumption approach would be higher than if based on a production approach which is consistent with the picture for most other developed countries. However, when taking into account the unusually large share of New Zealand's non-CO_2 agricultural emissions, our overall consumption-based emissions would likely be lower. This situation is exacerbated further if the export of wood products is taken into account, where New Zealand incurs the full emissions liability at the time a tree is harvested, even if the wood, and hence the embedded carbon, is exported. Based on recent trends, the difference between production and consumption-based emissions has been reducing but no long-term forecasts exist.

Fully accounting for emissions at the point where consumption occurs (including defining what constitutes a point of consumption or simply an intermediate point for further production) would be extremely complex. A consumption based approach would also make it more difficult, if not impossible in some cases, for the countries that are now responsible for those emissions to actually implement mitigation measures.

For these reasons, this report does not further explore implications of a consumption-based approach to emissions accounting, but notes that the production vs consumption perspective can be an important element for how national obligations and a 'fair share' are construed.

Section 4: Taking action

All New Zealanders should understand the risks of climate change, accept that we have to change the way we currently behave, accept that there are benefits but that also trade-offs have to be made, and become personally involved in implementing mitigation actions and changing our present 'carbon culture'. Policies can evolve to make it easier for people, communities, cities and businesses to reduce their carbon footprints.

Key messages

- Reducing emissions to net zero and creating a low-carbon economy within the next 35–50 years will involve changes in the behaviours of all sectors of society, from individuals, families and communities to businesses and government.
- The social and technological changes required are significant, but achievable if people and organisations are enabled so they can choose low-carbon options.
- The tools, technologies and systems available to reduce emissions are likely to change dramatically over the next decades. To avoid being locked into high cost choices and pick up attractive new options quickly we can be open to and actively trial new options, evaluate our past choices and be prepared to admit failure, and make choices that open up future options rather than excluding them.
- One starting point for behaviour change is for people and organisations to understand their emissions profile with a range of tools available to provide personalised assessments of carbon footprints.
- Behaviour is shaped by a comprehension of the climate change problem as well as by the wider context set by local and national government policies, and by infrastructure development.
- Policies including emissions pricing, infrastructure and cultures need to evolve to make it easier for people and organisations to consistently make low-carbon choices.
- Climate change policy can be developed in a way that involves New Zealanders, our organisations and businesses. Implementation requires action from all of us so the procedures should be open, well-informed, systematic, efficient and equitable.
- Being involved in the development of policy, or even just being informed, will influence our commitment to a low-carbon future.
- When setting targets, careful analysis of actions and measures and early discussion with sector stakeholders could help ensure that targets can be reached and policy effectiveness can later be evaluated.
- Public debate about climate change could be informed by provision of information about the strengths and weaknesses of different policy options.
- New procedures and institutions such as strategies, action plans, and independent monitoring and advisory committees may improve climate-change policy-making by making it more focussed, stable and accessible to the stakeholders.

To avoid serious social, economic and environmental harm from climate change, all anthropogenic activities and processes that currently emit significant quantities of GHGs will need to change. Section 5 focuses on the specifics of these changes, sector by sector. But change will not occur unless people, organisations and local, regional and national governments take action.

This section focuses first on behaviour, and what will be needed to support widespread behaviour change to achieve a low-carbon future. It then addresses the government policy measures that can be used to mitigate climate change, and the framework in which climate change policy is made in New Zealand.

Climate change calls for actions on different levels: personal, household, social circles, workplace and market, the wider economy, business, local government, regional, and national government and international interactions by New Zealanders. The focus on the actions that we can take through our individual and local actions is necessarily followed in this section by discussion of the actions that we can take in the public sphere led by governments. The myriad of actions that individual and businesses can take should not obscure the responsibility of central and local governments to provide leadership.

4.1 A socio-technical transition

It is an immense task to reduce annual emissions to net zero by the second half of the century, especially when linked to the need to rapidly reduce our present heavy reliance on fossil fuels and the aim for poorer countries to also achieve sustainable development. Transitioning to a low-carbon future involves changes that will affect everyday decisions and activities and impact almost all aspects of people's lives, at work and at home. Changes will also be needed in the contexts that shape people's choices, such as in policy and regulations, the provision and management of infrastructure, and the availability of low-carbon alternatives to fossil fuels.

Fossil fuels are an integral part of systems of production and consumption. For example, for someone to own and drive a car in New Zealand, they are reliant on a complex chain of supply of vehicles and fuels that includes steel mills, car manufacturers, car importers, car sales and maintenance companies, oil producers, oil shippers, oil refineries, vehicle regulations, tax systems, building and maintaining roads, car magazines and websites, garages and service stations. A transition in such a system is complex, in part because there are so many players, from multi-national companies to local businesses, many with vested interests in maintaining things as they are.

In addition, changing one part of a system inevitably involves changes in other parts as well. The scale of the changes are such that it will necessarily be a 'socio-technical transition' (Verbong and Geels, 2010; Geels, 2012) – 'transition' meaning a fundamental change from one way of doing things to another, and 'socio-technical' meaning that the transition will require technological change as well as changes in human behaviour. The world has seen many socio-technical transitions in the past – such as the rapid transition from horses to cars in the early 20th century, and the transition from film-based photography to digital in the late 20th century. Socio-technical transitions can be challenging, especially for 'sunset industries' (like blacksmiths and film developers and camera manufacturers), but they also open up new economic and societal opportunities as seen by the way information technology has revolutionised communication.

The low-carbon transition is already under way. Many innovators, businesses, communities, cities, banks and financiers are already actively involved in many ways, including for example making massive investments in renewable energy (UNEP, 2015a). However, it might not happen quickly enough to stay within the global carbon budget (Figure 2.1) unless there is a concerted effort across all sectors and at all scales of action. Businesses, iwi, local governments, government, non-governmental organisations and community groups will all need to consider their role in the transition, and potentially change the ways that they have traditionally operated.

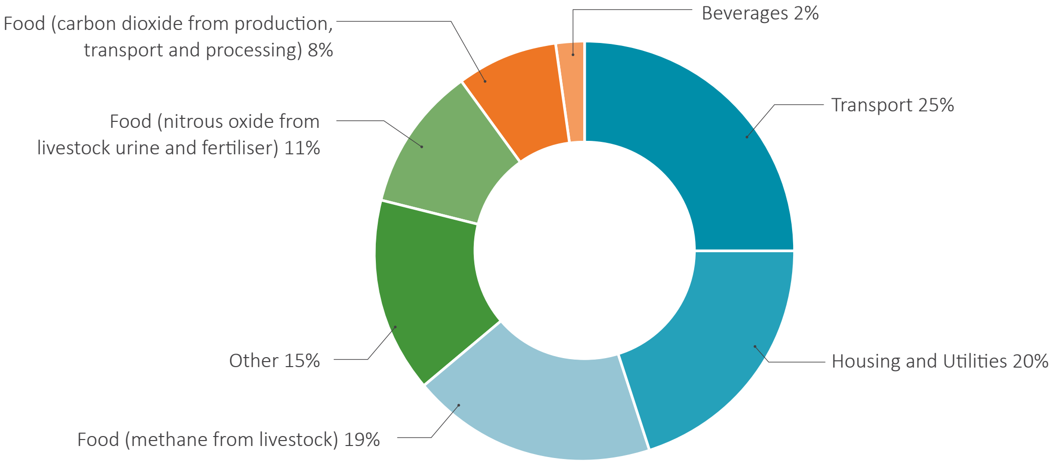
4.2 Assessing emissions

One of the first steps in changing behaviour to reduce emissions is to understand what it is that we do that produces them. Section 5 details the GHG emissions from sectors such as buildings, transport, and agriculture, but our lifestyles don't differentiate in this way. Hence there is reason to also look at the sources of emissions from the perspective of important groups of decision-makers: households; businesses and organisations; and cities, towns and regions.

Households

Householders use appliances, drive cars, eat food, and carry out many other activities that produce emissions. To understand how to reduce GHG emissions, consumption-based assessments help reveal how everyday activity gives rise to them and how this differs between households. The three main sources of GHG emissions from the average New Zealand household are from food, transport and utilities (mainly energy supplies) (Figure. 4.1).

Figure 4.1 Composition of average household emissions, 2012/13, based on an average household footprint of 17 t-CO2 eq.



Source: Allan *et al.*, 2015.

Housing and utilities such as electricity, gas, LPG and solid fuels account for around one fifth of an average carbon footprint of a household. Transport accounts for around one quarter, and food and beverages total around 40% of the emissions. Food-related emissions account for the GHGs produced in producing, processing, transporting, and retailing the food but most are from methane and nitrous oxide produced by farm livestock and nitrogenous fertiliser use (Section 5.5) (Allan *et al.*, 2015).

The composition of household emissions varies with income. Lower-income households have a larger proportion of emissions from home energy use, while higher-income households have a larger proportion from transport, particularly from air travel. Emissions also differ between regions: for example, Auckland households have more transport emissions on average, while Wellington households have higher emissions from home energy use (Allan *et al.*, 2015).

Average household emissions decreased by 4.6% between 2006 and 2012 (Allan *et al.*, 2015). This represented a reduction of about 1 t-CO_2-eq for a two-person household with around $80,000 of annual expenditure, and was in part due to a 10% decrease in emissions from household energy.

Roughly half of this reduction was assessed as responses by the householders to increased power prices, which is consistent with an observed decline in total residential electricity consumption. The remainder of the reduction aligns with general improvements in energy efficiency in homes and appliances (with the emission factor held constant for electricity in spite of growing shares of renewables reducing it).

As well as understanding the general sources of the emissions they create, householders may wish to calculate their own emissions profile. CarboNZero[33] offers New Zealand-specific web-based tools for households and travellers to assess their carbon footprints. Their Household Calculator allows individuals to estimate the amount of GHG emissions generated by their entire household through direct energy use and other activities.[34] (See also Box 4.4 for Motu's calculator). Their Travel and Tourism Calculator allows travellers to calculate GHG emissions for their domestic and overseas travel, and/or New Zealand-specific accommodation and recreational activities[35] (also see Section 4.6)

33 http://www.landcareresearch.co.nz/resources/business/the-carbonzero-programme

34 https://www.carbonzero.co.nz/EmissionsCalc/login.aspx

35 http://www.carbonzero.co.nz/EmissionsCalc/tourismeditor.aspx

Box 4.1: CEMARS certification case study

Kāpiti Coast District Council has been CEMARS certified since 2012. CEMARS certification tracks how they measure, manage and reduce their GHG emissions. The council aims to reduce its operational carbon footprint by 45% in 2014-15 compared to its 2009-10 baseline year, and increasing to 80% reduction by 2021-22.

Projects planned to reduce emissions include reducing sewage sludge emissions, deploying LED streetlights, using woodchip fuel to provide heat at the wastewater treatment plant, and improving energy efficiency in vehicles and buildings.

Businesses and institutions

Emissions from businesses and institutions vary greatly depending on what they do. Many are already undertaking assessments of their emissions, sometimes as part of a wider commitment to sustainability, to inform their shareholders as part of 'triple bottom line' reporting', or to track their progress towards their own carbon emissions reduction target.

Assessing emissions is a very complex exercise, and the International Organisation for Standardisation (ISO) has produced standards to ensure that this is done in a consistent way. For example, ISO/TR 14069:2013 describes the principles, concepts and methods relating to the quantification and reporting of direct and indirect GHG emissions for an organisation. ISO 14065:2013 specifies principles and requirements for bodies that undertake validation or verification of GHG emissions[36].

Enviro-Mark[37], a subsidiary company of New Zealand's Landcare Research crown research institute, provides tools and support for businesses and other organisations to implement an effective environmental management system (EMS). It has developed two forms of independent certification that are consistent with the ISO standards above to help a company prove it is taking creditable action for a better environment:

1) ***CEMARS*** (Certified Emissions Management And Reduction Scheme) certification enables emission reductions from products or services provided by businesses or councils to be measured and reduction claims verified (Box 4.1). This was the first GHG certification scheme in the world to achieve international accreditation. New Zealand businesses and organisations with CEMARS certification include Auckland Airport, NZ Post, The Warehouse Group, BMW Group and Kāpiti Coast District Council.

36 International Organisation for Standardisation http://www.iso.org/iso/catalogue_detail?csnumber=60168

37 http://www.enviro-mark.com/home

2) ***CarboNZero certification*** is for organisations, products, services or events that want to be able to make a carbon neutrality claim (Box 4.2).

In addition, Enviro-Mark works with the Energy Management Association of New Zealand to assist a business or organisation measure and manage its energy use and improve efficiency under its 'Energy-Mark' brand and offers businesses under its Enviro-Mark certification programme to measure and manage other environmental impacts.

Shareholders are becoming quite influential in the carbon reduction actions of businesses, that globally and nationally are tending to adopt forms of integrated triple bottom line (environmental, social, and governance (ESG)) reporting to shareholders (Box 4.3). This takes into account their social and environmental costs and benefits as well as their financial outcomes. These include such factors as accounting for water use and impacts on biodiversity as well as their GHG emissions

A number of international bodies are involved in setting standards and methods for this kind of reporting. For example, the International Integrated Reporting Framework ('<IR> framework')[38] was established to improve the quality of information available to providers of financial capital. The Global Reporting Initiative (GRI) produces sustainability reporting guidelines to assist companies and organisations to report their economic and ESG performance[39]. The Climate Disclosure Standards Board (CDSB) promotes climate change-related disclosure in mainstream reports through the development of a global framework for corporate reporting on climate change[40]. Most mainstream audit and financial advisory firms in New Zealand offer services that include these and other integrated reporting approaches.

Box 4.2: CarboNZero certification case study

Yealands Family Wines was the world's first zero-carbon winery to be certified under the carboNZero assessment process. An independent audit is undertaken annually which reviews the GHG emissions using a 'cradle to grave' approach, assessing all aspects of the winegrowing and winemaking process. All unavoidable emissions, such as the production of glass bottles, freight to market and business travel are offset through the purchase of certified carbon credits, which include from the regeneration of native forests and renewable energy generation.

CarboNZero also offers a carbon footprinting calculator to help New Zealand small businesses and schools to calculate their GHG emissions. There are many other carbon calculators available but inaccurate results are likely unless they are calibrated for New Zealand's particular characteristics.

Over 200 New Zealand businesses have committed to becoming carbon neutral through the CarboNZero certification scheme, which involves measuring, reporting and acting to reduce carbon emissions. Disclosure statements of their emissions are publicly available (see https://www.carbonzero.co.nz/members/cz_organisations_certified.asp).

38 International Integrated Reporting Council http://integratedreporting.org/resource/international-ir-framework/

39 Global Reporting Initiative www.globalreporting.org

40 Climate Disclosure Standards Board http://www.cdsb.net/

Box 4.3: GHG emission reporting in Annual Reports

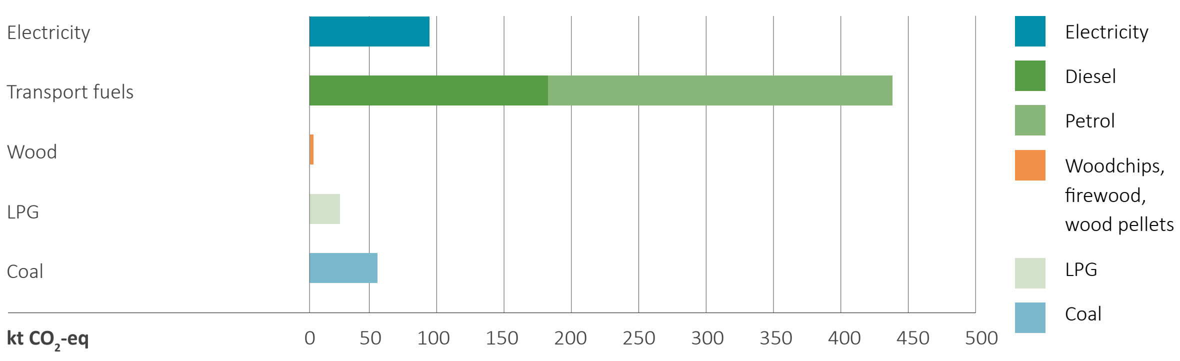
Sanford is a New Zealand fishing company which harvests, farms, processes and markets seafood. The company owns around one quarter of New Zealand's seafood quota. They use the <IR> Framework and GRI guidelines to illustrate the many ways in which the company creates value. Their 2015 annual report (http://www.sanford.co.nz/investors/reports-1/) explained that this includes protecting natural resources, engaging communities, innovating and building consumer trust as well as providing sustainable returns to shareholders. The report details Sanford's environmental, social and economic performance including their direct, indirect and total GHG emissions over the past three years.

Cities, towns and regions

Some councils have also established their own emissions reduction targets, usually as part of a broader environmental or sustainability strategy. For example, the Auckland Plan sets a target for that city to achieve a 40% reduction in GHG emissions by 2040 (based on 1990 levels). A number of councils have also undertaken analysis to identify the sources of emissions at a city or regional level. Dunedin, Kāpiti Coast and Wellington councils have undertaken CEMARS certification (Box 4.1).

A Dunedin study assessed the emissions arising from the direct use of energy as part of broader study assessing energy flows into the city from all sources for 2014 (Gabriel *et al.,* 2015). For a population of around 120,000, the total energy inputs were approximately 10.5 PJ. Of this, 58% was transport fuels, 31% electricity, 3% LPG, 5% coal and 3% woody biomass. The combustion of these fuels gave rise to nearly 600 kt CO_2 or around 5t CO_2 / capita. Three quarters of the emissions resulted from the use of transport fuels (Figure 4.2).

Figure 4.2 Estimated GHG emissions associated with direct energy supplies to the wider population of Dunedin (including the rural hinterland) in 2014.



Source: Gabriel et al., 2015.

Wellington City Council commissioned the Wellington 2050 Energy Calculator[41], an interactive website to enable residents to explore how different combinations of actions could lead to lowering GHG emissions city-wide (Section 6.1). Options for action include changing energy supplies, reducing emissions from waste, investing in infrastructure, changing travel modes, household heating and cooling, and industrial efficiency – making it clear that reducing emissions to reach the city's target levels will involve changes in the everyday activities in households, organisations and businesses throughout the city.

At the regional level, the Energy End Use database created by the Energy Efficiency and Conservation Authority (EECA) enables estimates of GHGs from energy use[42]. Studies such as these can help identify where city, district and regional councils could best put effort into reducing emissions through infrastructure investment, asset management and policies.

4.3 Influences on behaviour

Regardless of whether acting as individuals, part of a family, or part of an organisation, everyone can contribute to reducing their GHG emissions footprint through changes to their own lifestyles, providing support for others to make changes, and working with others to achieve change collectively. But how can people be inspired to make changes in the first place?

Commonly-heard explanations include that people don't change habits because they have insufficient knowledge, or that the costs of changing outweigh the benefits. But behaviour is very complicated, and is shaped by many different factors.

A review of international research concluded that behaviour change is more likely if people believe that climate change is real, but people's view on this can fluctuate (Leining, 2015). Around 70% of residents in the United States now believe in the science behind global warming, an increase of 7 percentage points in the first six months of 2015 (Borick *et al.*, 2015). Few studies in New Zealand ask the same questions repeatedly over time, but almost three-quarters of New Zealanders perceived climate change as an urgent or immediate problem in 2008, while only 52.4% had this view in 2012 (Leining and White, 2014). Nevertheless 68% supported more action on climate change by businesses; 64% considered citizens themselves should take more actions; 64% considered Parliament should take more action; and 63% felt all government officials should take more action. Another survey in 2014 found that 58% of respondents were concerned about the impact of climate change on themselves, and 63% were concerned about the impacts on society in general (Leining and White, 2014).

People's ideologies, world views and social norms strongly shape how they receive and respond to information about climate change. People's values and beliefs can influence what kinds of information they consider to be reliable and convincing (Kahan *et al.*, 2011). The way climate change is presented can also shape people's willingness to take mitigation actions. There is evidence that people respond more constructively and positively to feelings of concern, interest and hope, than to fear. Fear can make people disengage, especially when impacts are seen as distant and outside of their control. Highlighting the co-benefits of climate action for the economy, environment, community resilience, culture and health can encourage people to get involved (Leining, 2015).

Individuals and groups are also strongly influenced by what are seen to be widely-shared expectations and aspirations. A good example is the way in which it is now 'normal' not to smoke in most shared spaces, including public buildings and even grounds. This change occurred quite rapidly and was the result of a carefully developed programme to influence behaviour, involving changes in laws as well as public education and programmes to support smokers to give up. It is now almost inconceivable that anyone would condone smoking in a restaurant, and yet this social norm is relatively new. Changing behaviour to achieve a low-carbon future will similarly need to involve significant shifts in social norms relating to carbon emissions.

Behaviour is also shaped by the wider world that people live in – things like infrastructure (e.g. are cycle lanes available?), services (e.g. is public transport available?), technologies (e.g. are there charging stations for my electric vehicle?), the cost of different options (e.g. electricity relative to petrol for vehicle fuel), and regulations (e.g. are houses required to be insulated?) (Darnton & Evans 2013). Even if people have knowledge and attitudes that support low-carbon behaviour change, they may fail to make changes because of other factors outside their control. Personal capabilities, family situations, incomes, and other factors such as affordability, regulations, policies and infrastructure can make it very difficult or even impossible for people to make changes.

However, even if they are not driven by beliefs and attitudes about climate action, people can (and often do) make changes that will decrease their emissions, for different reasons. For example, they might choose to walk or cycle for health reasons; they may decide to put in a solar PV electric system at home because they want to reduce their power bills; or they may

41 http://climatecalculator.org.nz/

42 http://enduse.eeca.govt.nz/default.aspx

buy an electric car because they like the acceleration potential. To achieve a widespread decrease in emissions, it is most important to make low-carbon choices easy, and to communicate the many co-benefits of these choices. Increasing knowledge and understanding about climate change is important, but is only part of the behaviour change solution.

4.4 Encouraging behaviour change

New Zealand already has a number of initiatives that aim to change behaviour that will result in reduced GHG emissions, some of which are discussed elsewhere in this report. Some initiatives operate at a national scale (e.g. the emissions trading scheme); some at a city scale (e.g. investment in bicycle infrastructure); some focus on businesses (e.g. the EECA business energy awards); and some focus on households. The Household Climate Action Tool for example showcases simple actions to reduce a household's emissions (Box 4.4).

Box 4.4: Household Climate Action Tool

This simple information tool shows tangible, practical, and understandable ways to reduce a New Zealand household's greenhouse gas emissions.

The data behind the tool is based on average emissions profiles and average spending patterns and is not designed to provide an accurate account of household emissions or the impacts of various actions for specific households. The tool is designed to be simple and easy to use so that people can get an idea of the actions they can take to reduce their emissions, and to get an idea of how big the impacts of these actions may be.

http://motu.nz/our-work/environment-and-resources/emission-mitigation/shaping-new-zealands-low-emissions-future/household-climate-action-tool-2/

When considering interventions to help change behaviour, it is useful to consider the actor (who is enacting the behaviour?), the domain (what shapes or influences the behaviour?) the durability (how does the behaviour relate to time?) and the scope (how does the behaviour inter-relate with other behaviours?). Answering these questions can assist policy-makers to understand the many dimensions of behavioural influences and to think more broadly about the design of effective interventions (Chatterton and Wilson 2014).

Behaviour change initiatives often just focus on changes that individuals and households can make. A review of initiatives for emissions reduction in Scotland found that most attempted to change behaviour at the individual level, rather than within a social or material context (Southerton *et al.*, 2011). This report recommended that, to be successful, behaviour change initiatives should:

1. ***target social and material contexts, not just the individual*** by targeting moments of transition (moving home, having children, etc.) and using pressure points in infrastructural systems that represent opportunities for sustained behavioural change;
2. ***develop frameworks for coordinated initiatives*** *across sectors or domains* that provide an opportunity for otherwise individual, 'single action' schemes to complement one another when moving towards a common goal – and to reduce the possibility of them pulling in opposite directions; and
3. ***utilise less visible mechanisms and non-environmental messages to effect change,*** for example by encouraging initiatives based on health and fitness, diet or even concerns about time pressure (e.g. by encouraging working from home) that have low-emissions co-benefits.

Southerton *et al.*, (2011) also identified the needs for robust evaluation measures and for organisational/governmental leadership in initiatives. They pointed out that most initiatives only aimed for modest improvements, but that achieving change at the scale required to reach emissions targets will require wide-reaching system level changes that radically transform current consumption and production. Where capital investment is a barrier, the benefits could be offered as a service or the costs could be annualised to encourage adoption, for example where a council provides a loan for a solar hot water investment then adds an incremental repayment charge to the annual rates collected for the property.

Sometimes a small, well-planned change in a policy or process can 'nudge' people to change their behaviour, without them consciously intending to do so (Thaler & Sunstein, 2008). However this has been shown to be only effective in limited circumstances, and behaviour change is more likely to be enduring where it involves a change in social identity and internalisation of new norms (Mols *et al.*, 2015).

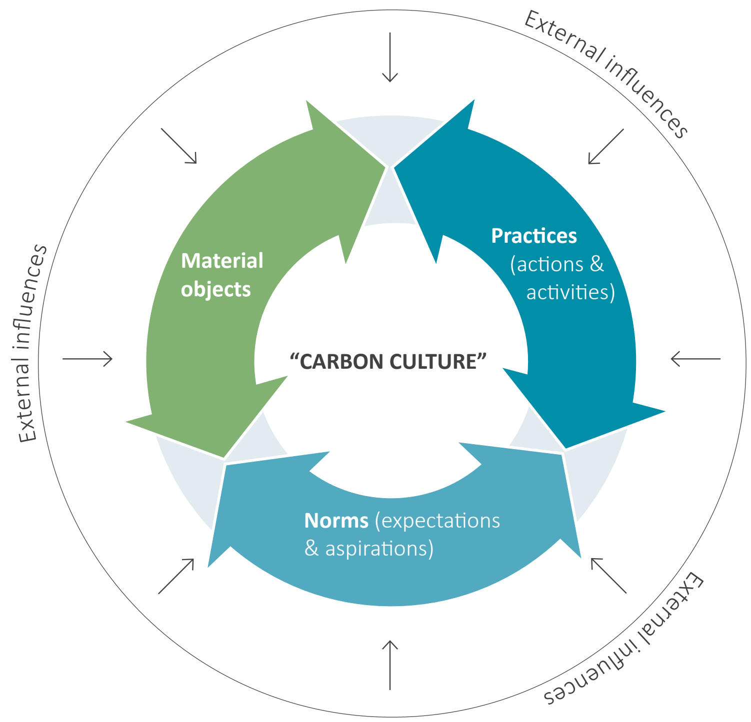
The International Energy Agency's implementing agreement *Demand-side management* (Task 24, Behavioural Change[43]) is another source of insights about behaviour change initiatives, particularly relating to energy efficiency[44]. New Zealand is a partner in this programme. The most recent report from New Zealand (Rotmann, 2015)[45] identified that New Zealand's main intervention programmes to increase efficiency were centred around the provision of information (particularly the 'Energy Spot' TV campaign); product information (minimum energy performance standards and labelling), business information, grants and audits; a voluntary commercial building ratings scheme (NABERSNZ); transport efficiency (particularly around heavy vehicle driver efficiency, biofuels and vehicle fuel consumption labelling) and the Warm Up New Zealand insulation and clean heat subsidy programmes.

The report concluded that 'behaviour changers' should be more aware of theories of behaviour change, as well as prior studies that help show what works and what doesn't, so as to minimise the chance of failure. Better collaboration is needed between organisations that influence different aspect of behaviour, and also more effort should be put into evaluating the success (or otherwise) of behaviour change interventions.

4.5 Changing our 'carbon cultures'

A useful way to bring together these different insights on behaviour is to use a 'cultures' framework (Figure 4.3). This is based on research into energy behaviour (Stephenson *et al.*, 2015), mobility behaviour (Stephenson *et al.*, 2014) and low-carbon behaviour (Young and Middlemiss, 2012). It is often said that a 'culture change' is needed to achieve a low-carbon future, and this approach helps depict what this might mean.

Figure 4.3: The 'cultures' framework – an integrative model of drivers of behaviour.



Source: adapted from Stephenson et al., 2015.

43 http://www.ieadsmtask24wiki.info/wiki/Main_Page

44 http://www.ieadsm.org/task/task-24-phase-1/

45 Rotmann, S. (2015). Closing the Loop – behaviour change in DSM – from theory to practice. Guidelines and recommendations for New Zealand. International Energy Agency Demand-Side Management Task XXIV http://www.ieadsm.org/task/task-24-phase-1/#section-8

From a 'cultures' perspective, the patterns of behaviour of an individual, household, business or organisation arise from the inter-relationships between what they have, how they think, and what they do. More specifically, their 'culture' consists of the material objects they possess; their norms (particularly their expectations and aspirations); and their practices (their actions and activities). These three factors strongly influence each other to create habitual patterns of behaviour or 'culture'. Applying this concept to carbon emissions, if a person has access to a car, and expects to get to the local shops quickly, then s/he will probably drive there, regardless of high emissions. The 'cultures' of people don't necessarily relate to demographic factors (Lawson & Williams, 2012)[46]. For example, families with similar incomes can have very different levels of emissions due to different lifestyle practices (such as how often they travel by plane or how often they eat meat) (Allans *et al.,* 2015).

While people's GHG emissions are affected by their carbon culture (what they have, think and do) they are not solely responsible for their emissions, as their choices are strongly shaped by influences outside of their control. These include the influences of friends and family; what knowledge and ideas they have gleaned from education and the media; what goods or services are available for purchase; the infrastructure available such as cycle lanes, public transport, and broadband; the regulations and policies of national and local government; and by the relative cost of optional technologies, products and activities. All of these things influence peoples' 'carbon culture' (indicated by the arrows in Figure 4.3). To change someone's carbon culture involves change to at least one of the three factors inside the circle, but this might require change to external influences in order to happen. Conversely, in changing their carbon cultures, individuals may come together with others to influence policy makers and other actors who create the external influences and thereby change these limiting structures (Young and Middlemiss 2012).

The 'cultures' framework helps focus on what external influences might need to change in order to create the conditions in which it is easier to make low-carbon choices. For example, a national household survey (Wooliscroft, 2014) showed that over half of New Zealanders say they would use public transport if it was available to them, and over half would cycle if there were safer routes. If people have these aspirations, then what changes can be made to external influences on behaviour in order to make it easier for them to adopt these new behaviours?

Organisations also have 'carbon cultures' which influence their emissions both from their organisational practices and also embedded in the goods and services they provide. For a business, for example, the combination of physical assets, business practices, and organisational norms, create a 'culture' that might result in a high or low level of emissions. Research has shown that businesses that have become more energy efficient may start with a change in a physical asset (such as a new technology), a change in practices (such as running a process in a more efficient way), or a change in organisational norms (such as deciding to change the business values). Once some aspect of a businesses' culture has changed, it can lead to change in other aspects (Walton, 2015).

Behaviour change can start in many ways. It can result from different choices being made as a result of personal choice. It can be stimulated by intentional changes in factors that shape the decisions made by people and organisations, such as provision of infrastructure, or a price on carbon. And change can also occur as a result of many factors all coming together in unintended ways, such as the changes in Generation Y's driving habits (Box 4.5).

46 Lawson R, Williams J. (2012). Understanding energy cultures. Presented at the annual conference of the Australia and New Zealand Academy of Marketing, December 2012, Adelaide. www.otago.ac.nz/csafe/research/otago055641.pdf Accessed 25.1.16

In other cases, interventions may be needed to change our carbon culture, because even if people think a change is a good idea, it can take a very long time for the changes to reach a level of uptake and scale to have a real impact on emissions. A good example is electric vehicles (Box 4.6).

Box 4.5: Generation Y – a changing mobility culture

Young people are driving less than they used to, and this is occurring internationally as well as in New Zealand. This is not happening because of any particular policy programmes, and it has important implications for reducing carbon emissions from car use in future, if this trend continues.

Research with young Kiwis has shown that it is the result of a number of factors, some of them to do with personal choices, and some to do with external influences.

Young people who choose not to drive typically think that they have more freedom without a car. They don’t like the expense and hassle of car ownership, and they’d rather spend money on an overseas trip or buying a house. They tend to live in cities and use public transport, walking and/or cycling, although they also share lifts with other people and use Uber taxis. They use the internet for shopping and connecting with friends, but it doesn’t replace getting out and meeting up socially. Environmental concerns are often part of the reason for not driving, but they are not the only reason.

The views of young people on driving are a good example of how a shift to low-carbon living often involves many causal factors working together. For policy makers it gives an important message about the importance of ensuring policy and infrastructure is in place to support people’s aspirations to shift to low-carbon transport (Hopkins and Stephenson, 2014).

Box 4.6: Stimulating uptake of electric vehicles (EVs)

EVs could play a part in reducing New Zealand's transport emissions (Section 5.2). Although there were only just over 1000 EVs in New Zealand as of February 2016[47], the global predictions are that the falling cost of EVs together with technological advancements (including improving battery storage) will lead to exponential uptake internationally over the next couple of decades[48]. However, modelling undertaken in New Zealand varies with some showing that uptake is likely to be slow due to the characteristics of New Zealand market, supply chains and policy environment. A further barrier is the tendency of New Zealanders' to hold on to their cars for a long time, and then often buy second-hand. These 'cultural' factors mean that EVs are likely to be slow to come into the fleet, although uptake could be hastened if commercial fleet owners invest significantly in EVs, such as Air New Zealand has recently done[49].

How could uptake be increased? We already know that New Zealanders like the idea of EVs. Survey work has shown that 60% of Kiwis feel fairly positive or very positive about driving EVs; and 75% would be willing to drive them in the future. Nearly 30% said they were already thinking about purchase, and 6% felt ready or nearly ready to purchase (Ford *et al.,* 2015).

The main barriers to purchase were upfront cost, charge time and range. Technology improvements, lower prices and establishing a network of charging stations will assist with these barriers.

A recent report (Barton and Schütte, 2015) identified five measures that could help hasten the uptake of EVs in New Zealand:

- a 'fee-bate' scheme for imported vehicles, providing a price benefit or charge on the basis of the carbon emissions of the vehicle;
- measures to improve public awareness, perceptions and knowledge of EVs as an option;
- measures to encourage the growth of a public charging infrastructure;
- demonstrating a clear policy intent; and
- a sufficiently high carbon price through the ETS to encourage behaviour change.

From a 'cultures' perspective, these are all external influences that can help turn New Zealanders' interest in EVs into a faster rate of uptake. To date, incentives to change behaviour have not been offered in New Zealand other than EVs being exempted road-user charges until 2020.

47 http://www.transport.govt.nz/research/newzealandvehiclefleetstatistics/

48 http://www.carbonbrief.org/blog/2015/03/electric-vehicle-batteries-already-cheaper-than-2020-projections/

49 http://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11606460

4.6 Tourism emissions

Tourism accounts for 5% of total global carbon emissions (Peeters & Dubois, 2010). Air travel accounted for 51% of all global international passenger arrivals in 2011 (IPCC, 2015) and 17% of all tourist travel in 2005 (UNWTO and UNEP, 2008). International aviation has been excluded from Kyoto Protocol obligations (Becken, 2007) and remains outside national emissions inventories due to questions of national accountability. In 2011, aviation accounted for 43% of global tourism transport CO_2 emissions, and this figure is expected to exceed 50% by 2035 (Pratt *et al.*, 2011).

This projected growth poses a particularly acute challenge for New Zealand, being a geographically isolated island nation with a tourism economy that now exceeds 3 million international visitors per annum, most of whom are long-haul travellers. New Zealand's global marketing brand, *100% Pure New Zealand*, has come under increasing scrutiny as a result of the energy intensive nature of the industry (Smith & Rodger, 2009).

The GHG emissions attributed to the air travel of international tourists travelling to New Zealand was calculated by Smith and Rodger (2009) to be 7.89 Mt CO_2-eq in 2005. Tourist aviation emissions are linked to visitor origin (Becken, 2002). New Zealand's European markets comprise 18% of total international visitor numbers, and account for 43% of the emissions associated with international visitor air travel (Smith & Rodger, 2009). Indeed, one return journey from Europe to New Zealand by a single traveller equates to approximately half of the average annual total per capita domestic CO_2 emissions of a European citizen (Smith & Rodger, 2009). This does not account for the fact that aviation emissions are greater than those of CO_2 alone (Penner *et al.*, 1999), requiring an aviation impact multiplier in the range of 1.5–4.0 (Brand & Boardman, 2008). In contrast, visitors from Australia represent 37% of total in-bound visitors to New Zealand, and 13% of tourism related CO_2 emissions.

The position of the aviation industry is that the environmental impacts of flying can be resolved through technology, alternative fuels and operational innovations (Sustainable Aviation, 2011). However the extended design life of aircraft commits society to the most current technology for a period of 30–50 years (Bows & Anderson, 2007). Furthermore, emissions from increased demand for air travel continues to far exceed marginal fuel efficiency improvements in aircraft and engine designs plus operational gains in flight paths and airport logistics (Mayor & Tol, 2010). Without a global market-based mechanism for aviation, the onus of responsibility for reducing personal transport emissions through behaviour change has effectively been devolved to individuals (Barr *et al.*, 2010). Relying on voluntary behaviour change in the public's demand for air travel raises its own issues and challenges (Lassen, 2010). Although there is evidence of public concern over the climate impacts of air travel in sections of some societies (Higham *et al.*, 2016), there is strong evidence of a dissonance between awareness and actual behavioural change (Hibbert *et al.*, 2013; Kroesen, 2013; Miller *et al.*, 2010). This 'value-action' gap (Kollmuss & Agyeman, 2002) is compounded by observations of a particularly entrenched gap between 'home' and 'away', insofar that consumers who engage in pro-environmental behaviour at home tend to suppress, reduce or abandon completely their climate concern when engaging in tourism practices (Barr *et al.*, 2010; Cohen *et al.*, 2013).

Low-carbon tourism transitions

Little traction has been gained in achieving emissions reductions in tourist air travel practices through voluntary consumer-led responses (Miller *et al.*, 2010; Mair, 2011). A variety of options are theoretically available, ranging from encouraging behaviour change via social marketing campaigns and/or 'nudge' initiatives, to the development of restrictive policies based, for instance, on taxation, caps on CO_2 emissions, and/or rationing. A change in consumer demand is required to fundamentally change the nature of tourism demand, in the form of a shift away from frequent, fast travel over long distances for short stays. The New Zealand government may foster low-carbon transitions through market-based, command-and-control and soft policy measures. International aviation emissions, and even maritime emissions from cruise liners, will need to be accounted for in the future (Smith & Rodger, 2009) while fuel taxes/ subsidies may facilitate modal shifts to low-carbon transport (Ryley *et al.*, 2010; Sterner, 2007).

International tourism marketing efforts by Tourism New Zealand, focusing on regional Asia-Pacific markets, could be combined with a renewed commitment to encourage domestic tourism to both reduce distance (and therefore aviation emissions) and, simultaneously, reduce the current loss of tourist expenditure resulting from out-bound tourists[50]. The New Zealand Tourism Industry Association (NZTIA) has an important role to play in encouraging a transition to low-carbon tourism business practices including fostering the uptake of EVs and other more sustainable forms of surface travel. The development of cycle trails provides an example of transition to active transport and to encourage low-carbon visitor experiences. Another area of focus is in assisting Regional Tourism Organisations and tourism businesses to identify and overcome the potential for negative rebound effects (Aall, 2011) and climate change mal-adaption (Hopkins, 2014; Espiner & Becken, 2014). Understanding and responding to the energy consumption patterns of tourism attractions and activities in New Zealand remains both a challenge and an opportunity (Becken & Simmons, 2002).

50 http://www.eco-business.com/news/eco-tourism-better-for-the-planet-better-for-you/?utm_medium=email&utm_campaign=Feb%2024%20newsletter&utm_content=Feb%2024%20newsletter+Version+A+CID_07c3926f446fd65af59290ad773f2140&utm_source=Campaign%20Monitor&utm_term=Read%20now]

4.7 Policy measures to mitigate climate change

There is considerable experience with climate change policies and measures internationally, and some countries have had such actions in place for many years, sometimes to address related problems such as energy efficiency or air pollution. The International Energy Agency (IEA) provides a simple classification of climate change policy measures (Table 4.1).

Table 4.1: International Energy Agency classification of climate change related policy measures[51]

Policy Type	Examples
Economic instruments	Direct investment, fiscal/financial incentives, subsidies, market-based instruments
Information and education	Advice / aid in implementation, information provision, performance labelling, professional training and qualifications
Policy support	Institutional creation, strategic planning
Regulatory instruments	Auditing, codes and standards, monitoring, obligation schemes, other mandatory requirements
Research, development and deployment	Demonstration projects, research programmes
Voluntary approaches	Negotiated public-private sector agreements, public voluntary schemes, unilateral private sector commitments

51 www.iea.org/policiesandmeasures/climatechange

There is abundant evidence internationally that well-framed laws, policies, and regulation are effective and cost effective for many aspects of climate change, and for energy efficiency in particular (Geller et al, 2006). The IEA (2014) identified four key global actions that together have zero net GDP cost and, given appropriate policies, would deliver 80% of the reductions needed to reach an economically optimal 2^{o}C scenario:

- An energy efficiency package.
- Reduction of inefficient coal-fired power generation.
- Phase down of fossil fuel subsidies.
- Reduced methane venting and flaring in upstream oil and gas production.

For New Zealand, this set of key actions needs some re-interpretation but the principles still apply.

History of New Zealand's climate policy approaches

After signing the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, New Zealand began developing climate policy, particularly on energy efficiency activities, information measures, and negotiated GHG agreements (Cameron (2011). Signing the Kyoto Protocol in 1997 accelerated policy development in order to comply with meeting the UNFCCC obligations for the first commitment period from 2008–2012. Energy efficiency, and information and awareness, continued to be favoured as non-price measures, but work was undertaken to develop a low-level carbon charge or tax. The Climate Change Response Act 2002 (CCRA), initially set up a registry for emissions credits, provided powers for the Crown to manage credits, and provided for inventory and the making of regulations. Its enactment enabled the government to ratify the Kyoto Protocol, which came into force on 16 February 2005. In 2002, the government announced a policy package with a carbon charge at its centre. It was accompanied in 2003 and 2004 by negotiated 'projects to reduce emissions' where projects such as wind farms received internationally-tradable joint implementation credits. The proposal for a carbon charge attracted opposition, and, in addition, technical analysis showed that it would have shortcomings in reaching its objectives.

Therefore, in 2007, the Labour government decided to proceed with an emissions trading scheme (ETS) instead (Leining and Kerr, 2016; also see below). It introduced an amendment to the Act for that purpose, which was passed in September 2008. The new National government came to power shortly afterwards, carried out a review, and amended the scheme to make a set of mainly short-term concessions including deferral of the inclusion of agriculture, reduction of the obligations of the transport, energy and industrial sectors by 50%, putting a cap on prices of $25 /t CO_2, and indexing allocation of free units to production for industrial and agricultural participants. On this basis the New Zealand ETS came into effect for transport, energy and industrial sectors on 1 July 2010. Forestry had entered as of 1 January 2008. Further amendments were made in 2012 after another review converted most of the short-term concessions of 2009 into indefinite ones. A number of other countries and regions have established emissions trading schemes; the European Union Emissions Trading System is the largest, that of California is another example, and China also has commenced a scheme in selected regions.

In 2012, New Zealand announced that it would not take a commitment under the second Kyoto commitment period from 2012 to 2020, but would work towards a different kind of international agreement, while setting an emissions target as part of UNFCCC obligations. That curtailed access to international Kyoto units. However, New Zealand remains a party to the Kyoto Protocol and ratified the Doha Amendment to the Protocol prior to the Paris COP 21, but still without taking a commitment. New Zealand produced its 'intended nationally determined contribution' (INDC) in preparation for the UNFCCC Conference of the Parties in Paris in December 2015, and joined the international consensus that emerged in the Paris Agreement (Section 2.2).

New Zealand's Climate change policies

The policy actions that have direct and indirect climate change implications in effect in New Zealand are described at length in the Sixth National Communication to the UNFCCC (MƒE 2013a) and the First Biennial Report (MƒE, 2013b)[52] and can be summarized as follows.

- ***New Zealand Emissions Trading Scheme*** (NZ ETS) under the Climate Change Response Act 2002. The New Zealand ETS is the principal policy response for reducing domestic emissions and the primary mechanism to meet international emissions reduction commitments. (MƒE, 2013a; MƒE, 2015b). It is an economic instrument that produces a price on carbon dioxide and other GHG emissions.
- ***Renewable energy support:*** research funding (e.g. for biofuels and renewable heat); National Policy Statement under the Resource Management

52 The 2nd Biennial report was published at the end of 2015 (MƒE, 2015e)

Act 1991 to facilitate environmental approval of renewable electricity projects; setting a target of 90% renewable sources of electricity by 2025 subject to maintaining security of supply.

- ***Energy efficiency:*** minimum energy performance standards under the Energy Efficiency and Conservation Act 2000; compulsory product labelling; voluntary product labelling; Warm Up New Zealand house insulation retrofit subsidies; business assistance for energy management; government agency leadership; government procurement; EnergyWise information provision.
- ***Transport:*** vehicle fuel economy labelling; commercial fleet advice and driver education; regulations to allow larger trucks; exemption of electric vehicles from road user charges; Auckland rail electrification; Model Communities Programme; investment in public transport and public transport subsidies; investment in active transport such as urban and national cycle ways.
- ***Industry:*** funding CCS research.
- ***Agriculture:*** funding research into reduction of ruminant and other GHG emissions, and into sustainable land management.
- ***Forestry:*** Permanent Forest Sinks Initiative; East Coast Forestry Project (subsidies); the Afforestation Grant Scheme.
- ***Waste:*** Waste Minimisation Act 2008, Waste Minimisation Fund; Resource Management (National Environmental Standards for Air Quality) Regulations 2004 to control landfill gas.

A number of these policies are part of higher-level strategies such as the New Zealand Energy Strategy (2011)[53] , National Energy Efficiency and Conservation Strategy (2011)[54] , Connecting New Zealand (2011)[55] , and Business Growth Agenda (2012)[56].

To this list can be added a variety of actions that are 'decentred' and not entirely government initiatives. They are still in the public sphere however, being in the hands of industry associations, corporations, and non-governmental organizations. Examples are the CEMARS certification scheme (developed by a Crown research institute and used by businesses; Box 4.1) and the Household Climate Action Tool (from Motu, an independent policy research institute; Box 4.4).

Also important in the list of policy measures are the actions of local bodies. Globally, cities and municipalities are becoming very active in working to reduce emissions. There are a number of global initiatives that promote good practice and create opportunities for urban leaders to share knowledge and aspirations.

Members of ICLEI (Local Governments for Sustainability) govern more than 20% of the world's urban population. They aim to make their cities and regions '*sustainable, low-carbon, resilient, ecomobile, biodiverse, resource-efficient and productive, healthy and happy, with a green economy and smart infrastructure*'. The Compact of Mayors has the sole aim of addressing climate change and is the world's largest coalition of city leaders, representing over 450 cities. Under the Compact, cities pledge to reduce their GHG emissions, track their progress and prepare for the impacts of climate change.

A third global initiative is C40[57], a recently established network of the world's megacities committed to addressing climate change. C40 supports cities to collaborate effectively, share knowledge and drive meaningful, measurable and sustainable action on climate change. Auckland Council is a member of C40 and Wellington is one of the Rockefeller Foundation's *100 Resilient Cities*.[58]

Within New Zealand, local bodies have important roles in relation to transport, urban form, housing and their own activities, even though they do not regulate GHG emissions directly.[59]

They also have important roles in relation to adaptation. Local government leaders from across New Zealand launched the Local Government Leaders Climate Change Declaration in October 2015. The declaration calls for urgent action to address climate change for the benefit of future generations, and outlines key commitments by the councils in responding to the opportunities and risks posed by climate change. Individual councils are also developing strategies and actions to reduce emissions, such as Wellington City Council's Climate Change Action Plan 2013.

53 http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-strategies/documents-image-library/nz-energy-strategy-lr.pdf

54 See previous footnote

55 http://www.transport.govt.nz/ourwork/keystrategiesandplans/connectingnewzealand/

56 http://www.mbie.govt.nz/info-services/business/business-growth-agenda

57 http://www.c40.org/

58 http://www.100resilientcities.org/

59 Resource Management Act 1991 ss 70A and 104E as interpreted in West Coast ENT Inc v Buller Coal Ltd [2013] NZSC 87

The New Zealand Emissions Trading Scheme

The NZ ETS is the country's primary policy measure for reducing GHG emissions and encouraging removals or sequestration. It is an economic instrument or market-based instrument that changes behaviour by putting a price on the negative externality of GHG emissions that harm the climate.

The NZ ETS was established after much debate in 2008, under the Climate Change Response Act 2002 (Cameron, 2011). It was designed to be comprehensive: 'all sectors, all gases' with a staged entry of different sectors. Forestry entered in 2008, while the entry of other sectors was deferred for a period, but liquid fossil fuels, electricity production, industrial processes, synthetic gases and waste are now included. Only biological emissions from agriculture remain outside the Scheme. There have been two reviews of the Scheme. Leining and Kerr (2016) provided a detailed history of the ETS and discussed some of the key lessons learned.

A company that is a 'point of obligation' must report estimates of emissions associated with its activity and surrender emissions units to the government. Emissions units of different kinds can be bought and sold, and can be valued depending on market demand and supply. A company can therefore deal with its emissions obligations either by buying emissions units, or by reducing emissions. The forestry sector is encouraged by being able to earn and sell units, while also facing responsibility for emissions from harvest and deforestation, and future technologies such as carbon dioxide capture and storage (CCS) have similar prospects of earning units. The businesses directly affected in the energy sector are generally upstream, in particular the companies importing or producing oil, natural gas, or coal but some large fossil fuel users such as power companies and airlines also choose to participate directly. Industrial emitters, such as cement and steel producers, are direct participants as are forestry businesses (some voluntarily and some compulsorily for deforestation). Most costs are passed on to users, such as when they purchase petrol, diesel, gas or electricity.

The government may issue New Zealand units (NZUs) by direction to the Registrar under section 68 of the Climate Change Response Act after a procedure that provides notice and public information. Free allocations are made under sections 80-86E to companies in emissions-intensive trade-exposed industries such as the production of steel, aluminium, pulp and paper, and greenhouse growers of capsicums, cucumbers and roses. These companies are competing internationally with manufacturers who do not face a price on carbon. One-off free allocations were also made to the holders of fishing quota and of pre-1990 forests to compensate for loss in asset values from the introduction of the NZ ETS. Scheme participants may also claim NZUs for removal activities, mainly via forests, under section 64.

The NZ ETS has a number of strengths in its conception and design being a market-based economy-wide system of imposing price pressure, but at the same time safeguarding flexibility and encouraging innovation. However the current settings mean that its efficacy is extremely limited.

Price fluctuations under the NZ ETS have been greater than many expected. Carbon prices were as high as \$20/t CO_2 in 2010/2011, then dropped to around \$0.20 in 2013/14 (M*f*E, 2015c), but in April 2016 had risen to around \$12 /t CO_2-eq[60]. Even these current values have long been regarded as too low to influence behaviour. For example, the NZ ETS component of the price of diesel is currently around 1.13 cents per litre, and of petrol 0.98 cents (MBIE, 2016a). This small charge, together with uncertainty about future prices, is unlikely to change transport behaviour or reduce emissions. Official recognition of the problem came in analysis that showed that, outside the forestry sector, the NZ ETS has provided no incentive to look at how to reduce emissions, and has had no significant influence on domestic emissions or business decisions (M*f*E 2016).

In November 2015, a third review of the ETS was initiated (M*f*E, 2015c) after government accepted that, on present projections, current policy measures will have little impact on gross GHG emissions in the future if current settings continue. It puts several important and contentious aspects of the Scheme up for debate. However, the continuing exclusion of agriculture from the Scheme is not open for review. One key question in the review is how long to continue the 50% reduction of obligations and the \$25 price cap. Another is how to allocate fresh units, especially under the system of free allocations for companies facing international competition. The review will consider whether emitters should still be allowed to use international units, assuming that they become available again in the 2020s. The past use of cheap international units caused prices to collapse and for companies to purchase credits off-shore and bank several years' supply of NZUs. In accepting that the price signal of the ETS on its own will not drive New Zealand towards a low-emissions economy because other market failures and market barriers may prevent the uptake of opportunities to reduce emissions, the review will consider what role the government should play in addressing them.

Using international units

60 https://www.commtrade.co.nz/ viewed mid-April 2016.

One of the most important settings in the NZ ETS, until it was modified on 1 June 2015, was the rule that allowed New Zealand companies to use international units to meet their obligations under the Scheme with no quantitative limit. The unit that particularly influenced carbon prices under the NZ ETS was the Emission Reduction Unit (ERU) under Kyoto Protocol Joint Implementation (JI) projects. Most of those units purchased and used as offsets by New Zealand participants (over 90%) came from the Russian Federation and Ukraine. In 2014, New Zealand participants relied on ERUs for 73.87% of the total units that they surrendered. They relied on Certified Emission Reductions (CERs), another international unit, for a further 21.70%. Together these total 95.57% of the total units surrendered (EPA, 2015).

Few of these units were environmentally credible as most of them did not really represent emission reductions anywhere in the world. A thorough study by the Stockholm Environment Institute has recently investigated ERUs in detail, analyzing a random sample of 60 JI projects and a number of other sources of information (Kollmus et al, 2015). It inquired particularly whether ERU projects provided a genuine reduction in emissions that was additional to the emissions that would otherwise have occurred in countries with a surplus of assigned amount units. This 'additionality' is central to the claim that ERUs actually represent emission reductions. The study found that the claims for additionality were not plausible for 73% of the ERUs issued and were questionable for another 12%. Most (80%) ERUs came from JI project types of questionable or low environmental integrity, and 90% came from Russia and Ukraine[61] where the environmental integrity of units is at its lowest. Auditor organizations were not performing their duties properly and national authorities had few incentives to ensure environmental integrity. The study concluded, inevitably, that crediting mechanisms in general, including for units like ERUs need to be designed very carefully to ensure environmental integrity.

Because of this problem, from 2013 the European Union tightly restricted the use of ERUs in its EU ETS (Woerdman, 2015). In contrast, New Zealand continued to accept them in the NZ ETS until it was prevented from doing so because of its decision for the period 2013–2020 not to enter into the Kyoto Protocol 2 obligation. New Zealand companies have not been able to surrender ERUs since 31 May 2015. The rush to use ERUs meant that companies could 'bank' their NZUs, so there is several years' supply overhanging the New Zealand market. The past use of ERUs therefore could continue to depress New Zealand carbon prices for a significant period, and their use unfortunately meant that New Zealand showed compliance with its international obligations by relying on units that had no real environmental integrity. Nevertheless, the New Zealand government has declared that it intends to meet its future emission reduction targets through a mix of the removal of carbon dioxide by forests, domestic emission reductions, and a return to some degree of reliance on international carbon markets units. For example, modelling commissioned by the Ministry for the Environment on how to cost-effectively meet the INDC target suggests that, based on the assumptions made, the reliance on international units could meet four-fifths of the emissions reduction target (Infometrics, 2015).

The New Zealand government made a provisional intended contribution in its INDC in mid-2015, with one of the conditions being '*Unrestricted access to global carbon markets that enable trading and use of a wide variety of units that meet reasonable standards and guidelines to: ensure the environmental integrity of units/credits generated or purchased; guard against double-claiming/double counting, and ensure transparency in accounting*.' The Paris Agreement in Article 6 agreed to the use of 'internationally transferred mitigation outcomes' (ITMOs) subject to a process of elaboration of rules. The rules about the environmental integrity of future units are yet to be determined and will be important for the operation and credibility of the NZ ETS. Several processes for funding and assigning credit for credible international mitigation are being developed in parallel. It is likely that more than one mechanism will operate simultaneously. Trading may happen bi-laterally or in 'clubs'. New Zealand could contribute to the development of effective approaches.

Free allocation of units

Another significant policy setting in the NZ ETS, as noted above, is the provision by the government of free NZUs to companies producing internationally-traded manufactured goods that are emissions-intensive and with trade-exposed activities. These companies are competing internationally with manufacturers who do not face a price on carbon and who either import goods into New Zealand or compete with our exporters. The free allocation of 'industrial allocation' NZUs made periodically by the government, maintains the competitiveness of these companies by reducing emissions cost of additional production under the NZ ETS. They do not affect incentives for companies to improve the emissions efficiency of their activities. In 2014, 4.4 million NZUs were allocated to businesses, compared to a total of 29.8 million units surrendered. The allocations are intended to be a temporary measure that will enable

61 Forthcoming report from Morgan Foundation

industries to adjust over time. The ETS review that is under way has asked what future conditions would warrant reducing the rates of free allocation, and when that may be (MfE, 2015d).

NZ ETS carbon price working with other policy measures

The carbon price that is established by the NZ ETS is central to its success as a mitigation policy, but that price will be more effective in combination with other policy measures that operate in different sectors. New Zealand's approach to climate change policy tools needs to take into account the many different social and economic dimensions that are involved in mitigation; GHG emissions are fundamental to our society and economy. Recognizing this complexity implies not relying entirely on the price signal of the ETS. To achieve effective and efficient change, other policy tools are also likely to be needed. In fact, internationally, broad economy-wide policies such as carbon pricing are not usually implemented without other sector-specific policies being implemented as well (regulation in particular). In many countries regulatory approaches and information measures are widely used, and are often effective (IPCC, 2014b).

A carbon price is generally considered necessary for enabling least-cost emissions reductions, and should be the cornerstone element of a climate policy package, but on its own it is not sufficient (Hood, 2013). Certainly, carbon prices across the economy can change behaviour if they are high enough. But there are non-price barriers (such as split incentives, lack of information, lack of capital, adversity to risk) which is why some carbon abatement actions have a negative cost. Non-price barriers can affect behaviour and prevent prices from being effectual.

Such non-price barriers are especially evident in energy efficiency, where good potential for decarbonisation is to be found. The difference between the actual level of energy efficiency and the higher level that would be cost-effective from the point of view of an individual or firm is described as the 'energy efficiency gap'[62]. Carbon pricing is a pre-requisite for least-cost action to help reduce this gap, but it is not enough to overcome all the barriers to cost-effective actions (Ryan *et al.*, 2011). In other words, barriers include information costs, high discount rates and lack of access to capital. Market failure barriers include imperfect information, principal-agent relationships, and split-incentive situations. Within an organisation, decisions about energy and carbon matters may be associated with people with low power and status, so given little attention. In addition, as discussed in Section 4.3, behavioural science identifies other barriers, such as the form and framing of information, the credibility of informants, inertia, and values.

A different situation where carbon pricing is unlikely to be enough is around novel technologies, such as advanced biofuels from waste wood, carbon dioxide capture and storage, deep geothermal energy, ocean energy[63], or hydrogen fuel. Many such innovative technologies remain very costly ways to reduce GHG emissions while they are still evolving and we are learning how to use them most efficiently. Even if the NZ ETS produced a very high carbon price, it might not be sufficient to give those technologies an economic advantage. However, in the long term they may provide important options for decarbonisation. In the mean time they need financial and regulatory support measures to promote research, development and early deployment.

In other situations, different policy instruments sometimes need to be directed at different aspects of behaviour in a sector. For example, making electric vehicles cheaper with a grant or subsidy reduces their up-front capital cost (which can help facilitate early adoption and hence learning and network building), while the emission price increases the running costs of an internal combustion vehicle and hence brings forward decisions about retiring an inefficient one. In addition, some measures can provide multiple co-benefits; for example, a measure to encourage public transport and non-motorised active transport is likely to address objectives in public health, air quality, and congestion as much as climate change objectives. Furthermore, existing policies and laws should be reviewed in order to identify provisions that may inadvertently encourage high carbon emissions. 'Silver bullet' policy-making is not realistic. Policy complexity is necessary and inevitable, and requires careful crafting to ensure an integrated and synergistic policy landscape. So a broad conclusion is that multiple policy measures must be brought to bear, and that additional policies must be carefully designed to address market failures relating to innovation and technology diffusion (IPCC, 2014a Chapter 13).

In summary, the carbon price created by an economic instrument such as the NZ ETS is important, and with suitable settings, can be a very effective means of modifying behaviour and reduce emissions. But it often needs to be accompanied by measures targeted to particular problems. Even with a carbon price, market barriers and other market failures prevent cost-effective actions such as installing insulation. Different policy instruments all have different roles to play.

62 Sanstad et. al. (2006); IEA (200b); Sorrell (2004)

63 http://www.awatea.org.nz/ and http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch06.pdf

4.8 Enabling policy development

It is important to consider the overall national framework for the making of climate change policy. The framework for policy-making shapes the way that individual policy options and implementation are considered in order to support widespread GHG reductions. A sound over-arching policy framework is all the more necessary because climate change pervades so many different aspects of society and the economy. Public policy of any kind should be formulated in ways that are open, well-informed, systematic, effective, efficient and equitable (Scott and Baehler, 2010). Good policy-making entails gathering relevant information, identifying problems, setting objectives, choosing policy instruments to reach the objectives, implementation, and then monitoring to see if the policy instruments are working. Climate change policy arrangements can be considered in the light of such criteria.

Present climate change policy arrangements

The present institutional arrangements for climate change are relatively conventional. The Ministry for the Environment (MƒE) is the lead agency for climate change policy, and the Ministry of Foreign Affairs and Trade (MFAT) is the lead agency for international negotiations, both agencies being responsible in these respects to the Minister for Climate Change Issues. The NZ ETS is administered by the MƒE (MƒE, 2015e), working alongside the Environmental Protection Authority and Ministry of Primary Industries. A number of other departments and agencies are necessarily involved with respect to the many ramifications of climate change, in the economy and in the energy, (including efficiency), transport, agriculture and forestry sectors. Climate change presents an enormous problem of coordination of the work of the multiple agencies involved. Several ministers have important roles alongside the Minister for Climate Change Issues. The Climate Change Response Act 2002, the primary legislation on the issue, has detailed provisions for the establishment and operation of the NZ ETS, but in respect of other aspects of climate change policy it is less detailed.

It is important that policy-making provides individuals and businesses with a reasonably clear picture of the nature and evolution of policy far enough into the future to provide confidence over investment horizons. Concerns about regulatory certainty around the NZ ETS were highlighted by Richter and Chambers (2014) and by a survey of personnel from different sectors who agreed there needed to be long-term signals of stability and surety in the policy settings around the NZ ETS for it to influence business decisions (MƒE, 2016).

Another issue is how climate targets are set and how measures are put in place to achieve them. At present, there is not a strong linkage between emissions targets and the policy actions that will allow them to be achieved. The INDC Discussion Document (MƒE 2015d) took the position that domestic policies and measures to achieve the target were a separate matter from the setting of the INDC target for the Paris negotiations in 2015. The target was therefore not accompanied by the indication of any suite of measures that would ensure that it could be reached. The Climate Change Response Act 2002 provides for the setting of a target but it says very little about its purpose or effect, or about the process in which targets are to be set. Only one of New Zealand's targets has been set through the statutory procedure. The Act does not require a target to be accompanied by the development of projections, carbon budgets, strategies, or plans that will lead to achievement of the target[64]. The Climate Change Response Act requires certain reporting and monitoring to occur, but it is aimed primarily at international responsibilities rather than national ones, and there may be room to improve its support for sound national policy development. Similarly, the Act provides for reviews of the NZ ETS, but not of climate change policy generally, and not on any particular schedule. It is arguable that policy coherence can be improved (Macey, 2014).

International expert review teams under the UNFCCC have reported on related shortcomings in New Zealand's projections, policies and measure (PaMs), and monitoring. The review by the UNFCCC (2014) of our First Biennial Report noted that New Zealand had not reported the mitigation actions it planned in order to reach the conditional target of 2020; did not explain how progress with PaMs is to be monitored; and did not provide a quantified estimate of the impacts of most individual PaMs. The team recommended that New Zealand provide a full list of the individual PaMs that are in effect, and encouraged New Zealand to provide a projections scenario showing the pathway to its 2020 and 2050 targets, linked to a set of additional planned mitigation actions for meeting those targets. This concern with the lack of information about PaMs, quantitative estimates of their impacts, their monitoring and evaluation, and institutional arrangements echoed the earlier report of the In-Depth Review of New Zealand's Fifth National Communication (UNFCCC, 2011). Issues of this kind indicate that there are opportunities for improvement in how we make climate change policy in New Zealand.

64 Allocation plans are authorised under s 70, but only in relation to forestry and fishery activities.

On the other hand, the more recent Second Biennial Report (MfE, 2015e) provided quantified estimates of the effects of some specific PaMs. It also stated New Zealand is likely to meet our unconditional 2020 target of 5% below 1990 emission levels without additional mitigation actions[65] (largely based on forest removals and carry-over NZUs). Issues of this kind indicate that there may be opportunities for improvement in how climate change policy can be developed in New Zealand.

Comparisons

Insights about improvements in the framework for climate change policy can be obtained from comparisons, firstly with other fields in New Zealand, and secondly with climate change policy frameworks of other countries.

Other New Zealand Policy Processes

One interesting comparison is how New Zealand develops policy for public finances. The budgetary cycle is a field where policy making is subject to a well-defined set of actions under the general rubric of fiscal responsibility. Ministers and departments proceed through established processes for information disclosure, reporting, statements, and decision-making. In the Budget Policy Statement, usually published in November or December, the government must indicate the high-level financial and policy priorities that will guide the preparation of the Budget that will appear some months later. This reduces the likelihood of surprises and improves investment confidence. The main requirements are set out in the statutory form of the Public Finance Act 1989 that provides stability and predictability and embodies social and political commitment while leaving the setting of the policy itself firmly under the control of the relevant department and minister.

Environmental management also makes a useful comparison. The Resource Management Act 1991 directs national, regional and territorial authorities to set objectives and make strategies, policies, and plans that are appropriate to achieve those objectives. This is a tighter connection than exists at present between climate change targets and PaMs since RMA authorities are required to develop an information base about issues before setting the objectives. There are ample opportunities for public participation and challenge of proposals, but within a framework that seeks to provide transparency along with effectiveness.

In energy efficiency and renewable energy policy (a field related to climate change), there is a process of setting five-yearly strategies including policies and objectives, supported by targets that are 'measurable, reasonable, practicable, and considered appropriate by the Minister' as stipulated by the Energy Efficiency and Conservation Act 2000. The target is a clear statement of government intentions in the field, for which specific policies are designed. Decision-makers under other legislation such as the RMA are in some circumstances required to take the New Zealand Energy Efficiency and Conservation Strategy into account in their work.

Collaborative planning or governance may have some attraction as a template for climate change. The main New Zealand example, the Land and Water Forum, has had significant successes building social capital and establishing consensus between different stakeholders in the freshwater management sector (Sinner and Berkett, 2014). It has made recommendations that set the limits and paved the way for essential government action on water quality. However the relationship between the Forum and ministers and ministries has not always been easy. The idea of establishing a Climate Change Forum or similar body is under discussion. However collaborative governance has significant limitations, which would need to be considered carefully in making any proposal for a climate change collaborative governance forum. For example, whether the forum is to be purely advisory or would carry out actual governance would need to be determined, and so would its procedures such as in respect of confidentiality. Its role in relation to conventional governmental processes would need to be well thought out. Furthermore, it is not clear whether climate change is a sectoral issue with clearly identifiable stakeholders; it may be too spread through society and the economy for collaborative governance to work well.

Climate Change Policy Processes Overseas

Two overseas comparisons illustrate possibilities for improving climate change policy processes.

1. *United Kingdom.*

The Climate Change Act 2008 sets the national target for 2050, but it allows for amendments by the Minister if justified as a result of significant developments in scientific knowledge about climate change or in European or international law or policy. The Act requires the Minister to set carbon budgets for five-year periods that will lead to achievement of that 2050 target. This process of setting carbon budgets supports the long-range target by clarifying what needs to be done, in what time period and what will be the sector contributions, thereby making the target-setting a more meaningful exercise.

65 http://www.mfe.govt.nz/climate-change/reporting-greenhouse-gas-emissions/latest-2020-net-position

- The timing and procedure for budgeting (and for amending the 2050 target) are set out in the statute, ensuring that the process is predictable and open.
- The matters that the Minister must take into account in making a budget are carefully specified.
- The Minister must report an indicative annual range for the net UK carbon account for each year in the budget period.
- Critically, the Minister must prepare proposals and policies that will enable the carbon budgets that have been set under the Act to be met, and must report to Parliament on their carbon budget and economic effects;
- The Minister must report emissions annually against budgets, and must produce periodical reports on the impact of climate change and on progress in adaptation to that impact.

The UK Act 2008 established the *Committee on Climate Change*[66] to provide evidence-based expert advice to the government and Parliament. The Act gives the Committee considerable independence and the Minister is obliged to obtain the Committee's advice, and take that advice into account when setting carbon budgets, revising targets, and impact reporting. The Committee operates openly and its advice is made public. It reports on progress towards meeting budgets, carries out its own research and analysis, and engages with a range of organizations and people.

The UK Act was a major institutional innovation, intended to promote political commitment and investor confidence, and to give policy reform a better chance of enduring. It has survived a change of government and has ensured that the process of setting carbon targets and budgets continues, even if sometimes surrounded by controversy (Lockwood, 2013).

2. *California*

The state has been active for decades on air pollution, GHG mitigation, energy policy and energy efficiency, but in 2006 the State Legislature enacted umbrella legislation, the Global Warming Solutions Act that prescribed the procedure for setting a target for 2020 GHG emissions, and authorized regulations to be made for a wide range of emissions reduction measures. It authorized the California Cap and Trade Regulations and designated the Air Resources Board as the agency primarily responsible, directing it to develop a Scoping Plan, which is the state's main strategy for action on climate change and updated every five years. New targets for emissions reductions by 2030 and 2050 have been set by executive order and are reflected in the updating of the Scoping Plan. The Air Resources Board works with the California Energy Commission (CEC), California Transportation Agency, California Public Utilities Commission, and other agencies that provide support through sophisticated planning and regulatory processes, such as the Integrated Energy Policy Report of the CEC. Again, this example shows how the processes of developing climate change policy can be institutionally embedded in legislation, promoting stability, commitment, and investor confidence.

Options for Climate Change Policy Development

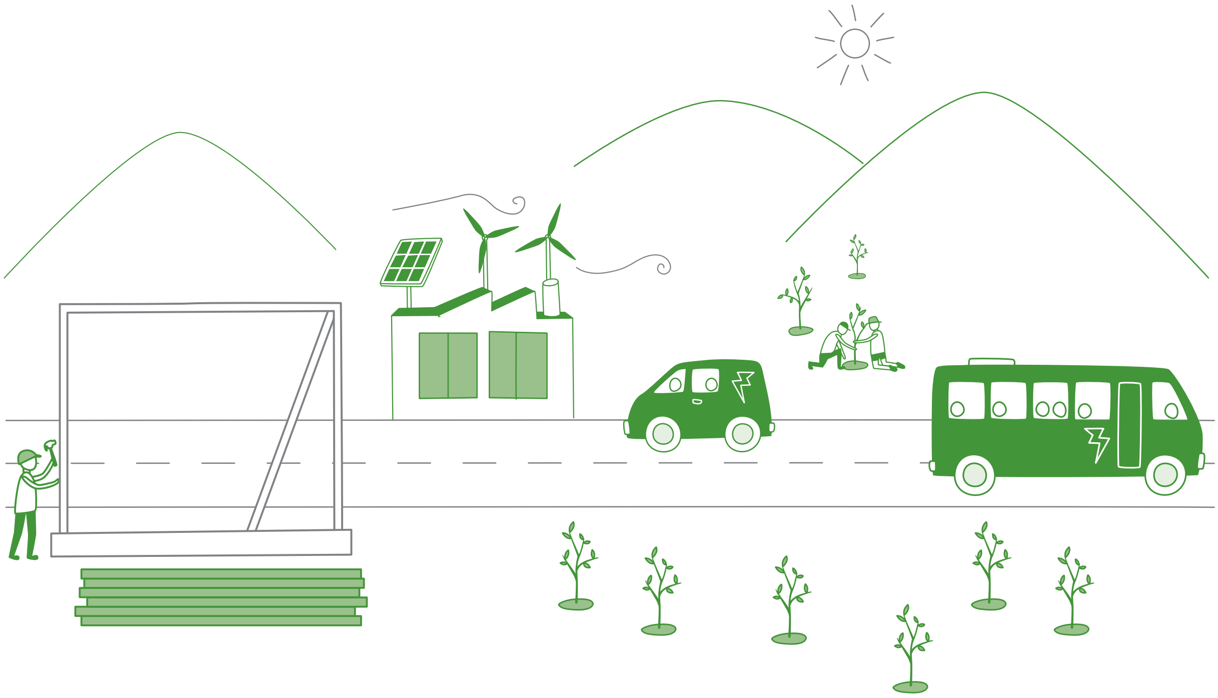
While every country has a unique set of circumstances, the comparisons above suggest that there are a number of options used in different jurisdictions that apparently improve policy-making and implementation and that could be applied in New Zealand. For example:

- providing clearly-defined processes, such as in legislation, to promote systematic cycles of climate change policy making;
- making arrangements stable and predictable to improve confidence in the regulatory system and to improve investment certainty;
- linking the setting of targets, caps, pathways and corridors for emissions more directly to the selection and analysis of the policies and measures that will enable them to be achieved or followed;
- aligning the NZ ETS better with other national and local policies and measures;
- coordinating climate change policy among the many national and local authorities involved; and
- making climate change policy in a way that best promotes understanding, participation, acceptance and support by the public in order that ambitious targets can be set.

66 https://www.theccc.org.uk/

Section 5: Sectoral mitigation options

Greenhouse gases (GHGs) can be practically reduced in each sector in the short to medium terms based on current technology development and the existing limited knowledge of comparative costs and behavioural change. The overall goal is to eventually reduce GHGs to zero for each sector. Due to a dearth of literature on uncertainties, risks, cultural aspirations and costs for most sectors, it was not possible to undertake detailed analyses, advocate a least cost pathway, or assess how we might optimise priorities for action within the future constraint of reducing GHG emissions. Removal of CO_2 from the atmosphere by forests could be increased by both additional planting and enabling regeneration of natural forests.



5.1 Heat and power supply

Key messages

- Around 80% of New Zealand's electricity is generated from renewable sources (primarily hydropower).
- This can be further increased, cost effectively, to reach 90% by 2025 – New Zealand's renewable electricity target.
- Technically renewables in the mix could achieve close to 100% without reducing the reliability and security of the power grid. However, very high penetration that includes high shares of variable renewable energy systems would need a more flexible grid, energy storage, and back-up generation (possibly thermal plant) to meet seasonal peaks, especially in dry years when hydro is constrained.
- Even 100% renewable electricity would not be zero-carbon since some subterranean CO_2 is released during geothermal generation.
- Distributed generation systems and 'smart grids' are expected to become more common by overcoming technology integration issues, though the rate of deployment could be constrained by the structure of our electricity market.
- Cost effective options in the heat sector to reduce or prevent GHG emissions, including the greater uptake of biomass, solar and geothermal resources to displace coal and natural gas, are not being fully realised.
- Heat accounts for 28% of consumer end-use energy yet is generally ignored in energy policy that has been dominated by electricity (with lower total end-use energy).
- The co-benefits from installation and operation of renewable energy plants are often significant and should be included in decision making alongside the energy cost evaluation.
- An increased uptake of renewable energy projects would probably be the outcome of an increased carbon price ($ /t CO_2) being placed on emissions from thermal generation of heat and electricity.

The term 'energy supply' embraces all fuels and energy carriers used by all sectors. However, this section covers mainly heat and electricity supply with energy for transport discussed in Section 5.2. Since the heat and electricity is consumed by other sectors, mainly buildings and industry, allocation of the GHGs has to be made (see Figure 3.2).

Sources of GHG emissions

Where does our electricity and heat come from?

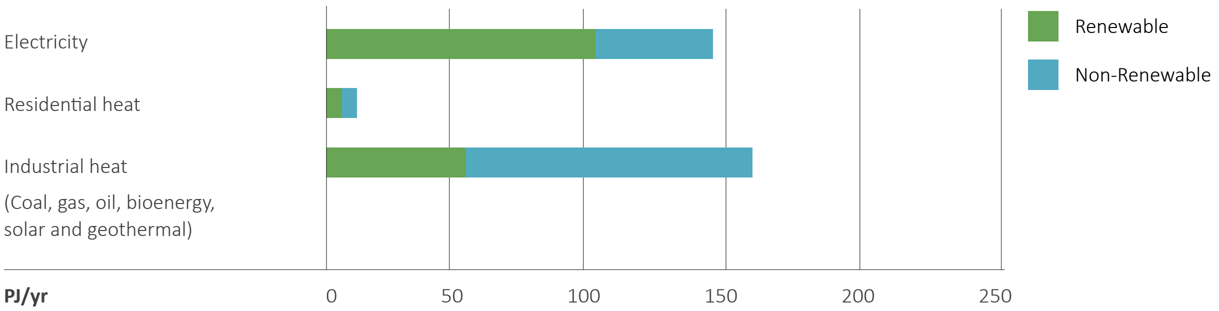
Fossil fuels continue to dominate New Zealand's energy supply with approximately 60% of primary energy coming from coal, oil and gas and the remaining 40% from renewable energy sources.[67] When natural gas and coal are combusted they produce heat which can be used directly in buildings or for process heat for industry, or used to raise steam that drives steam-turbines for generating electricity. Renewable energy already has a high share of total electricity generation but lower shares of the heat markets (Figure 5.1).

Demand for consumer energy grew steadily from 1990 to 2005, since when it has levelled off, but the consumer energy supply mix has changed relatively little (Figure 5.2). Total electricity demand has also stabilised, growing by around 0.2% per year, on average, in the past decade, although the shares of renewable energy generation have recently grown, partly displacing coal-fired and natural gas-fired thermal power plants. Buildings use around 56% of total electricity generated, industry 37% including 17 percentage points by basic metal processors, including the Tiwai Point aluminium smelter, and 7 percentage points by wood processors. Energy efficiency improvements across all end-use sectors saved New Zealand around 10 TWh of electricity from 2001 to 2011 (MBIE, 2015).

For heating for use by industry and for space heating of buildings, the main sources have been from the combustion of natural gas, coal and biomass, plus a little geothermal (Figure 5.2). (Oil dominates consumer energy demand being used mainly for transport of people and freight, domestically and internationally; Section 5.2). The combustion of biomass has increased 70% since 1990 with 12% of dwellings now burning some firewood and 20% of installed heat plant capacity in the commercial and industrial sectors being fuelled by biomass. Geothermal direct heat is used for greenhouse heating, shellfish farming, kiln drying of timber, and with the wood pulping plant at Kawerau being the largest industrial user of geothermal heat in the world.

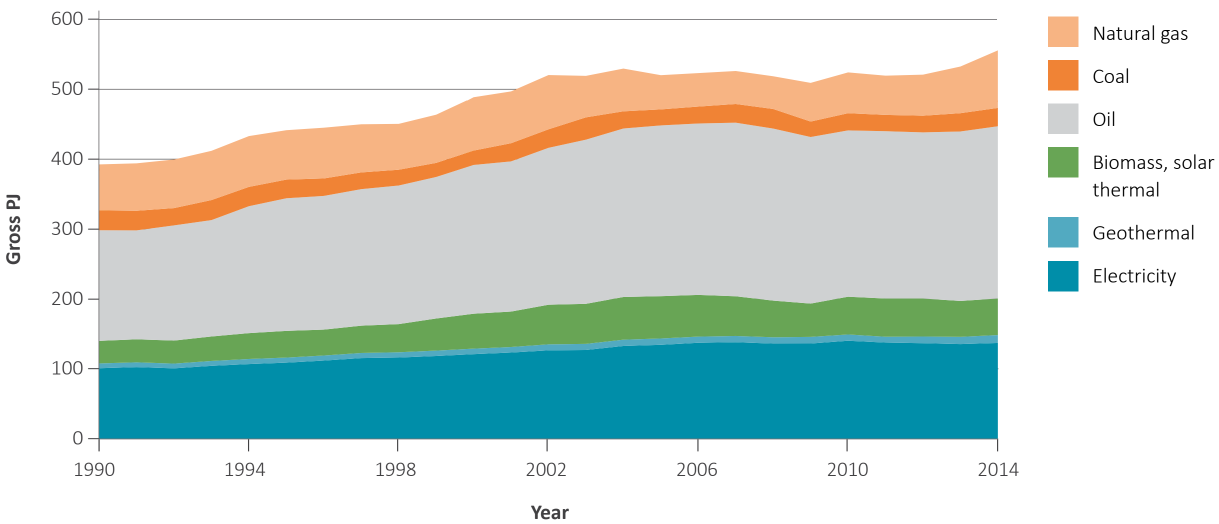
67 Includes geothermal at ~10% efficiency (200 PJ primary energy gives 20 PJ consumer electricity). Hence, quoting primary energy levels can be misleading as it varies with the accounting method employed (IPCC, 2011 Annex 2).

Figure 5.1 Renewables had around an 80% share of electricity in New Zealand in 2013 with consumer heat energy demand being met mainly by fossil fuel combustion together with some renewable bioenergy (including domestic firewood), solar and geothermal sources.



Source: MBIE (2014).

Figure 5.2 New Zealand consumer energy demand by fuel from 1990 to 2014.



Notes: 'Natural gas' and 'Coal' as shown are when combusted to provide direct heat supply. When combusted in thermal power plants they are included under 'Electricity' as are renewable hydro, wind, bioenergy, solar power and geothermal. 'Biomass, solar thermal' and 'Geothermal' as shown also provide direct heat supply.

Source: MBIE (2014).

In 2014, New Zealand had almost an 80% share of electricity generation from renewables (Figure 5.3), one of the highest in the world. This share has grown from around 60% in 2005 without any external incentives or direct government subsidies[68]. Around 9,400 MW_e of total electricity generating capacity was installed and actively generating in 2014 (MBIE, 2015). A further 5,000 MW_e or more of renewable electricity generation capacity is either planned or consented (MBIE, 2016a).

In 2014, the national peak power demand was approximately 45% higher than the average electricity demand. Lowering this peak can help reduce the need to invest in additional generation capacity, make it easier to reach the 90% renewable electricity target, lower the needs for future investment in distribution line capacity, and help make electricity cheaper to generate overall. In addition, the uptake of electric vehicles (EVs including E-cars, E-buses and E-cycles) could affect the peak. These will require regular recharging, often at off-peak times, so could help flatten the demand curve which could help improve the overall efficiency of operating the New Zealand electricity system. This could be coupled with solar PV generating systems and demand-side management of appliances operating in a 'smart-grid' (SGF, 2015) although issues of meeting seasonal peaks, especially in dry hydro years will have to be addressed (see opposite).

The average 2014 domestic electricity tariff at ~$0.29 /kWh was 10th lowest in the OECD countries and the average industrial tariff at ~$0.08 /kWh was 4th lowest. Included in these tariffs are line charges imposed by both Transpower, for high-voltage transmission, and by the 29 line companies to meet local, low-voltage distribution costs. Fixed line charges are typically around 40% of a total domestic account. Based on these domestic tariffs, the cost of recharging an electric vehicle equates to a gasoline fuel price for travelling the same distance of around $0.30–0.40 per litre equivalent[69] (assuming the crude oil price is around USD 50–60/ barrel (bbl)).

To meet the total 170 PJ heat demand in 2014, around 100 PJ came from natural gas. New Zealand's remaining reserves of natural gas and LPG were around 8900 PJ in 1990 but had declined to around 2900 PJ by 2015 (MBIE, 2015). Around 30% of the total annual LPG production of around 10PJ is exported. The production profile from existing gas fields has been forecast out to 2050 (Figure 5.4) although the production-to-reserves ratio changes over time due to new extraction technologies and exploration successes[70].

For every 100 PJ of natural gas combusted, whether for electricity generation or direct heat, approximately 6.4 Mt CO_2 is emitted. Displacing natural gas (or coal) by using more renewables for heat generation will reduce these emissions. In 2013, over 65 PJ (38%) of heat demand was met by renewable sources (Figure 5.1), mainly biomass residues used by the wood processing industry on-site. Also, domestic heating with firewood was employed as one method of space heating in over one third of New Zealand households. Biomass resources, together with solar thermal and geothermal resources could be utilised to meet the total heat demand. For example, Miraka's milk drying plant buys heat from the nearby Mokai geothermal field to provide direct ultra-high temperature process heat[71]. Also, Christchurch International Airport is heated and cooled using a ground source heat pump system that could be replicated in many other buildings throughout New Zealand since a direct geothermal heat source is not required[72].

Industry is the main heat and electricity consuming sector in New Zealand, accounting for around 60% of total end-use demand in 2014 (Section 5.4), with around 18% used in residential buildings, 15% in commercial buildings (Section 5.3), 6–7% in the primary production sector (Section 5.5), and a small amount of electricity used for rail, trolley buses in Wellington, and a growing demand for electric road vehicles (Section 5.2) (MBIE, 2015).

68 In past decades the main hydro power plants and the Wairakei geothermal plant were developed by the government of the time using public funding.

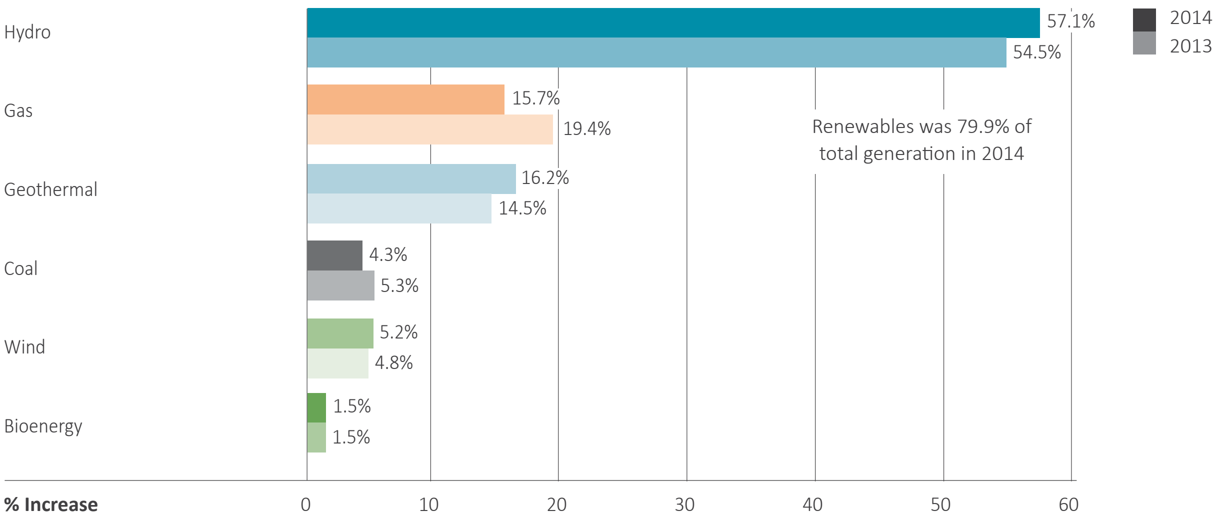
69 https://www.energywise.govt.nz/on-the-road/electric-vehicles/

70 http://gasindustry.co.nz/work-programmes/gas-transmission-investment-programme/supply-and-demand/long-term-gas-supply-and-demand-scenarios/

71 http://www.tuaropaki.com/our-business/dairy-processing/

72 http://www.irhace.org.nz/uploads/2015ConferencePresentations/Graeme%20Wills%20-%20Justin%20Hill%20PDF.pdf

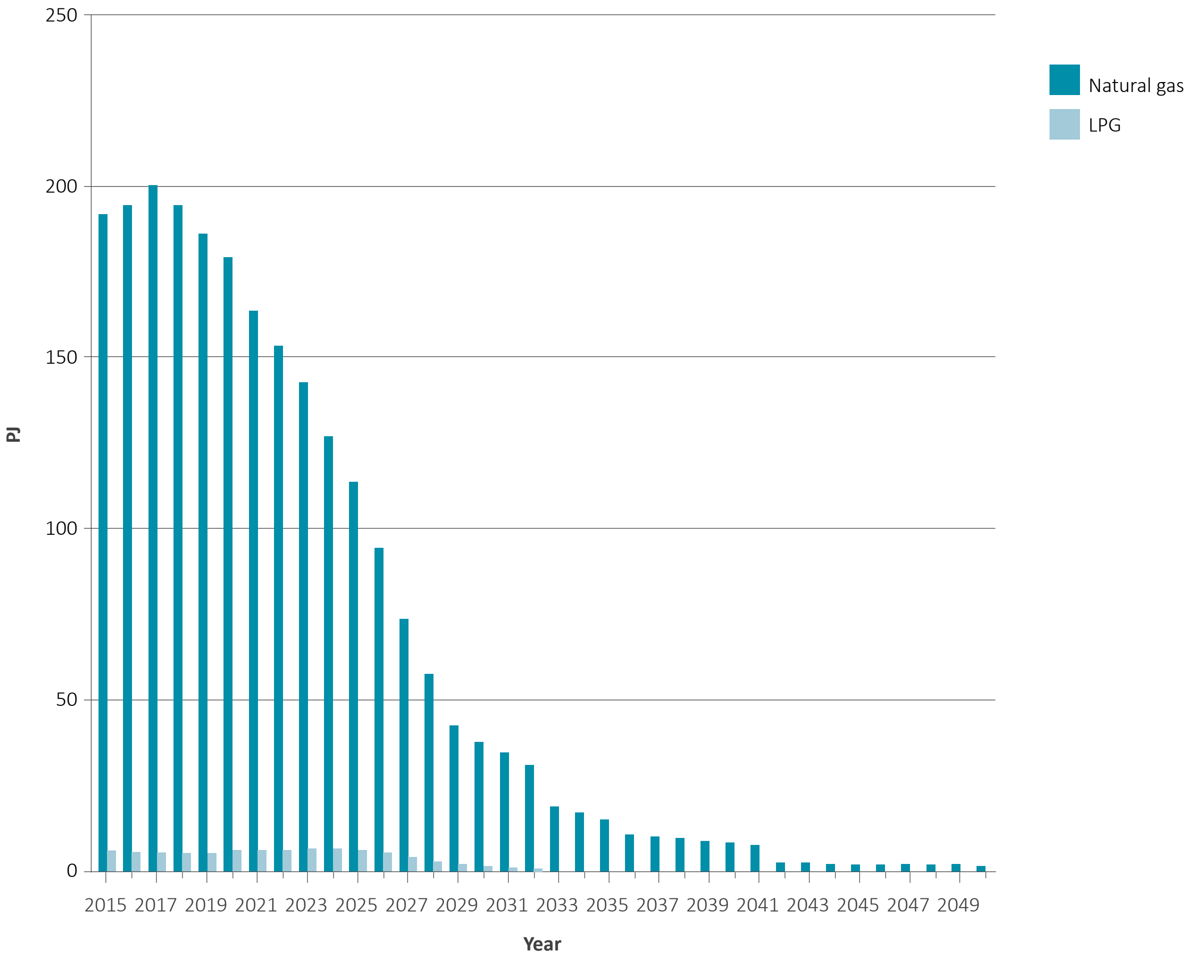
Figure 5.3 Shares of electricity from renewables in 2014 (42,231 GWh) increased from 2013 as coal and gas generation shares both declined.



Solar PV not shown = 16 GWh or 0.04% total generation

Source: MBIE (2015).

Figure 5.4 Production profiles as forecast for natural gas and LPG from existing fields between 2015 and 2050.



Source: Based on MBIE (2005).

Global GHG emission trends for the sector

Where do most global GHG emissions come from?

Globally, 63% of total GHG emissions are produced by the energy sector (including energy for transport), mainly as CO_2 emitted during the combustion of fossil fuels. By way of comparison, New Zealand's emissions from energy supply (including energy for transport) account for around 44% of total GHG emissions (Section 3).

To avoid a future average global temperature rise of more than 2°C, decarbonisation of the global electricity sector is needed by 2050, which will be easier to achieve than decarbonising the heat or transport sectors (IPCC, 2014c). This is especially so if carbon dioxide capture and storage (CCS) eventually proves to be successful and economic (Box 5.1).

Box 5.1: Carbon dioxide capture and storage (CCS) and links with bioenergy (BECCS)

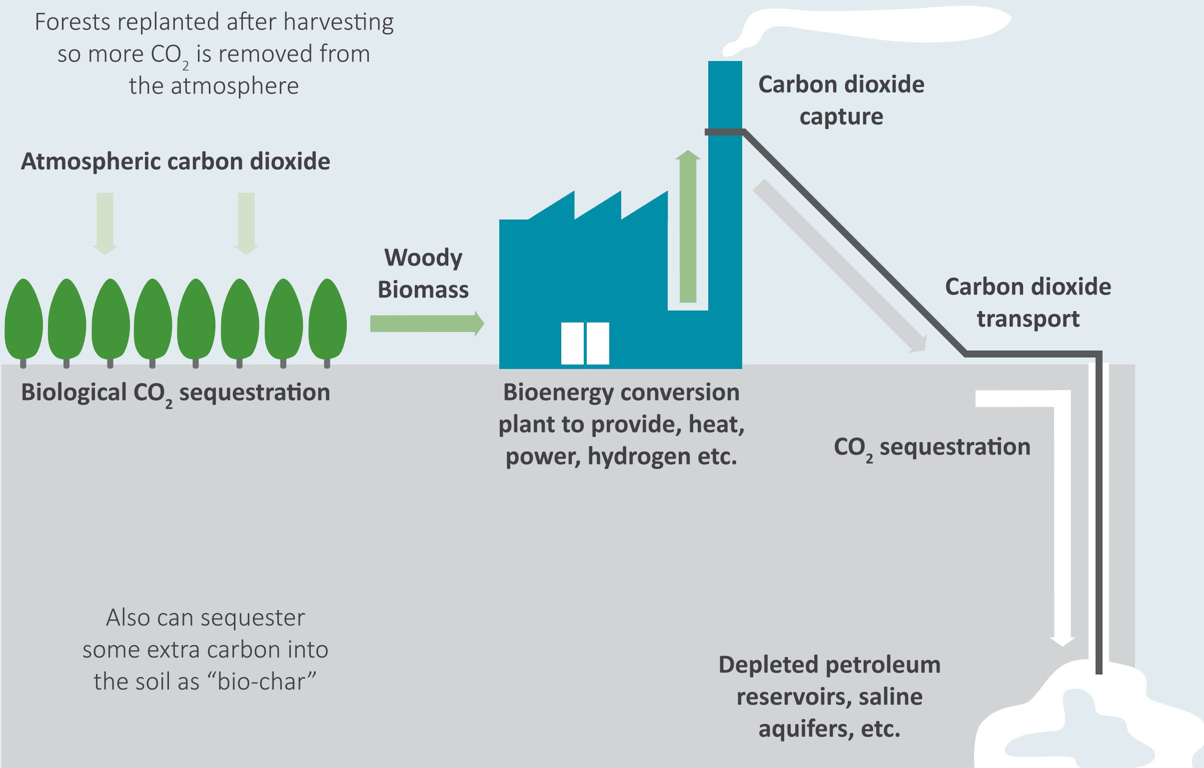
Large, single point sources of CO_2 emissions offer CCS opportunities for new power plants or by converting existing coal-fired and gas-fired power plants to be CCS compliant. At present, only one coal-fired power plant exists with CCS[73] but, being the first, it is fairly expensive. CCS can also be applied to industry applications (Section 5.4).

If CCS technology can ultimately be proven to be economically feasible with reduced energy input, and also be applied in association with the combustion of biomass for electricity generation (using any forest or crop biomass to supply the fuel but ensuring it is replanted soon after harvest), then the combination of coupling bioenergy with CCS (known as BECCS) may offer the most likely route to producing negative emissions before the end of this century (Figure 5.5).

Many integrated assessment models show this is necessary in order to keep global temperature rise below 2°C unless more ambitious immediate reductions can be implemented.

If successfully implemented, BECCS could provide a means to relax the overall requirement to reach zero GHG emissions on sectors that are more difficult and costly to decarbonise. (Note the potential for biological carbon sequestration through soil biochar is discussed in Section 5.5).

Figure 5.5 Bioenergy linked with carbon dioxide capture and storage (BECCS). Capturing the CO_2 produced from biomass combustion and sequestering it can lower atmospheric concentrations but only if the biomass used is regrown.



73 The Boundary Dam plant in Canada http://saskpowerccs.com/ccs-projects/boundary-dam-carbon-capture-project/

GHG emissions profile and baseline trends in New Zealand

What amount of greenhouse gas arises from the supply of heat and electricity?

In 2014, electricity generation in New Zealand from non-renewable generation produced ~7 Mt CO_2 emissions. Together with the generation of heat from fossil fuel combustion, this accounted for around 40% of the 35 Mt of total CO_2 emissions. The remainder came mainly from transport fuels, cement manufacture and deforestation (MfE, 2015a).

Total GHG emissions from electricity generation have declined in recent years as greater shares of renewable energy generation have appeared in the electricity mix and demand has remained flat. Annual emissions from the generation of electricity vary with the amount of fossil fuels combusted in thermal power plants. This can be higher in dry years when generation from hydro-power plants is constrained and thermal plants are run more often. Other than methane emissions from natural gas leaks in pipelines etc., leakage of fugitive CO_2 emissions have tended to increase (Figure 5.6), mainly as a result of more geothermal plants becoming operational, since these release some CO_2 during extraction of the hot brine from below the ground.

GHG mitigation options

How can we reduce GHG emissions in the heat and electricity sector?

Examples of the many technical and operational options that exist for reducing GHG emissions in this sector are based mainly on improving energy efficiency of the generation plants and end-uses of the heat and electricity, using a range of measures: switching natural gas for coal (as an interim solution); substituting renewable energy for fossil fuels; and modifying consumer behaviour to reduce heat and electricity demand.

Possible GHG mitigation options (although the amount of emission reductions for some options will depend on the specific circumstances), include:

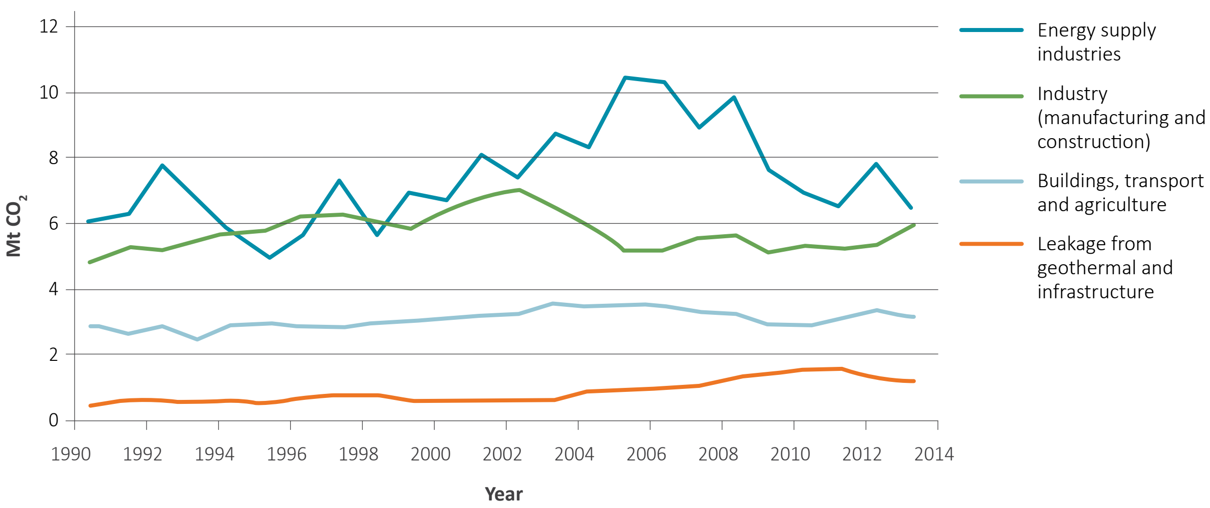
For everyone:

- Improved energy efficiency measures.

For individuals:

- Individual decisions by householders to invest in solar PV (possibly linked with electric vehicle recharging), pellet stoves, ground source heat pumps, etc.

Figure 5.6 Emissions of CO_2 by the heat and electricity sector from 1990 to 2014.



Source: MfE (2015b).

For businesses:

- Improving efficiency of existing wind turbines.
- Expanding uptake of bioenergy (wood, biogas etc) and geothermal to displace coal and gas.
- Using electro-technologies from a high-share renewable grid for process heat.
- Using solar water heating and air-to-water or geothermal (ground source) heat pumps.

For local and regional government:

- Utilising organic waste in landfills and sewage treatment plants to produce biogas.
- Utilisation of renewable energy heat solutions in municipal facilities such as community halls and swimming pools.
- Supporting electric vehicle (EV) rechargers in municipal areas.
- Community actions to become more sustainable including reducing GHG emissions.
- Cities taking a greater leadership role in reducing emissions by, for example, investment in renewable energy generation.

For national government:

- Increase share of renewables to meet 2025 target.
- Further increasing shares of renewables towards 100%.
- Encouraging and managing the uptake of smart-grids and local distributed generation.
- Undertake R, D &D investment to demonstrate the potential for promising future low-carbon technologies such as carbon dioxide capture and storage (CCS) and ocean energy.

EECA manages the OPENZ modelling tool that can be used across all sectors to compare present technologies with new technologies that optimise the supply of end-use consumer electricity or heat in terms of energy efficiency, costs and emissions out to 2050. A marginal abatement cost curve is also being developed (Section 6.1).

Electricity

In spite of the high shares of renewable electricity, New Zealand has only around 39% of total energy demand being met by renewable energy. Therefore, there remain good opportunities for further uptake, particularly for heating. The IPCC *Special Report on Renewable Energy* (IPCC, 2011) outlined the issues and solutions, and also confirmed that globally, the technical potential[74] of renewable energy technologies, based on the renewable resources available, exceeds the current energy demand by a considerable amount. Less than 3% of the globally available technical potential for renewable resources is presently used, confirming that the availability of renewable sources will not be a limiting factor. The technical potential for renewables has also been assessed for New Zealand (Sims *et al.,* 2005) with similar conclusions. However, accelerating the deployment of cost-competitive renewable energy systems could present new technological and institutional challenges when integrating them into existing energy supply systems and end-use sectors.

The current target to achieve 90% renewable electricity by 2025 is achievable and could be even more ambitious given the number of renewable energy power plants that have already received consents but are not yet under construction (MBIE, 2016a). A higher share of renewables can be achieved if either electricity demand grows, (such as to meet demand for recharging EVs, more electric rail, or thermo-electric process heating), or old thermal plants are retired. Integration of higher shares of variable wind and solar PV generation systems is feasible by making the national grid more flexible. There would need to be an accompanying programme to reduce peak loads so they are closer to the mean loads and for significant system operation issues to be addressed in order to achieve a very high renewable percentage.

Because of the way in which the New Zealand electricity wholesale market functions, the over-capacity and degree of wastage that could result when moving closer to 100% renewables would have additional cost implications. Assuming wind and solar are ‘must-run’ generation and geothermal and bioenergy are ‘baseload’, hydro, being easily dispatchable, would probably then be used to meet fluctuating demands. In winter months, storage lakes decline as a lot of the hydro generating capacity is

74 The technical potential of a technology or system ignores any cost constraints but considers and current practical limits to uptake, based on climate, engineering, competition for resources such as land. It can increase over time when technologies using an available resource become operational in future years after the socio-economic conditions change, given certain economic and operating conditions.

locked up as snow. Therefore, additional geothermal, wind and solar capacity would be needed to cover peak seasonal demands. (Demand-side management options can only shift loads for short periods.) In summer, surplus capacity of hydro, geothermal, wind and solar would necessitate spilling resources. The lower load factors of the generation plants as a consequence will result in increased generation costs.

Adding storage systems such as batteries or capacitor banks into the system, possibly at the local distribution level, is another option to maintain frequency control and system stability. This is being considered elsewhere[75] but every grid is unique so lessons to be learned are limited, and storage is often relatively more costly compared with making the grid more flexible (IPCC, 2011, chapter 8). The potential for developing smart-grids (linked with small local generation systems, smart-meters, intelligent appliances with fast response times etc.) is being evaluated to assess their reliability and potential contribution and uptake (SGF, 2015).

Single-cycle gas turbines could be used as back-up to overcome seasonal and diurnal peaks and hence reduce overall system operation costs, but unless the gas comes from landfill or biogas sources, achieving 100% renewable electricity may not then be economically or technically viable. To achieve a high level of security for dry years, having suitable back-up generation capacity installed (likely to be at least in part fossil-fuelled but only to be used in extreme dry years) will also increase overall system costs. To achieve a high renewable share, it may prove necessary for the owner of the back-up power capacity to be paid sufficiently to only offer to run it in dry years or at times when supply security is at high risk of brown-outs or black-outs. To reach close to 100% renewable electricity overall, there may even be a need to consider government ownership of the back-up plant since, in theory, it would exist solely for security of supply.

The recent lower investment costs for solar PV panels has created an increased number of residential and commercial installations that in 2015 totalled around 25 MW_e installed capacity (Miller *et al.,* 2015). The costs of batteries for energy storage are also declining, from around US$1300–1500 / kWh in 2005 to around US$400-500 / kWh a decade later (Nykvist and Nilsson, 2015). New Zealand's deregulated electricity industry, with corporate ownership of generation plant and many distribution line assets, could choose to either constrain the further uptake of grid-connected solar PV systems and smart grids, or drive it. In countries where the electricity system is more closely regulated, government interventions encourage smart-grid developments to provide future benefits, including reduced GHG emissions. However, since electricity generation is already around 80% renewables in New Zealand, investment in solar PV by householders and small businesses could result in lower reductions in GHG emissions ($/t CO_2 avoided) than if making a similar investment in an EV that would directly displace gasoline or diesel fuels (Concept, 2016).

Heat

EECA has a 'Regional Renewable Heat' programme of work to promote the switching on industrial process heat to renewable energy. In the South Island with no natural gas distribution, there have been few options other than coal, but the 3-year 'Wood Energy South' programme is encouraging a switch to woody biomass[76]. EECA is assisting businesses to invest in bioenergy heat plant by co-investing in feasibility studies to provide information on costs and savings over the lifetime. The supply of both high and low temperature heat can be decarbonised by the increased use of electro-technologies for industry; the substitution of fossil fuels by biomass, geothermal and solar thermal systems; the uptake of heat pumps including ground source (ideally using renewable electricity); co-generation of heat and power; and district heating and cooling systems (UNEP, 2015b). Several of these heat supply technologies appear to have good realisable potential but further analysis is required to assess their costs and potentials under New Zealand conditions. An attempt was made to provide an overview of estimated mitigation potentials, costs, and possible priority sequencing of mitigation actions across all sectors (Annex 1) although data is limited.

75 See for example, https://www.gov.uk/government/publications/smart-power-a-national-infrastructure-commission-report

76 http://www.woodenergysouth.co.nz/

What opportunities and barriers exist around GHG mitigation options?

There are a number of enablers for GHG mitigation options:

- The cost competitiveness of many renewable energy conversion technologies against fossil fuel technologies is increasing.
- Co-benefits have been identified, such as lower local air pollution.
- Electro-technologies for providing heat and mobility services are becoming cheaper for some applications (such as medium to high temperature heat pumps with high efficiency), and easier to implement.
- Biomass when combusted in stoves, boilers and furnaces, and geothermal heat systems, can displace coal and natural gas.
- An increasing carbon price would be a strong driver.

Existing barriers include:

- Renewable energy tending to have high capital costs (but low operating costs) which can put it at a disadvantage with North Island gas-fired power plants which, with low capital but higher operating costs, can affect investment decision-making and needs comparisons of the options using full life-cycle assessments.
- Little recognition given to the opportunities to reduce GHG emissions within the heat market despite its accounting for around 28% of New Zealand's consumer energy use, whereas electricity equates to only 23% in energy terms.
- The heat market is distributed with many small players and so does not have the power and wealth of the electricity or petroleum companies.
- Resistance by consumers to behavioural change.
- Cheap fossil fuel prices, such as coal for heat in the South Island, due to over-supply and/or unpriced externalities.
- Electricity wholesale market participants not fully engaging in low-carbon options.
- Resistance to change by incumbents in the market.
- Knowledge gaps.

Influence of long term ambitions on near term actions and pathways

What are the pathways and potentials for reducing emissions from heat and power generation?

To help achieve the transition to a low-carbon economy in New Zealand that contributes to the global goal of maintaining temperature rise below 2 °C, there is high technical potential for emission reductions in this sector over the next 20-30 years. However, future deployment of low-carbon technologies and systems will depend on comparative costs and any policy interventions. The market potential would be increased if a higher carbon price on fossil fuels resulted under the ETS (Section 4.8).

Further decarbonisation of the electricity sector to exceed the current target of 90% renewable electricity by 2025 is technically possible and probably cost-effective. For example, default values and assumptions used in the *Interactive Electricity Generation Cost Model – 2015* (MBIE, 2016) confirm that renewable electricity generation, particularly from wind and geothermal, is cost-competitive with combined cycle gas turbine plants delivering gas baseload. This tool could also be used to assess whether 100% renewable electricity has technical potential, as shown by early modelling confirming supply reliability could be maintained even in a dry year (Mason *et al.,* 2013). However, integration of higher shares of variable renewables (IPCC, 2011, Chapter 8), would still need further evaluation.

Expanding the current share of renewable heat is also technically possible. Considerable experience could be gleaned from other countries (IEA, 2007a; IPCC, 2011) with the opportunities well understood by the various industry associations[77].

77 Bioenergy Association of NZ www.bioenergy.org.nz; Solar Association of NZ www.solarassociation.org.nz; NZ Geothermal Association, www.nzgeothermal.org.nz

Co-benefits

What other benefits exist when reducing GHG emissions in the heat and power sector?

- The skilled and semi-skilled employment opportunities for labour needed for developing, installing and maintaining renewable energy heat and power systems is well documented. For bioenergy plants, labour is also required to provide and deliver the biomass resource.
- Biomass in the form of waste organic matter, such as municipal solid waste, animal manure, sewage sludge, cereal straw, and forest residues, can be used as feedstocks for heat and power plants with many examples already in place around the world. The utilisation of these biomass feedstocks on-site through anaerobic digestion, combustion, gasification or pyrolysis can avoid costly waste treatment, transport and disposal as well as avoid emissions of methane and nitrous oxides. The CO_2 produced during their conversion is reabsorbed by future crops so is carbon neutral.
- The future energy security of New Zealand will be enhanced if local energy resources can be utilised to reduce dependence on imported energy sources.
- Increased business resilience will occur because of diversity.
- Improved human health can result from reduced local air pollution where renewable energy systems displace coal-fired or diesel-engine powered heat and electricity plants.
- Cost savings can result from a change to low-carbon technologies, both from improved energy efficiency of generation plants as well as from savings on fuel costs. The levelised costs of renewable energy can compare well with conventional fossil fuel costs, especially where good renewable resources exist (IPCC, 2011, Chapter 10) such as wind and geothermal in New Zealand.

Insights on enabling policies

Would policy interventions be useful to encourage more rapid technology deployment?

Local experience has confirmed that the share of large-scale renewable electricity generation projects can continue to increase in New Zealand without government intervention, although increasing carbon prices would encourage more rapid displacement of thermal generation. The need for policies to encourage development of small- and mini-generation projects by small businesses and householders is currently being assessed by the Smart Grid Forum (SGF, 2015).

For supporting the greater deployment of renewable heat projects in buildings and industry, the *Domestic Renewable Heat Incentive Scheme,* set up by the UK Government in 2011 to encourage the uptake of renewable heat technologies amongst householders, communities and businesses through financial incentives, is a good model to study. Various amendments have been made by the regulator since it was introduced (OFGEM, 2015). Similar policies could be applied in New Zealand.

Knowledge gaps

What else would be useful to know in order to increase the uptake of low-carbon technologies?

The electricity and heat sector is mature in New Zealand and well understood. However, the potential for the uptake of renewable heating systems is not clear. The number of boilers and their capacity is available on a heat database, but the amount of useful heat produced is not usually metered so any seasonal variations in demand are not known. The opportunity to convert them to biomass, including having reliable local supplies of feedstock, could be assessed. Geothermal direct use databases complement the heat plant database but the NZ Geothermal Association advocates for user surveys at all scales.

Costs of low-carbon technologies need detailed evaluation, not just the current investment costs but also the operational, maintenance, management and life cycle costs including for plant decommissioning. To accurately assess the realistic potential for the many low-carbon opportunities in the heat and electricity sector when taking into account the costs, risks, but also the many co-benefits, detailed analyses are required. Demonstration projects with wide dissemination of costs and benefits would help promote businesses utilising renewable energy since many similar enterprises may be unaware of the opportunities.

Case studies

Are there good examples that others might follow?

- Large scale renewable electricity projects are widespread throughout New Zealand. Around 7000 small-scale solar PV systems have been installed ranging from less than 1kW on houses to over 100 kW by Palmerston North City Council. Many autonomous buildings also exist without connection to the electricity grid.
- There is a growing interest by small communities to invest in their own electricity generation plant, the foremost being Blueskin Bay north of Dunedin[78], Parihaka in Taranaki, and several others.
- Industrial renewable heat projects have been common for many years, for example the combined heat and power plant at Kinleith pulp mill using bark peelings and forest residues[79] and the Wairakei prawn farm using low temperature geothermal heat since 1987[80].
- The Christchurch City rebuild, linked with feasibility study grants and rapid and favourable resource consent approvals, has produced an uptake of geothermal (ground source) heat pumps for interconnected heating and cooling schemes. More recently, K&L Nurseries, flower growers from Christchurch, moved away from coal and invested in a biomass boiler fuelled by their own cut flower crop residues. The project received the EECA 2014 Supreme Award[81]. The Bioenergy Association of New Zealand provides many case studies of other heat applications from woody biomass combustion[82].

78 www.brct.org.nz/

79 www.mynoke.co.nz/vdb/document/11

80 www.gns.cri.nz/Home/Search?cx=000739735540594332840%3A7p51qeexgyk&cof=FORID%3A9%3BNB%3A1&ie=UTF-8&q=prawn&sa=Search For other case studies see http://www.gns.cri.nz/Home/Learning/Science-Topics/Earth-Energy

81 www.eeca.govt.nz/about-eeca/eeca-awards/past-awards/eeca-awards-2014/bioenergy-trailblazer-k-and-l-nurseries-wins-2014-eeca-supreme-award/

82 www.bioenergy.org.nz/bioenergy-case-studies

5.2 Transport

Key messages

- Our transport sector is 99% dependent on fossil fuels, so mitigation actions are possible by individuals, communities, businesses and local governments.
- New Zealand's GHG emissions from road transport could reduce by at least 60% by 2050 if large-scale uptake of low emissions technologies such as electric vehicles (EVs) occurs; fuel efficiency standards and other measures are introduced; and fuel retail prices increase as a result of high oil and carbon prices.
- Unless the purchase price of zero emission electric or hydrogen fuelled vehicles declines, in spite of their lower running and maintenance costs, large-scale rapid adoption in the short term will require the use of policy instruments.
- Rail has significantly lower emissions than road per kilometre for carrying a given volume of freight. At the present level of rail electrification, the transport of freight by rail on average per tonne kilometre typically produces only around a third of the emissions compared with transporting freight by road.
- Domestic biofuels based on food processing by-products (from whey, used cooking oils, tallow and biogas from organic wastes) don't compete for land use and can be competitive with petroleum products. However, available feedstock volumes limit them to around 3-5% of road transport fuels.
- Production of bio-ethanol and other drop-in biofuels from ligno-cellulosic feedstocks are emerging technologies but remain costly so require lower feedstock prices that will be challenging to meet in New Zealand.
- The use of private vehicles can be substantially reduced through:
  - urban design that prioritises walking and cycling;
  - accessible and timely low emission public transport, especially rail; and
  - early adoption of smart transport technologies and possibly driverless vehicles, though the benefits are uncertain.

Sources of transport fuels

Where do our petroleum based transport fuels come from and who uses them?

Over 99.9% of New Zealand's transport fuels are derived from crude oil (Figure 5.7) (MBIE, 2015).

In 2014 New Zealand was about 35% self-sufficient in oil. It exported 98% of the crude oil it produced as its low density and low sulphur content give it a high value on the international market. Over 80% of New Zealand's oil product imports came from refineries in Singapore and South Korea in 2014, with 8% from the USA (MBIE, 2015).

How much fuel do we use?

In 2014, the domestic transport sector was responsible for approximately 36% of New Zealand's total consumer energy demand,only exceeded by the industrial sector at around a 38% share (Figure 5.8) (MBIE, 2015).

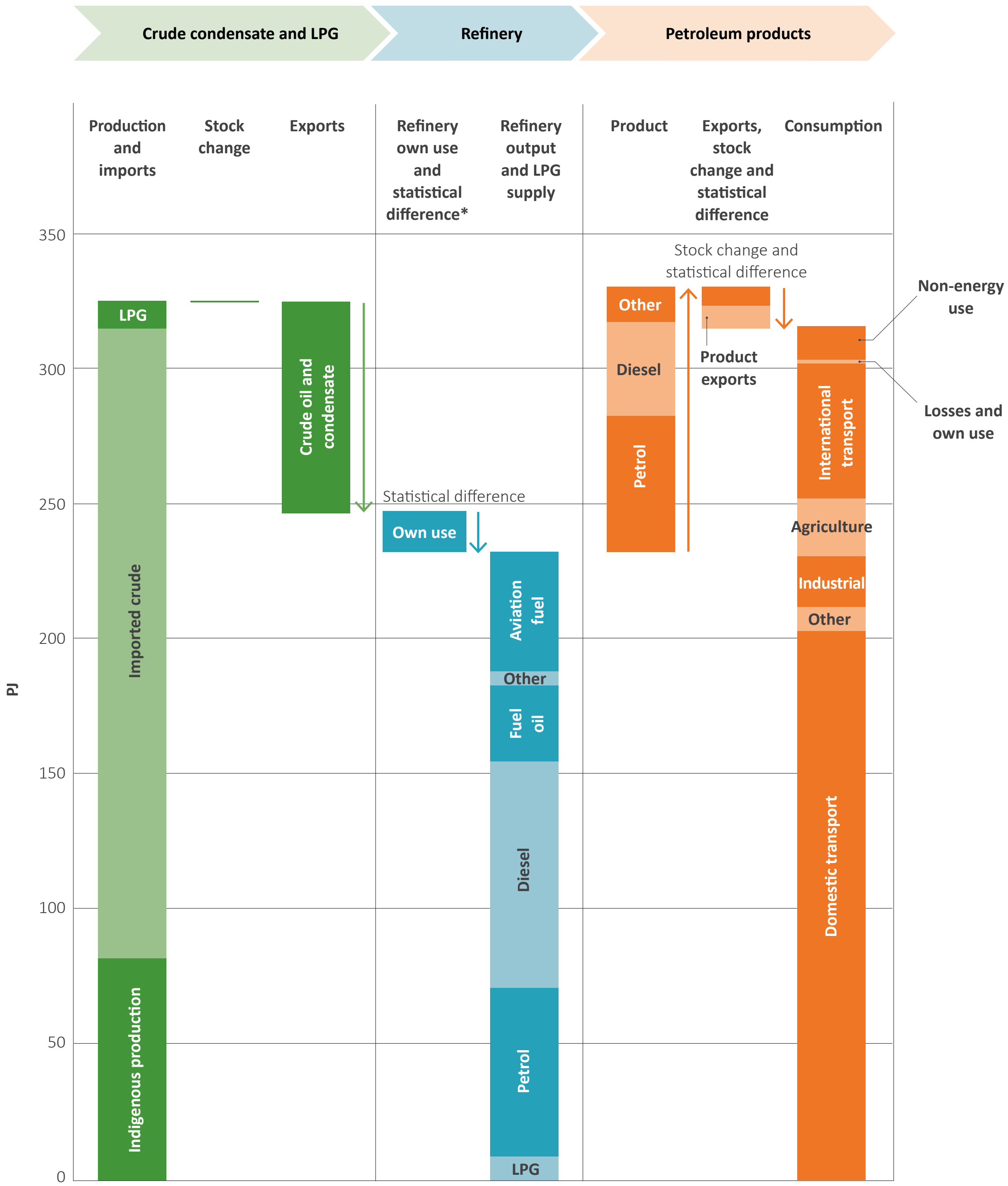
The combined domestic and international transport fuel use in New Zealand in 2014 was 255.6 PJ. This had increased 56.5% since 1990 (Figure 5.9). During this period the proportion of total fuel demand used in international transport remained relatively stable. Since 2007 both domestic and international transport energy consumption has remained almost static due to the improving fuel economy of new and imported vehicles and lower per capita annual road travel (MBIE, 2015; MoT, 2014a).

The sharp reduction demand for liquid fuels between 2008 and 2009 coincided with the global financial crisis and the associated slowdown in domestic economic activity. Diesel fuel consumption increased 34% between 2000 and 2013 (MBIE, 2016a) driven by both fleet growth of 29% and increased shares of diesel vehicles in the light duty vehicle (LDV) fleets over the same period of 43% (to 17% of the total fleet) and heavy duty vehicles (HDVs) of 5% (to 98% of the total fleet) (MoT, 2014a). Transport fuel use in 2014 was dominated by petrol (41% of total transport fuel energy demand at 52,100 barrels /day), diesel (33% at 54,000 barrels /day), and international aviation fuel (15%) (Figure 5.10) (MBIE, 2015).

How much biofuel do we consume?

Liquid biofuels accounted for less than 0.1% of New Zealand transport fuel consumption in 2014 with ethanol (produced by fermenting whey locally plus volumes imported from sustainably produced sugar cane feedstocks) accounting for 78% by volume and biodiesel the remainder. A typical fuel blend is 10% ethanol/90% gasoline which results in a 5–6.5% reduction in GHG emissions per litre compared with regular gasoline (MBIE, 2015).

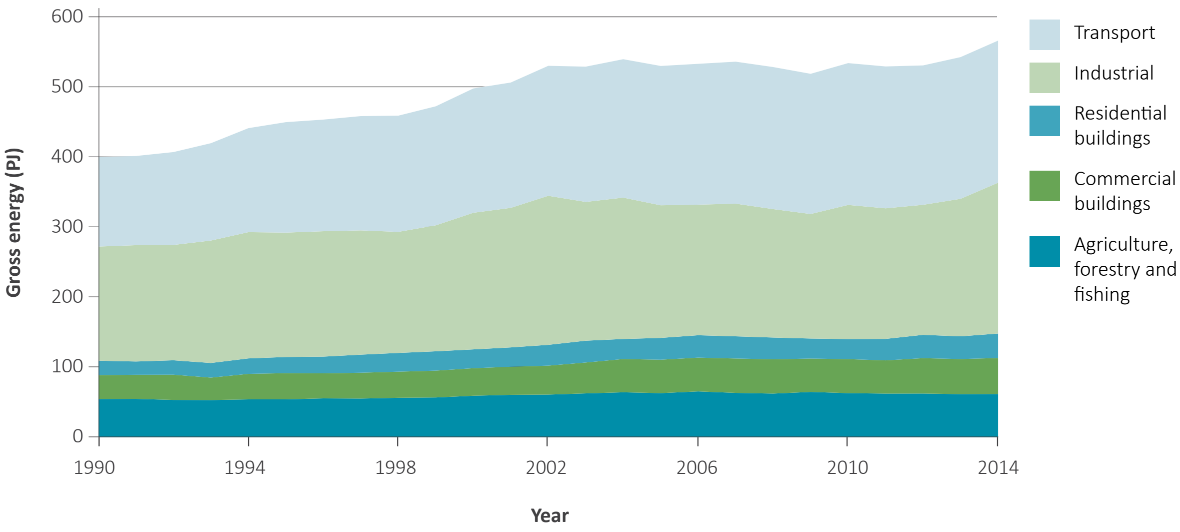
Figure 5.7 Oil product annual flows for transport fuels and other uses in New Zealand.



*Statistical difference is difference between supply and demand

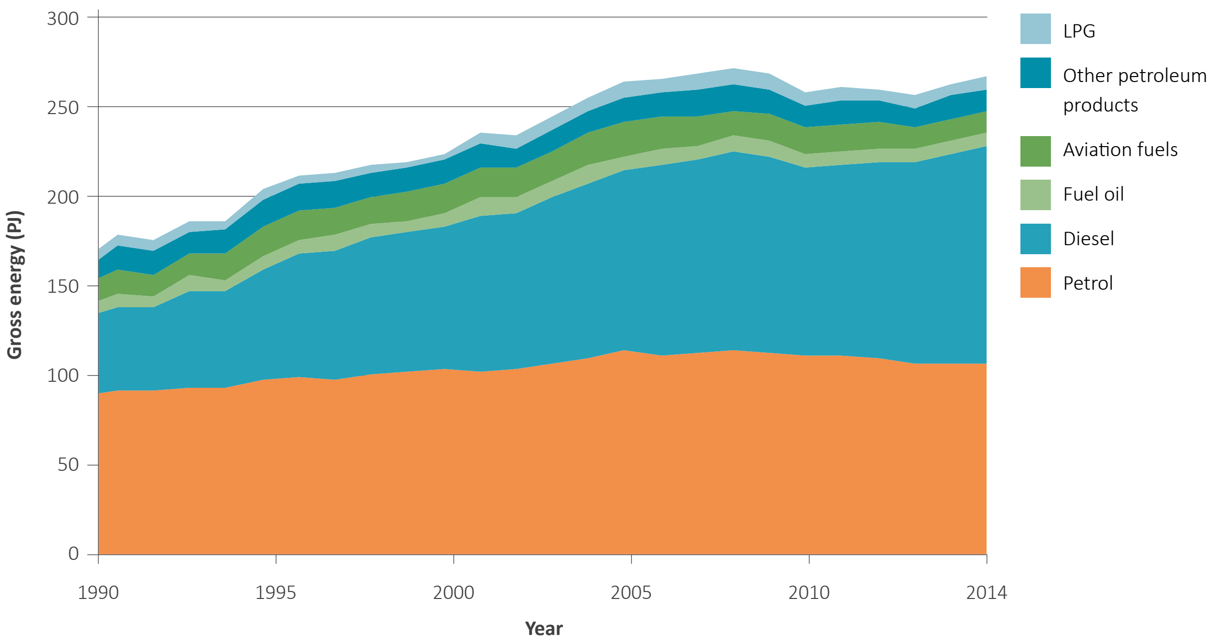
Source: MBIE (2015).

Figure 5.8 New Zealand consumer energy demand by sector, 1990–2014.



Source: MBIE (2015).

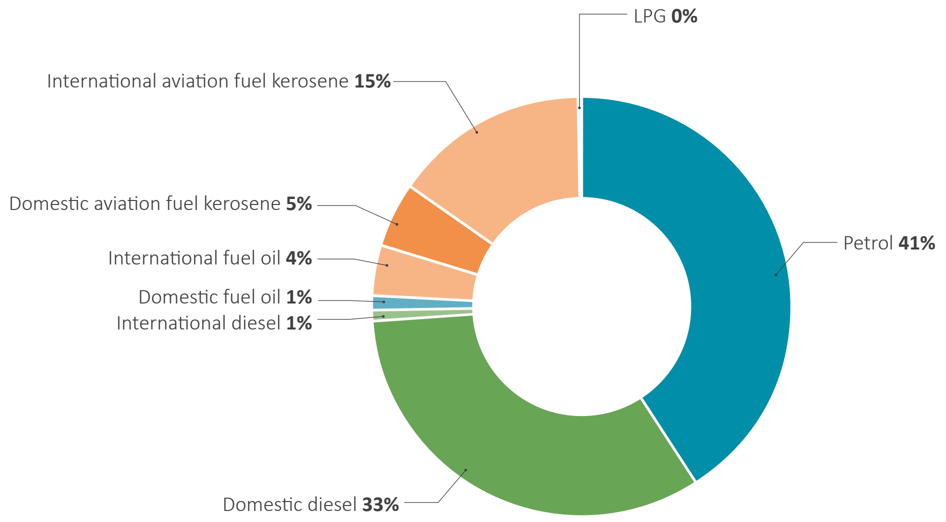
Figure 5.9 Liquid fuels energy consumption shares in the New Zealand transport sector from 1990 to 2014.



Note: Biofuels = 0.1 PJ

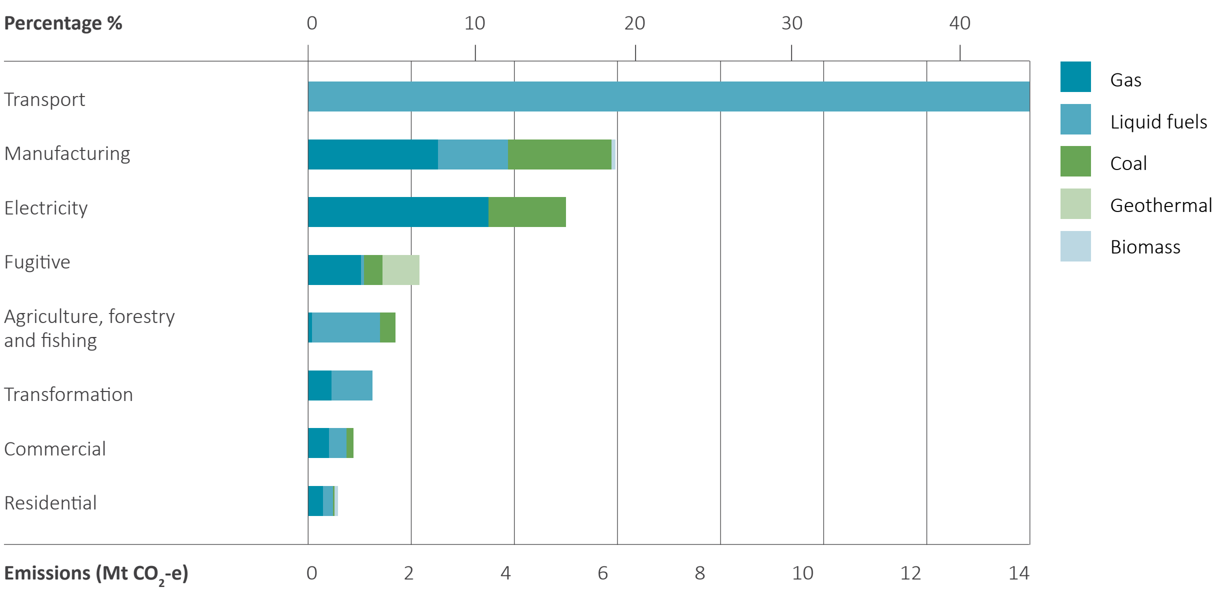
Source: Adapted from MBIE (2015).

Figure 5.10 Share of liquid fuels transport fuel consumption in New Zealand in 2014.



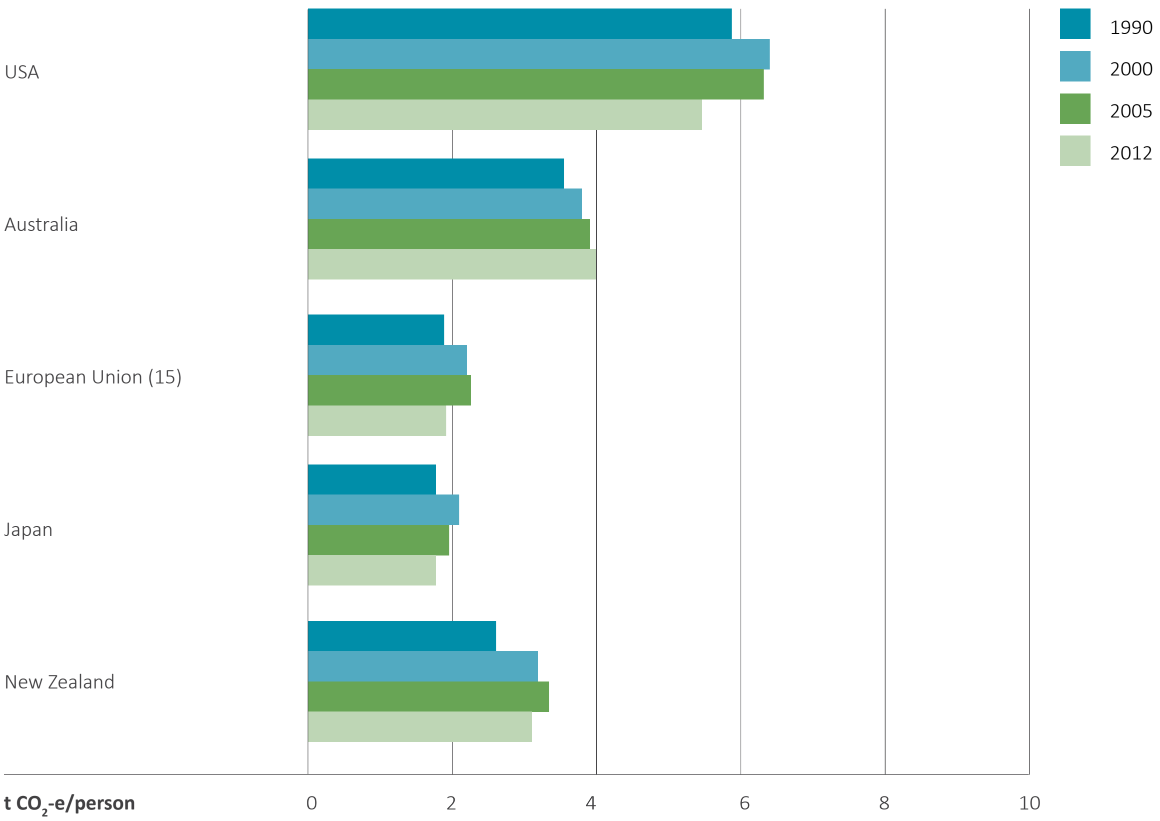
Source: MBIE (2015).

Figure 5.11 Energy GHG emissions by sector in 2013 and shares from various fuels.



Source: MBIE (2014b).

Figure 5.12 Domestic transport GHG emissions per capita for selected countries and years.



Source: MBIE (2014a).

Greenhouse gas emissions

How much GHG is emitted by the transport sector?

In 2013 the domestic transport sector, including aviation and shipping, produced 14.1 Mt CO_2-eq (MBIE, 2014b) representing 17.4% of New Zealand's total gross annual GHG emissions of 80.9 Mt CO_2-eq (MƒE, 2015a) and 44% of energy sector emissions (Figure 5.11).

New Zealand has the second highest private car ownership rate in the OECD at 604 cars per thousand people in 2013. GHG emissions from the New Zealand domestic transport sector in 2012 were 3.13 tCO_2-eq/capita that was about average for developed countries (Figure 5.12). The average age of the light vehicle fleet was 13.2 years in 2012, compared with 11.4 years for the USA and 10.0 years for Australia. Over the past ten years, freight transport in New Zealand has moved away from rail and coastal shipping, and is now predominantly carried by road truck, which is a more energy and emissions intensive mode (MBIE, 2014b).

Road transport emissions (excluding domestic rail, aviation and marine) from gasoline, diesel, LPG and CNG were 12.7 Mt CO_2-eq in 2013 and made up 40.1% of all energy sector emissions. Emissions were up 69% over 1990 levels of 7.5 Mt CO_2-eq (Table 5.1) although the trend has been flatter since about 2007 due to lower transport demand and improving vehicle fuel efficiency[83]. New Zealand road transport emissions in 2013 were dominated by the light duty fleet at 64.8%, heavy duty fleet 21.5%, light commercial fleet 15.8%, and motorbikes 0.4% (MoT, 2014a).

83 http://www.transport.govt.nz/ourwork/tmif/freighttransportindustry/ft008/

Table 5.1: Transport emissions (Mt CO_2-eq) by mode and shares of total energy-related CO_2 emissions in 2013.

Calendar Year	Road	Rail	Domestic Aviation	Marine	Total
1990	7.49	0.08	0.95	0.26	8.78
2000	10.54	0.25	1.18	0.38	12.36
2008	12.57	0.16	1.09	0.29	14.11
2009	12.43	0.17	1.04	0.30	13.93
2010	12.68	0.15	1.01	0.26	14.09
2011	12.68	0.15	0.97	0.29	14.09
2012	12.58	0.16	0.83	0.30	13.86
2013	12.69	0.15	0.86	0.38	14.07
Increase 1990/2013	69.4%	87.8%	-9.9%	49.6%	60.4%
Annual increase 1990/2013.	2.3%	2.8%	-0.5%	1.8%	2.1%
Increase 2012/2013	0.9%	-3.9%	3.6%	28.7%	1.6%
% of total 2013 energy CO_2-eq emissions	**40.1%**	**0.5%**	**2.7%**	**1.2%**	**44.5%**

Source: MBIE (2014b).

The transport of freight by rail per tonne kilometre produces only about a third of the GHG emissions than if transported by road, and about half of the GHG emissions if transported by sea (MoT, 2014c) (Table 5.2). In 2012, about 16% of New Zealand domestic freight (t-kms) was carried by rail, 14% by sea and 70% by road (MoT, 2014d) (Table 5.2). International port facilities that can accommodate larger ships would decrease international shipping fuel costs and by implication, GHG emissions (MoT, 2014b). However, large capital investment to upgrade ports is difficult to justify as most (with the exception of Tauranga and Lyttelton) already have sufficient capacity to meet forecast volumes based on smaller ship sizes.

Table 5.2: GHG emissions from freight transport by mode in 2014.

	Rail	Coastal shipping	Road freight
GHG Emission (g-CO_2-eq/t-km freight)	36	69	106
Annual freight movement 2014 (million t-km/yr)	4492	3930*	23,301
GHG (Mt/yr)	**0.16**	**0.27**	**2.47**

** Estimate based on MoT 2014d*

Source: based on MoT 2014c and 2014d.

What are the health effects of emissions in the transport sector?

Vehicle emissions can produce harmful health effects in addition to contributing to global warming. Around 6% of annual lung cancer deaths in the U.S. and Europe may be due to diesel emission exposure (Vermeulen *et al.* 2014). The most noxious emissions are black carbon particulates of less than 2.5 microns predominantly from diesel vehicles. Black carbon is also a short-lived radiative pollutant that can increase the rate of global warming (Sims *et al.* 2015*).* Thus reducing its emissions can both improve human health and offer some mitigation co-benefits. In New Zealand, black carbon emissions are estimated to annually cause 235 premature deaths from respiratory and cardiac illnesses, 133 extra hospital admissions and 327,000 restricted activity days. The total social costs were estimated to be $940 million per year (2010 dollars) (Kuschel *et al.* 2012).

By 2030, more efficient direct injection spark ignition engines could start replacing conventional port-injected engines and direct injection compression ignition diesel engines. These new engine designs emit less CO_2, but unless the effective emission control systems are well-maintained, they can emit 10 to 40 times more particulates than conventional engines (EUFTE, 2013).

Mitigating actions

What actions can we take to reduce greenhouse gas emissions from the domestic transport sector?

Mitigation actions can be organized under the headings 'Avoid-Shift-Improve' putting the emphasis on avoiding unnecessary travel (for example by reducing journey lengths through urban planning), then shifting modes (for example from cars to public transport), and then improving the emissions performance of various modes (German Ministry for Economic Cooperation and Development, 2011). GHG emissions in the transport sector can be reduced as follows (Sims *et al.*, 2014; IEA-RETD, 2015):

Avoid

- Minimising the use of private vehicles by using public transport, walking or cycling[84].
- Journey avoidance by encouraging greater access to, and use of, video conferencing technology, internet shopping, pre-planning and combining trips.

Shift

- Switching to biofuels, LPG or natural gas in conventional vehicles or adopting advanced technology low emission vehicles such hybrids, plug-in hybrids, battery electric vehicles or renewable-hydrogen electric fuel cell vehicles.
- Switching freight from road to rail or coastal shipping where practicable.
- Increasing the proportion of renewables in the electricity system to minimize emissions from recharging battery electric vehicles or producing renewable hydrogen.
- Introducing policy initiatives that encourage uptake of low emission technologies and encourage installation of supporting infrastructure.
- Promoting ride-sharing to lower the vehicle kilometres per passenger-kilometre.
- Facilitating behavioural change to adopt low emission practices through policy initiatives and education.

Improve

- Adopting more compact urban design that is pedestrian and cycle friendly.;
- Improving freight logistics by road, rail, sea and air.
- Use of intelligent transport management techniques and logistics control systems to maintain traffic flows, reduce local air quality and global emissions such as the New Zealand government's 'ITS Technology Action Plan' [85].
- Supporting research on low-emission vehicle and fuel technologies.

Reducing the use of petroleum fuels in transport vehicles has a number of flow-on benefits such as:

- Reduced air and noise pollution and therefore a healthier population.
- Increased personal activity and health through physical activity replacing vehicle use via walkways and cycleways.
- Improved energy security due to a lower dependence on imported oil.
- Improved road safety due to lower vehicle numbers.
- Improved employment opportunities in domestic businesses associated with supplying equipment for low-emission transport systems.

84 In June 2015, Government announced a $128M investment in cycleways plus $105M from local government.

85 http://www.transport.govt.nz/assets/Uploads/Our-Work/Documents/ITS-technology-action-plan-2014.pdf

This list of mitigation actions and benefits does not take into account maximising the economic, social and environmental well-being for New Zealanders including providing affordable mobility for all. Further work is required in this regard. The potential co-benefits and adverse side effects of main mitigation measures that could be adopted in New Zealand require careful evaluation not conducted to date and are summarised in Tables 5.3 and 5.4.

Table 5.3: Potential co-benefits and adverse side effects of mitigation measures in the transport sector.

Mitigation measures	Effect on additional objectives/concerns		
	Economic	**Social (including health)**	**Environmental**
Reduction of fuel carbon intensity: electricity, hydrogen, CNG, biofuels, and other fuels	Energy security (diversification, reduced oil dependence and exposure to oil price volatility) . Technological spillovers (e. g., battery technologies for consumer electronics)	Health impact via urban air pollution by CNG, biofuels: net effect unclear Electricity, hydrogen: reducing most pollutants Shift to diesel: potentially increasing pollution Health impact via reduced noise (electricity and fuel cell LDVs) Road safety (silent EVs at low speed)	Ecosystem impact of electricity and hydrogen via: – urban air pollution – material use (unsustainable resource mining) Ecosystem impact of biofuels
Reduction of energy intensity i.e. GJ/GDP	Energy security (reduced oil dependence and exposure to oil price volatility)	Health impact via reduced urban air pollution Road safety (crash-worthiness depending on the design of the standards)	Ecosystem and biodiversity impact via reduced urban air pollution
Compact urban form and improved transport infrastructure Modal shift	Energy security (reduced oil dependence and exposure to oil price volatility) Productivity (reduced urban congestion and travel times, affordable and accessible transport) Employment opportunities in the public transport sector vs. car manufacturing jobs	Health impact for non-motorized modes via Increased physical activity Potentially higher exposure to air pollution Noise (modal shift and travel reduction) Equitable mobility access to employment opportunities, particularly in developing countries Road safety (via modal shift and/or infrastructure for pedestrians and cyclists)	Ecosystem impact via – urban air pollution – land-use competition
Journey distance reduction and avoidance	Energy security (reduced oil dependence and exposure to oil price volatility) Productivity (reduced urban congestion, travel times, walking)	Health impact (for non-motorized transport modes)	Ecosystem impact via – urban air pollution – new/shorter shipping routes – Land-use competition from transport infrastructure

Source: Sims et al., 2014.

Table 5.4: Transport technologies and practices with potential for GHG reduction and the related barriers and opportunities

Transport technology or practice	Short-term possibilities	Long-term possibilities	Barriers	Opportunities
BEVs and PHEVs based on renewable electricity.	Over the life cycle, BEVs have 60% lower GHG emissions than gasoline vehicles. Rapid increase in use likely over next decade from a small base, so only a small impact likely in short-term.	Significant replacement of CE-powered LDVs.	EV and battery costs reducing but still high. Lack of infrastructure, and recharging standards not uniform. Vehicle range anxiety. Lack of capital and electricity in some least developed countries.	Universal standards adopted for EV rechargers. Demonstration in green city areas with plug-in infrastructure. Decarbonized electricity. Smart grids based on renewables. EV subsidies. New business models, such as community car sharing.
CNG, LNG, CBG and LBG displacing gasoline in LDVs and diesel in HDVs.	Infrastructure available in some cities so can allow a quick ramp–up of gas vehicles in these cities.	Significant replacement of HDV diesel use depends on ease of engine conversion, fuel prices and extent of infrastructure.	Insufficient government programmes, conversion subsidies and local gas infrastructure and markets. Leakage of gas.	Demonstration gas conversion programmes that show cost and health co-benefits. Fixing gas leakage in general.
Biofuels displacing gasoline, diesel and aviation fuel.	Niche markets continue for first generation biofuels (3% of liquid fuel market, small biogas niche markets).	Advanced and drop-in biofuels likely to be adopted around 2020–2030, mainly for aviation.	Some biofuels can be relatively expensive, environmentally poor and cause inequalities by inducing increases in food prices.	Drop-in fuels attractive for all vehicles. Biofuels and bio-electricity can be produced together, e.g., sugarcane ethanol and CHP from bagasse. New biofuel options need to be further tested, particularly for aviation applications.
Improved internal combustion engine (ICE) technologies and on-board information and communication technologies (ICT) in fuel – efficient vehicles.	Continuing fuel efficiency improvements across new vehicles of all types can show large, low-cost, near-term reductions in fuel demand.	Likely to be a significant source of reduction. Behavioural issues (e.g., rebound effect). Consumer choices can reduce vehicle efficiency gains.	Insufficient regulatory support for vehicle emissions standards. On-road performance deteriorates compared with laboratory tests.	Creative regulations that enable quick changes to occur without excessive costs on emissions standards. China and most OECD countries have implemented standards. Reduced registration tax can be implemented for low-carbon vehicles.

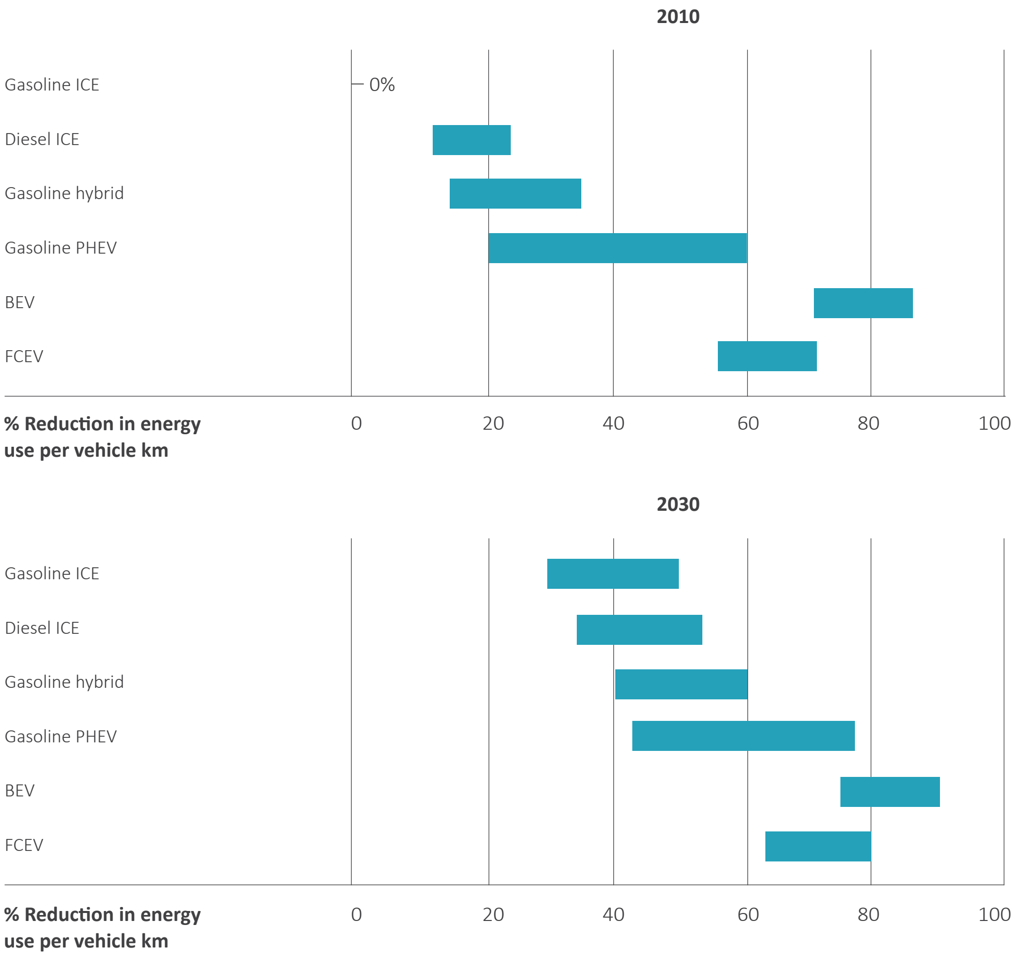
Source: Sims et al., 2014.

Transport technology or practice	Short-term possibilities	Long-term possibilities	Barriers	Opportunities
Modal shift by public transport displacing private motor vehicle use.	Rapid short-term growth already happening.	Significant displacement only where quality system infrastructure and services are provided.	Availability of rail, bus, ferry, and other quality transit options. Density of people to allow more access to services. Levels of services. Time barriers on roads without right of way Public perceptions.	Investment in quality transit infrastructure, density of adjacent land use, and high level of services using innovative financing that builds in these features. Multiple co-benefits especially where walkability health benefits are a focus.
Modal shift by cycling displacing private motor vehicle use.	Rapid short-term growth already happening in many cities.	Significant displacement only where quality system infrastructure is provided.	Cultural barriers and lack of safe cycling infrastructure and regulations. Harsh climate.	Demonstrations of quality cycling infrastructure including cultural programmes and bike-sharing schemes.
Modal shift by walking displacing private motor vehicle use.	Some growth but depends on urban planning and design policies being implemented.	Significant displacement where large-scale adoption of polycentric city policies and walkable urban designs are implemented.	Planning and design policies can work against walkability of a city by too easily allowing cars into walking city areas. Lack of density and integration with transit. Culture of "walkability".	Large-scale adoption of polycentric city policies and walkable urban designs creating walking city in historic centres and new ones. Cultural programmes.
Urban planning by reducing the distances to travel within urban areas.	Immediate impacts where dense transit-oriented development (TOD) centres are built.	Significant reductions where widespread polycentric city policies are implemented.	Urban development does not always favour dense TOD centres being built. TODs need quality transit at their base. Integration of professional areas required.	Widespread polycentric city policies implemented with green TODs, backed by quality transit. Multiple co-benefits in sprawl costs avoided and health gains.
Urban planning by reducing private motor vehicle use through parking and traffic restraint.	Immediate impacts on traffic density observed.	Significant reductions only where quality transport alternatives are available.	Political barriers due to perceived public opposition to increased costs, traffic and parking restrictions. Parking codes too prescriptive for areas suited to walking and transit.	Demonstrations of better transport outcomes from combinations of traffic restraint, parking and new transit/ walking infrastructure investment.
Modal shift by displacing aircraft and LDV trips through high-speed rail alternatives.	Immediate impacts after building rail infrastructure.	Continued growth but only short-medium distance trips suitable.	High-speed rail infrastructure expensive.	Demonstrations of how to build quality fast-rail using innovative finance.

Transport technology or practice	Short-term possibilities	Long-term possibilities	Barriers	Opportunities
Modal shift of freight by displacing HDV demand with rail and preservation of existing rail electric rail freight services.	Suitable immediately for medium – and long-distance freight and port traffic.	Substantial displacement only if large rail infrastructure improvements made, the external costs of freight transport are fully internalised, and the quality of rail services are enhanced. EU target to have 30 % of freight tonne-km moving more than 300 km to go by rail (or water) by 2030.	Inadequacies in rail infrastructure and service quality. Much freight moved over distances that are too short for rail to be competitive.	Upgrading of inter-modal facilities. Electrification of rail freight services. Worsening traffic congestion on road networks and higher fuel cost will favour rail.
Modal shift by displacing truck and car use through waterborne transport.	Niche options already available. EU 'Motorways of the Sea' programme demonstrates potential to expand short-sea shipping share of freight market.	Potential to develop beyond current niches, though will require significant investment in new vessels and port facilities.	Lack of vision for water transport options and land – locked population centres. Long transit times. Tightening controls on dirty bunker fuel and SOx and NOx emissions raising cost and reducing modal competitiveness.	Demonstrations of quality waterborne transport that can be faster and with lower carbon emissions than alternatives.
System optimisation by improved road systems, freight logistics and efficiency at airports and ports.	Continuing improvements showing immediate impacts.	Insufficient in long term to significantly reduce carbon emissions without changing mode, reducing mobility, or reducing fuel carbon intensity.	Insufficient regulatory support and key performance indicators (KPIs) covering logistics and efficiency.	Creative regulations and KPIs that enable change to occur rapidly without excessive costs.
Mobility service substitution by reducing the need to travel through enhanced communications.	Niche markets growing and ICT improving in quality and reliability.	Significant reductions possible after faster broadband and quality images available, though ICT may increase the need for some trips.	Technological barriers due to insufficient broadband in some regions.	Demonstrations of improved video-conferencing system quality.
Behavioural change from reducing private motor vehicle use through pricing policies, e.g, network charges and parking fees.	Immediate impacts on traffic density observed.	Significant reductions only where quality transport alternatives are available.	Political barriers due to perceived public opposition to increased pricing costs. Lack of administrative integration between transport, land-use and environment departments in city municipalities.	Demonstrations of better transport outcomes from combinations of pricing, traffic restraint, parking and new infrastructure investment from the revenue. Removing subsidies to fossil fuels important for many co-benefits.
Behavioural change resulting from education to encourage gaining benefits of less motor vehicle use.	Immediate impacts of 10–15% reduction of LDV use are possible.	Significant reductions only where quality transport alternatives are available.	Lack of belief by politicians and professionals in the value of educational behaviour change programmes.	Demonstrations of 'travel smart' programmes linked to improvements in sustainable transport infrastructure. Cost effective and multiple co-benefits.

Mitigation costs (\$/t-CO_2-eq) are uncertain and range from negative values for efficiency improvements in conventional road vehicles, aircraft and ships to more than USD100/tCO_2-eq for some new EVs and aircraft. Technology improvements have significant potential to reduce emissions 20–50 % relative to 2010 depending on mode and vehicle type (Figure 5.13) although reductions for aircraft are expected to be slower to deploy due to longer life and limited options for fuel switching, apart from biofuels (Sims *et al.*, 2014).

Figure 5.13 Indicative fuel consumption reduction potential ranges for a number of LDV technology drive-train and fuel options in 2010 and 2030, compared with a base-line gasoline internal combustion engine (ICE) vehicle consuming 8 l/100km in 2010.



Note: ICE – Internal Combustion Engine; PHEV – Plug-in Hybrid Electric Vehicle; BEV – Battery Electric Vehicle; FCEV – Fuel Cell Electric Vehicle (H_2).

Source: Sims et al., 2014.

Biofuel potential for the future

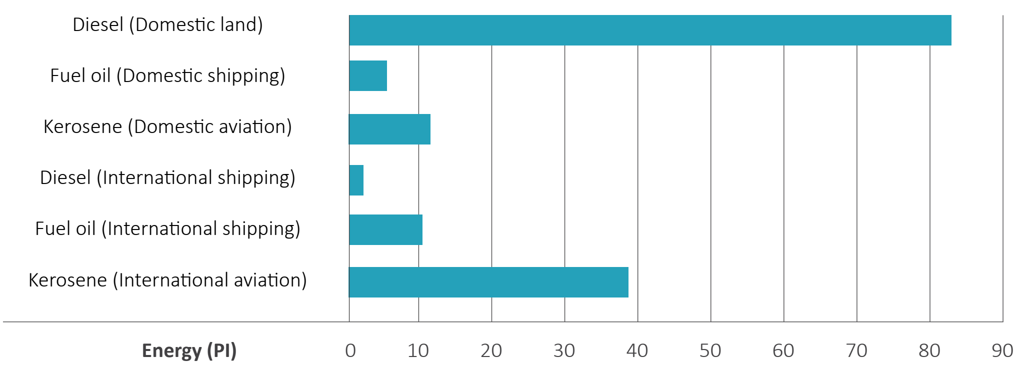
What is the potential for using biofuels in the vehicle fleet of the future?

Traditional biofuels technologies use either fermentation of sugars and starch to produce ethanol or the esterification of natural vegetable oils or animal fats to produce biodiesel. Bioethanol is produced in New Zealand from whey and yeast slurry that are by-products of cheese and beer production respectively. However, volumes are limited. Biodiesel production is currently produced mostly from recycled cooking oils, however, late in 2016 a new plant with a capacity of 20 million litres per year, or about 2% of total transport diesel demand, will be producing bio-diesel from tallow, a by-product of the meat industry (Z-Energy, 2015). It has been estimated that, based on current sheep and beef numbers, New Zealand produces sufficient low-grade inedible tallow to meet about 5% of the country's diesel fuel demand (MoT, 2013).

New advanced biofuel technologies are now becoming commercialised to convert ligno-cellulosic feedstocks (such as wood or agricultural wastes) into liquid fuels. Zhao *et al.*, (2014) found that, from a financial analysis, the cheapest of eight methods for such advanced ethanol production in the United States, could be technically feasible for a breakeven fuel price of around US$0.82/litre of gasoline equivalent, using fast pyrolysis and hydro-processing of residual corn stover as feedstock. The breakeven price in New Zealand would be heavily dependent on the delivered feedstock price. Hall (2013) showed that around 1.8 million hectares of new plantation forest stands could supply more than 80% of New Zealand's liquid fuel demand. The resulting annual production of 7 billion litres of drop-in biofuels would result in an annual GHG reduction of 15.5 Mt CO_2-eq. Assuming an exchange rate of US$ 0.65 / NZ$ 1.00, an average feedstock price of NZ$85 /m3, and the same government revenue policy on all fuels, the price of oil would need to reach over US$200/bbl (or around US$100/bbl if a carbon tax of around NZ$130/t CO_2-eq was in place) to make biofuels competitive for the majority of the vehicle fleet (Hall, 2013). Utilisation of organic solids or sewage waste for the production of liquid biofuels or biogas has a significant benefit in that collection is already a sunk cost and municipal authorities are focused on reducing disposal to landfill.

The energy consumption of petroleum fuels consumed for shipping and aviation in New Zealand is small compared to diesel used for land transport (Figure 5.14). However, potential exists for the reduction and displacement of fossil fuels in shipping (Zahedia *et al.*, 2014) and in aviation (NASA, 2016; Dumas *et al.*, 2014) (Box 5.2).

Figure 5.14 Annual energy consumption of diesel for land transport compared with domestic and international aviation and shipping fuels.



Source: MBIE (2016c).

Box 5.2: How can we reduce emissions from international aviation and shipping?

In 2013 international aviation and shipping in New Zealand emitted 2.5 Mt-CO_2-eq and 0.97 Mt-CO_2-eq respectively representing 17.9% and 6.9% of annual domestic transport emissions (MBIE, 2014b). INDC's do not have to include emissions from international aviation and shipping (UNFCCC, 2015a). However, given that New Zealand is the responsible party for these emissions, and the likelihood that they could be included in a future revision of NDC inventory requirements, it is important that efforts are made to minimise international transport emissions.

Fields of action include:

- Avoiding unnecessary international air travel by greater use of advanced on-line video-conferencing technologies.
- Using biofuels and/or renewable hydrogen to displace fossil fuels for ships and aircraft.
- Optimising the size of ships and aircraft so that near 100% capacity of passengers and freight can be maintained and our ports and airports can accommodate them.
- Maximising fuel saving technologies and performance efficiency in the design of ships and aircraft such as using lightweight materials, installing solar and wind power systems on ships, utilising airships for freight[86].
- Considering, under a worst case scenario, shorter trade routes by favouring nearest neighbours to become our principal trading partners to minimise the travel distance for exports, imports and tourists (Section 4.6).

86 See for example http://www.independent.co.uk/news/uk/home-news/92m-long-aircraft-to-fly-in-uk-skies-for-the-first-time-a6862546.html

Progress is being made in the production of biofuels for aviation and shipping however the economic viability is still uncertain. Overseas Companies such as Dynamic Fuels, Diamond Green Diesel and Neste Oil have commercial facilities producing biofuel by hydro-isomerization of lipids while KiOR Technology is using commercial scale pyrolysis (Milbrandt *et al.*, 2013). A study of production of jet fuel production by advanced fermentation (AF) from perennial grasses showed that, in 2030, a carbon tax of US$ 42 /t-CO_2-eq to US$ 652 /t-CO_2-eq will be required to make the biofuel competitive with conventional fuels (Winchester *et al.*, 2015).

Air New Zealand flew one of the aviation industry's first biofuel test flights back in 2008, using a jatropha-derived second generation biofuel, which proved the technical feasibility of using alternative fuels (Rye et al, 2010). The test flight also provided supporting data to the subsequent ASTM certification of plant based biofuels for commercial airline operations. The development of standards in aviation both for the quality of biofuel mixtures (ASTM D7566) and for emissions (ICAO, 2016) will assist in lowering the barriers for biofuel uptake.

Transport fleet of the future

What will the future of the road transport fleet look like?

- The penetration of new vehicle technologies into the conventional fleet depends on:
- Technology cost.
- Consumer choice behaviour.
- Policy environment.
- Infrastructure availability.
- Lifecycle emissions.
- Environmental, health and other externality costs.

There are major uncertainties when projecting the rate of future uptake of rapidly developing technologies and concepts (Wadud *et al.*, 2016). These will have a significant impact on the future of mobility in New Zealand and include driverless vehicles, vehicle asset sharing, inductive electric charging, electric grid-vehicle interactions, aviation biofuels, renewable hydrogen production, and enhanced, smart, digital transport and logistics control systems. Significant policy inertia may be required to be overcome to move the vehicle fleet to low emission mode. However, the fuel efficiency of conventional vehicles is improving and their retail price is coming down. Zhao *et al.*, (2015) found that EVs would not be economically competitive with internal combustion engine vehicles (ICEVs) in the Chinese market until at least 2031. So one view is that new technologies such as EVs may not easily compete, whereas other views predict a very different future[87].

"We now face an uncertain future. We cannot be certain demand will return to pre-2005 levels of growth nor can we be certain it will remain flat. This means we can no longer rely on traditional forecasting".

This statement is from the 'Future Demand' project of the Ministry of Transport[88] that explored the uncertainty of future personnel travel with the past growth of 3% per year flattening in 2005 and remaining at around 40 billion kms/yr since then. This equates to 77% of road journeys, the rest being for road freight. Attempts to model the future New Zealand fleet profiles have been undertaken by the industry advocacy organisation Business Energy Council (BEC, 2015) and by Unitec (Leaver *et al.*, 2009). BEC modelled the entire economy using highly simplified, consumer preference decision making for retail vehicle purchase along with value limits to prevent occasional unrealistic fleet profiles being generated (BEC 2015; Loulou 2004). The Unitec model (Leaver *et al.*, 2009; Shafiei *et al.*, 2014) used more realistic non-linear consumer choice behaviour (Train, 2008) without the need to use bounded logic.

The BEC modelled two scenarios called '*Waka*' and '*Kayak*' under the assumptions shown in Table 5.5. The *Waka* scenario has higher numbers of alternative vehicles by 2050 than the *Kayak* scenario principally as a result of the higher carbon tax assumed and a 20% subsidy on biofuels (Table 5.5: Scenario assumptions for assessing the number of electric and hydrogen light duty road vehicles (<3.5 t) in New Zealand in 2030 and 2050 from BEC 2050 and Unitec models.). The BEC *Waka* scenario assumptions were replicated in the Unitec *Waka-S* scenario.

Table 5.5: Scenario assumptions for assessing the number of electric and hydrogen light duty road vehicles (<3.5 t) in New Zealand in 2030 and 2050 from BEC 2050 and Unitec models.

	2030			**2050**		
Scenario	BEC Kayak	BEC Waka	Unitec Waka-S	BEC Kayak	BEC Waka	Unitec Waka-S
Oil Price (USD/bbl)	NS*	NS	120	NS	NS	150
Carbon Price (USD/tCO_2)	60	115	115	60	115	115
Consumer decision based on	NPV	NPV	Choice	NPV	NPV	Choice
**Annual alternative light duty vehicle growth rates	40%	57%	43%	-	-	-

*NS=Not specified. **Assumes Dec 2014 base of 500 alterative vehicles.

Note: The battery price in all scenarios was USD 104 /kWh in 2050 based on the US Department of Energy (DOE) projection of USD 125/kWh in 2022 (Faguy, 2015). The fuel cell price projection of USD 35/kW in 2050 was based on DOE projections of USD 40/kW in 2020 and USD 30/kW in 2050

Source: Satyapai, 2015.

87 http://www.carbontracker.org/report/lost_in_transition/

88 http://www.transport.govt.nz/ourwork/keystrategiesandplans/strategic-policy-programme/future-demand/

The projected rate of adoption of new vehicle technologies to 2030 could be constrained to lower annual growth than the 40% to 57% growth predicted by the scenarios, given that a range of 32% to 37% /year was the early period growth rates for Toyota Prius (Toyota Motor Corporation, 2015), Nissan Leaf battery electric vehicles (Nissan Motor Corporation 2013), and Ford cars from 1903 to early 1920s (excluding 1914-1918) (Kruger and Leaver, 2010).

The *Waka-s* scenario showed that in 2050, the light duty vehicle (LDV) fleet share will be 58% for carbon free (hydrogen internal combustion engine vehicle, hydrogen fuel cell vehicle, battery electric vehicle) plus near-carbon free (internal combustion engine vehicle with 85% ethanol and 15% petrol, plug-in hybrid electric vehicle) vehicles (Figure 5.15). By comparison, Unitec scenarios gave a 46% share with the difference due primarily to exclusion of biofuels by the BEC 2050 model on the assumption they would be uneconomic, and also the different consumer-choice algorithms used.

In the heavy duty vehicle (HDV) fleet over 3.5 tonnes, the Unitec model (Figure 5.15 (d)) predicted 20% of the fleet would be powered by carbon free hydrogen in 2050 with no uptake of electric trucks due to the high cost and heavy weight of batteries reducing a portion of the payload.

The average vehicle numbers in 2050 across the Unitec and BEC scenarios was projected to be 4.5 million LDVs and 160,000 HDVs. These numbers could possibly be lowered given some form of government intervention such as subsidies for early adoption of new technologies and support for new infrastructure.

More optimistic scenarios for EVs also exist including Mighty River Power projecting 0.5 million will be running in NZ by 2025 (Munro, 2014) and Bloomberg Business stating the costs of EVs by 2022 will equate to their ICE counterparts and will account for 35% of all new small vehicle sales globally by 2040 (Randall, 2016).

What is the likely reduction in GHG emissions by 2050?

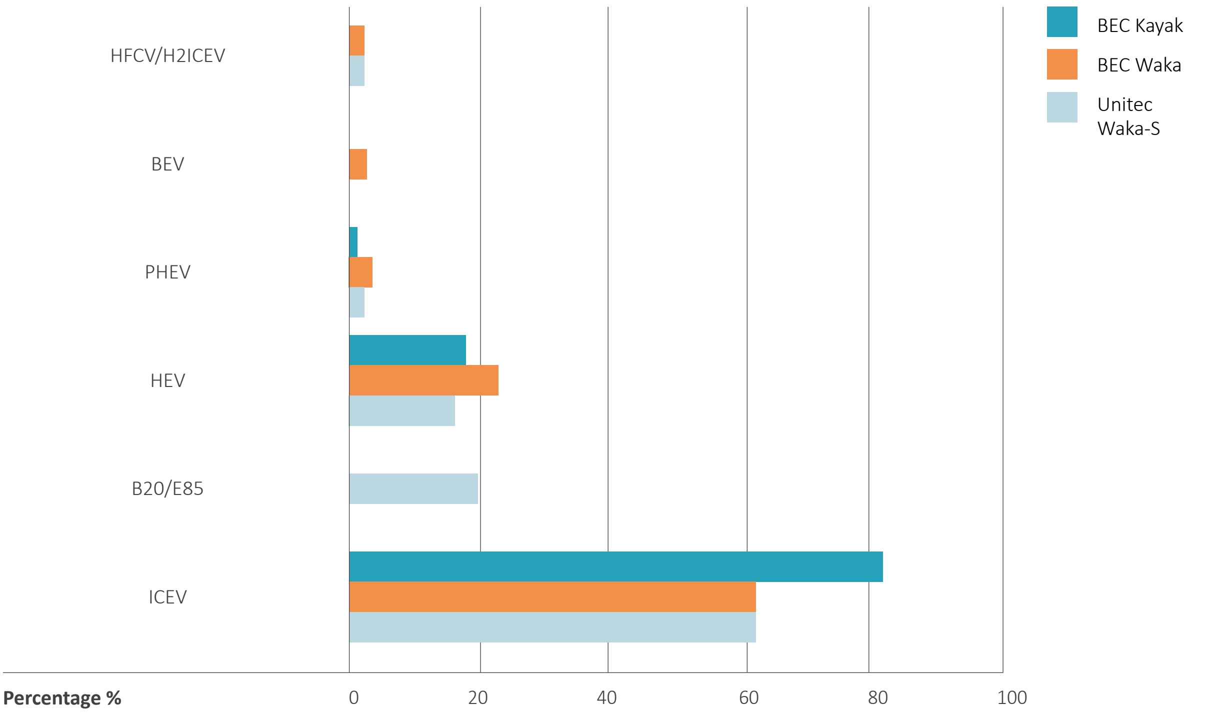
By 2050, New Zealand's GHG emissions from the road transport sector have the potential to decline to around 60% of the 12.69 Mt CO_2 emissions in 2013 (MBIE, 2014b) based on Unitec modelling and the *Waka* scenario of BEC 2050 (Figure 5.17).

How much extra electricity do we have to produce if 30% of the light duty vehicle fleet was powered either by battery electric vehicles (BEV) or hydrogen fuel cell vehicles (HFCV)?

A typical BEV such as the Nissan Leaf has a rated fuel consumption of 0.188 kWh/km. A HFCV such as the Toyota Mirai has a fuel consumption of 106 km/kg-H2 (U.S. EPA, 2015). Assuming 10% energy losses from the electricity source to either charge the battery or fill the hydrogen tank through high temperature electrolysis, New Zealand's present annual electricity generation output would need to increase by 5.4% for EVs and 15% for HFCVs to fuel 30% of the 2013 vehicle fleet. More electricity is required for HFCVs due to the electricity consumed during the extraction of hydrogen from water by electrolysis. Should most BEVs be recharged off-peak, or hydrogen produced from electrolysis off-peak then stored, the need for additional generation capacity could be avoided except during exceptionally dry years when longer term generation shortages could occur. In the future, hydrogen could be produced using solar PV systems either integrated into vehicles or installed at parking spaces including at households.

Figure 5.15 New Zealand light duty and heavy duty road vehicle fleet profiles for 2030 and 2050 from BEC 2050 and Unitec scenarios.

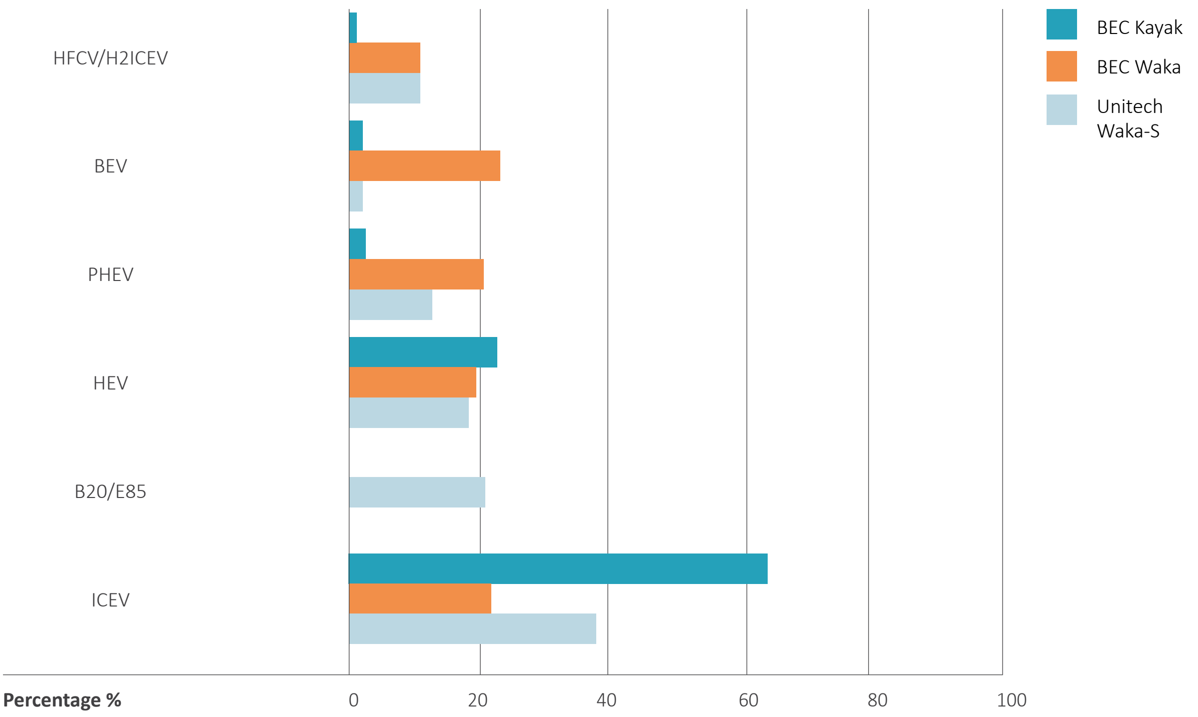
(A) Light Fleet 2030



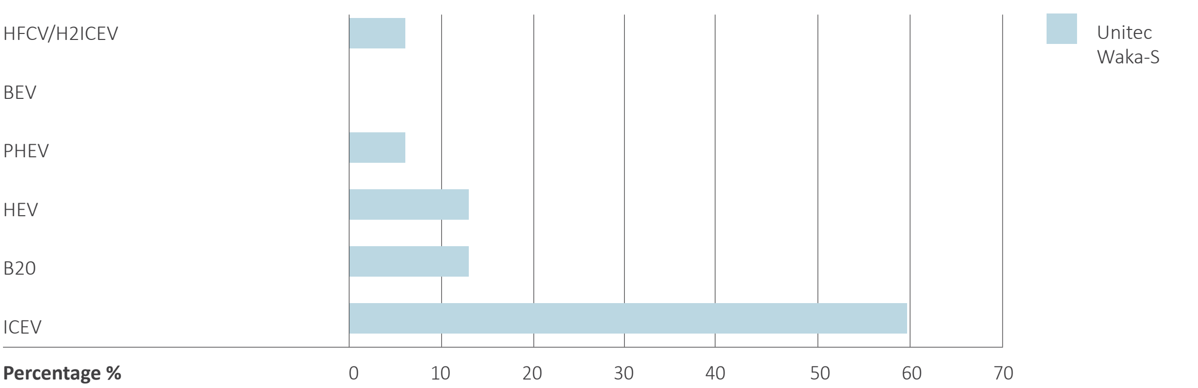
Note: ICEV – internal combustion engine vehicle (petrol or diesel); HEV – hybrid electric vehicle; HFCV – hydrogen fuel cell vehicle; H_2ICEV – hydrogen ICEV; BEV – battery electric vehicle; PHEV – plug-in HEV; B20 – ICEV with 20% biodiesel and 80% diesel; E85 – ICEV with 85% ethanol and 15% petrol.

Sources: BEC 2050; Leaver et al. 2009; Shafiei et al. 2014.

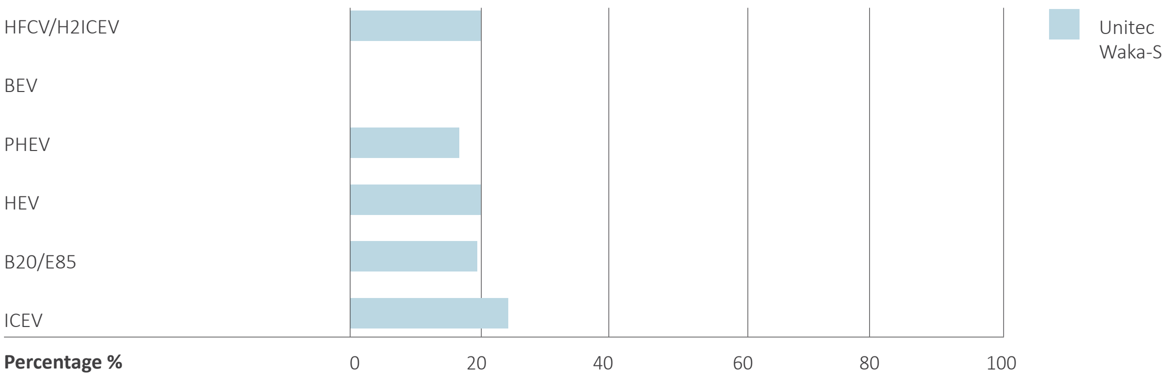
(B) Light Fleet 2050



(C) Heavy Fleet 2030



(D) Heavy Fleet 2050



National and regional mitigating actions and policies

What actions are being planned now?

The New Zealand government's overall objective for transport is 'an effective, efficient, safe, secure, accessible and resilient transport system that supports the growth of our country's economy, in order to deliver greater prosperity, security and opportunities for all New Zealanders' (MoT, 2011). One of the intended key government actions for road transport is continued reduction in emissions of CO_2 from land transport over time. The government sees the sector as having an important role to play in New Zealand achieving its emission reduction target and wants an energy-efficient transport system by intending to:

- Focus on improving vehicle fuel efficiency.
- Improve modal choice in our main urban areas, so people can make greater use of public transport, walking and cycling, thereby reducing their emissions.
- Encourage the uptake of more efficient vehicles and low-carbon fuels and technologies, and other efficiency measures in the freight sector.
- Trial and introduce intelligent transport systems.
- Improve the efficiency and reliability of key freight corridors and metro passenger networks.
- Seek better integration of regional freight movement across road, rail, sea, and air.

Current policy actions include:

- Public funding of public transport.
- Greater provision of cycle ways.
- Proposed changes to allow larger, more efficient trucks on certain roads (MoT 2015);
- continued funding for advanced biofuel research (MƒE, 2015d).
- Fuel efficiency labelling requirements under the Energy Efficiency (Vehicle Fuel Economy Labelling) Regulations 2007.
- Exemption of EVs from road user charges until 2020 (MoT, 2016).

Local governments can also play a role (Box 5.3).

Neither New Zealand nor Australia have fuel efficiency standards which are common in other countries. Fuel efficiency standards, whether regulations or equivalent fiscal policies, cover over 80% of passenger cars sold globally (Miller *et al.*, 2014). A fee-bate system could provide the benefits of fuel efficiency standards suited to New Zealand's circumstances. When a vehicle is imported into New Zealand it would be assessed for its emissions efficiency. Very efficient vehicles would get a tax credit and inefficient vehicles that produce more GHGs would have to pay a charge (Barton and Schütte, 2015).

Box 5.3: How local governments can influence low-carbon transport options

The Auckland Plan (Auckland Council, 2015) aims for 45% of trips in the morning travel peak to be made by walking, cycling or public transport in 2040 compared to 23% at present. Currently, 85% of all trips in Auckland are by private car, with an additional 1.8% or 15,000 extra cars being added to Auckland's roads every year. Inter-regional freight in the upper North Island is forecast to grow by 100% over the next 25 years, with roads expected to account for 86% of transport movements. Transport currently accounts for 39.7% of Auckland's GHG emissions.

Reducing these emissions could be achieved by improved street design; integrated planning; cycleways and footpaths to complement the public transport network; improving the convenience of public transport; and introducing the single-system approach to multi-mode journeys. Several specific actions have already been endorsed by the Auckland Council to achieve these ambitions:

- Implement a single-system approach in the planning, design, management and development of the transport system (including for motorways, state highways, arterial and local roads, freight, rail, bus and ferry services, walking and cycling, ports and airports).
- Implement travel demand management techniques, such as travel plans for schools, organisations and businesses, to manage the growth in demand for private vehicle travel and improve the way existing infrastructure networks operate, before providing additional capacity to the transport system.
- Achieve the appropriate balance between movement and place, considering capacity and environmental character.
- Ensure that long-term land use, accessibility, and activities drive long-term transport functionality and that transport investment aligns with growth as envisaged.
- Optimise existing and proposed transport investment.
- Reassess roading infrastructure based on movement and place, building on existing corridor management and network operating plans.
- Recognise existing community investment and the need to enable connectivity between and within communities.
- Embed sustainability in procurement and project design and management
- Align urban and rural community expectations with appropriate levels of service, and investigate the use of mobility on demand services, such as car-pooling, car ownership sharing, and UBER taxis.
- Ensure that transport is low emission and maximises use of renewable biofuels.
- Improve the capability of the transport system to withstand adverse events.
- Develop walking, cycling, and public transport accessibility levels across the region including in greenfield and brownfield areas.
- Achieve a balance between movement and place functions with pedestrians and cyclists given priority.

Knowledge gaps

What other information do we need to move to a low emission transport sector?

A priority for research on low-carbon transport options in New Zealand includes the following areas (Sims *et al.*, 2014):

- Evaluation of the costs of mitigation from the transport freight sector and to a lesser extent passenger modes.
- Assessment of long-term costs and high energy density potential for on-board vehicle energy storage from batteries or hydrogen that influences vehicle range.
- Management of trade-offs for electric vehicles between performance, driving range and recharging time.
- Identification of exemplars of successful business models in the transport sector overseas.
- Behavioural analysis of the implications of norms, biases, and social learning in journey decision making, and of the relationship between transport and lifestyle.
- Evaluation of costs and impact of infrastructure development for battery and hydrogen vehicles.
- Assessment of regulatory changes needed to encourage the introduction of driverless vehicles and community ownership that together have the potential to reduce traffic congestion.

An attempt was made to provide an overview of estimated mitigation potentials, costs, and possible priority sequencing of mitigation actions across all sectors (Annex 1).

5.3 Buildings

Key messages

- The buildings sector is responsible for around 20% of New Zealand's energy-related GHG emissions, mostly arising from the fossil fuels consumed to meet the demand for heating, cooling and electricity. The majority of buildings that will be in existence in 2050 have already been built so we need to concentrate on improving the performance of current building stock.
- The energy efficiency performance of existing buildings can be largely determined by the original design but tools to help improve performance are currently unavailable for most building types.
- Renewable heat options for buildings have high mitigation potential including wood pellet burners, ground source heat pumps, and passive solar systems.
- It is sensible to minimise the potential energy demand of new buildings at the design stage (such as orientation and solar system integration) otherwise they will have high energy demands for many years.
- The New Zealand Building Code clause on energy efficiency provides a minimum bottom line, and instruments such as Greenstar and NABERSNZ can help encourage new building developers and owners to aim higher.
- Government procurement policies are often a barrier to greater uptake of renewable energy technologies as they often do not consider choice based on a life cycle analysis.
- Appliances have shorter lives than buildings but can still be consuming energy 15 to 20 years after purchase. The application of minimum energy performance standards (MEPS) can help by removing the least efficient appliance designs from the market. 'Doing better' labels, such as EnergyStar, can help encourage manufacturers to supply more efficient appliances.
- Education and training for people designing, constructing, installing and using buildings and appliances is key to reducing GHG emissions over time.
- There is limited up-to-date knowledge on how energy is used in residential or commercial buildings in New Zealand so if this sector is to play a greater mitigation role, this knowledge gap needs to be addressed.

Sources of GHG emissions

Where do GHG emissions from buildings come from?

The role of commercial and residential buildings in GHG emissions is mainly as a consumer of fossil fuels, leading to both direct emissions (e.g. burning of natural gas) and indirect emissions (e.g. GHG emissions from natural gas electricity generation). In some buildings, on-site use of renewable energy (e.g. solar water heating, solar PV, pellet stoves) is changing this situation, but the change is not occurring uniformly or quickly. Some on-site generation may have limited outputs, such as micro-wind technologies, whereas the use of solar PV on building roofs for day-time recharging of electric vehicles (EV) could provide significant opportunities. Reducing energy use by improving thermal performance through greater levels of insulation, or improving energy efficiency of appliances and systems, is continuing, largely through EECA programmes.

Global GHG emission trends for the sector

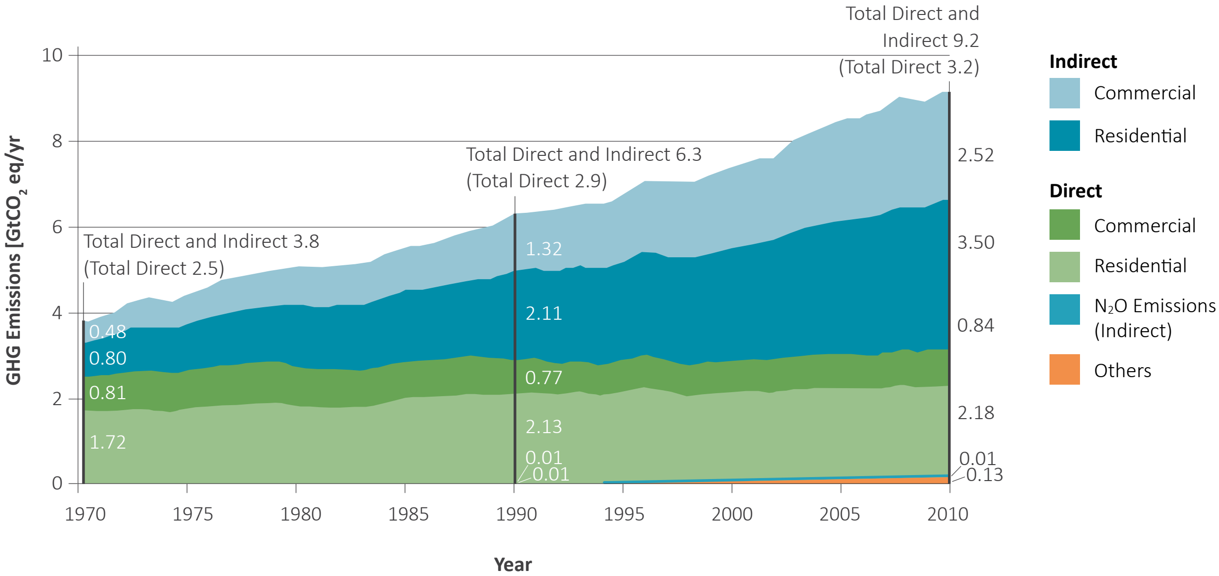
In 2010 buildings accounted for 32% of total global final energy use, 19% of energy-related GHG emissions (including electricity-related), approximately one-third of black carbon emissions mainly from cook stoves, and various shares of F-gases (HFCs, PFCs, SF6). Global growth in future construction requirements is expected to provide increased shelter and energy access for billions of people in developing countries without adequate housing, electricity, and improved cooking facilities (Lucon *et al.* 2014).

What is influencing GHG emissions from buildings?

Globally, GHG emissions from the building sector have more than doubled since 1970 to reach over 9 $GtCO_2$-eq (Figure 5.16). This represented around one quarter of total GHG emissions excluding agriculture, forests, and land use. The high share of indirect emissions in the sector means that the overall emissions depend on emission factors from electricity generation and heat plants.

Without strong actions, global building sector emissions are likely to grow considerably and may even double by mid-century due to the construction of many new buildings, space conditioning (heating, cooling and fans), increased use of appliances, changing behaviours and lifestyles (Lucon *et al.* 2014).

Figure 5.16 Direct and indirect emissions (from electricity and heat production) in the global building sub-sectors.



Source: IPCC (2014b data base).

GHG emissions profile and baseline trends in New Zealand

What are New Zealand's GHG emissions from buildings?

Unlike many other developed countries, New Zealand's comparatively high levels of GHGs from agriculture have resulted in low importance being given to GHG emissions from buildings. They are not explicitly reported (MƒE 2015a), so it is necessary to use energy use as a surrogate. Although national electricity end-use data is published annually for the residential and commercial sector (MBIE 2016a), not all energy used in the commercial sector is used in ways directly related to a building (e.g. for water pumping). So overall there is a limited understanding of mitigation opportunities in this sector. For the purpose of this analysis, it was assumed that all the energy demand by the commercial sector relates specifically to buildings.

Total energy demand in New Zealand's commercial sector is around 9% of total energy end-use, increasing by 50% from 34.5 PJ in 1990 to 51.8 PJ in 2014. Residential energy use has increased 14% (from 55.2 PJ to 62.7 PJ) over the same period. The residential share of total energy end-use reduced from 14% in 1990 to 11% in 2014 (MBIE, 2016a) due to greater growth of energy demand by other sectors. The residential sector has shown a relatively slow compound annual growth in energy demand of 0.5% per year from 1990, due probably to the various energy efficiency improvements coupled with significant increases in the price of electricity (Bertram, 2015). Growth of the commercial building sector is higher at 1.7% /yr but still below transport (1.9%/yr) and agriculture, forestry and fishing (2.2%/yr).

The total use of electricity use in buildings continues to grow from 36.7PJ in 1990 to 44.9 PJ in 2014 with an annual compound growth of 0.8%. In the commercial building sector alone, electricity use was 19.4 PJ in 1990 increasing to 33.5 PJ in 2014 – a compound growth of 2.3%/yr. The use of coal for direct heating has decreased while the use of natural gas has increased in both the residential and commercial sectors.

Although the total energy demand of the residential sector has grown as more dwellings have been constructed, the average energy use per dwelling has been falling since 2000 with the energy efficiency of the average dwelling expected to continue to improve out to 2030. The decline in energy use per house is being driven by a decline in the average use of wood and electricity most likely due to appliance efficiency improvements, changes in the technologies being used, and fuel switching (Energy Consult, 2015).

In order for the total residential energy use to decline further, it will be necessary for the efficiency improvements to occur at a faster rate than the increase in total number of dwellings.

GHG mitigation options

How can we reduce GHG emissions in the building sector?

New residential and commercial buildings are already subject to thermal performance requirements in the energy efficiency clause of the New Zealand Building Code (MBIE 2014c). These include minimum requirements for the building envelope (roof, walls, floor and windows) and for the domestic hot water systems. In addition lighting power density limits are established for commercial buildings. However, to encourage new building developers and owners to strive for improved thermal and lighting performance levels through, for example, higher R-value glazing and insulation (Jaques, 2016), the current minimum energy efficiency requirements requirements of the Building Code should be made far more stringent than they are currently are, given that a new building will be consuming energy over its 50 year or more lifetime.

Research has been undertaken into the use of electricity and heat in houses and offices and shops but there has been little or no data collected on energy use in apartments, marae, communal residential buildings, communal non-residential buildings, industrial buildings or commercial buildings other than offices and shops. Two major projects have been published:

- *Household Energy End-use Project* (HEEP) dealt only with detached dwellings and was completed in 2007 with data collected from 1999 until 2005 (Isaacs *et al.*, 2010).
- *Building Energy End-use Study* (BEES) dealt with office and retail building uses and was completed in 2013 with data collected mostly from 2009 to 2012 (Amitrano *et al.*, 2014).

However, data from both of these projects has not been updated. Technology is changing, and many of the changes can have important impacts on energy use including the following:

- Government action to promote higher appliance efficiency through the use of 'Energy Star™' labelling for whiteware and home electronics.
- The Energy Star labelling being used for commercial electric light units, space and water heating, windows and lighting which all have a direct impact on a building's energy demand (EECA, 2016).

- The shift in lighting technology from incandescent lamps to halogen lamps to compact fluorescent lamps(CFLs) to light emitting diodes (LEDs) that has taken place over about 20 years and resulted in decreased energy use for similar (or even better) lighting quantity and quality.
- Use of 'smart meters' that, as well as recording electricity use, have the potential to implement time-of-use tariffs and hence help to shave peak demand. This feature can be used to control the operation of appliances where time of operation may not be significant (e.g. clothes washing) or demands (e.g. hot water heating) which in turn can change the time and nature of peaks, and hence the need for grid investment (Jack *et al.*, 2016).

While appliances have become more efficient, they have also tended to become larger and, as a result, consume more electricity, often called 'take-back' or 'rebound effect' (Galvin, 2015). For example, the shift from CRT (cathode ray tube) to plasma to LED flat screen televisions has led to lower energy use per unit screen area, but the energy savings have been offset by consumer demand for increased screen size. Coupled with reduced prices, the increasing numbers of large screen televisions have resulted in increased energy use in spite of the more efficient technology. Whereas households used to have only one television, many now have several. In the commercial sector, the use of a simple notice board has commonly been replaced by a monitor screen through a central computer system.

While some efficiency improvements will come from appliance manufacturers, local policies are also helpful to reduce energy consumption such as:

- Removal from the market of the most inefficient appliances through the use of MEPS minimum energy performance standards (MEPS).
- Promotion of more efficient appliances through programmes such as EnergyStar.
- Promotion of more efficient buildings through programmes such as Greenstar and NABERSNZ[89].
- Development of more stringent minimum building performance levels for implementation in the New Zealand Building Code.
- Education and training for those involved in designing, constructing, manufacturing, installing and using buildings and their equipment.

What opportunities and barriers exist around GHG mitigation options for buildings?

Opportunities may exist in the export of locally developed energy efficiency and energy management solutions for buildings. Barriers appear to be the lack of:

- Appropriate standards.
- Support to remove inefficient appliances and equipment from market.
- Up-to-date energy use data.
- Stringent guidelines and regulations to improve designs and energy performance of new building and the retrofitting of existing buildings.

Residential building energy use

How is energy used in residential buildings?

There are approximately 1.5 million occupied dwellings in New Zealand, with a total floor area of about 222 million m^2, giving an average floor area of about 160 m^2 per dwelling (including any internal garage).

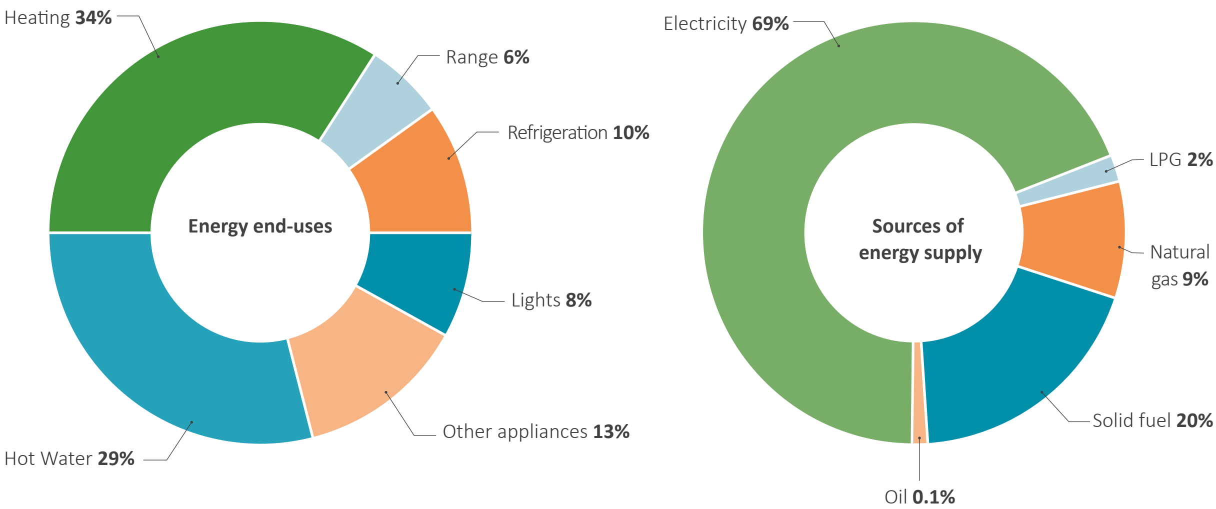
The average household mainly uses energy for heating of space and hot water with electricity being the main energy source (Figure 5.17) (Isaacs *et al.* 2010). Based on a survey of 400 free-standing houses in the HEEP study of the early 2000s, it was apparent that the averages may not represent any individual household due to variations in comfort levels and number of residents.

Since this 2005 study, lighting and appliances have become more efficient, patterns of cooking and eating have changed with an increased use of factory-prepared foods and electric air-to-air heat pumps have become increasingly popular forms of heating, adding a new cooling load in many dwellings. Increasingly, tighter environmental requirements on solid fuel space heating in some locations, have shifted more heating energy demand onto the electricity grid.

Residential space heating globally is around 32% of total energy demand that is comparable to New Zealand's demand of 34%. Domestic hot water in New Zealand at 24% compare to 29% globally (Figure 5.18). The greatest difference is for appliances with NZ at 13% of total energy demand compared to 29% internationally (Lucon *et al.* 2014).

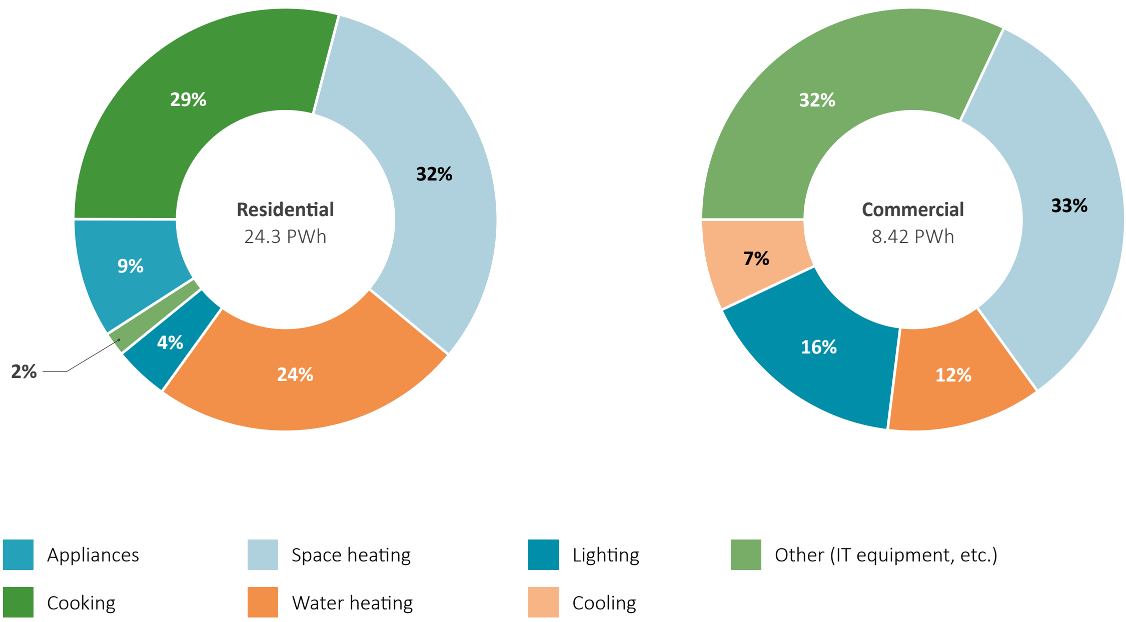
89 National Australian Built Environment System for NZ.

Figure 5.17 Average shares of energy end-use demand and sources of energy supply for New Zealand households from 1990 to 2005.



Source: Isaacs et al., 2010.

Figure 5.18 World final energy consumption by end-use for buildings in 2010.

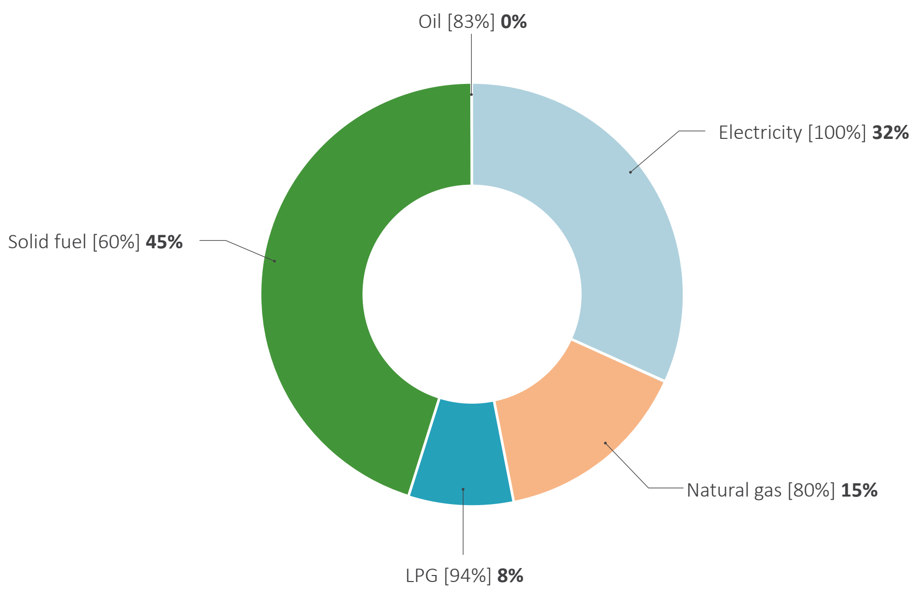


Note: 1 PWh equates to 1 million GWh or 1 billion MWh.

Source: IPCC (2014b, Chapter 9).

Figure 5.19 Shares of space heating fuels used in New Zealand households in 2005.

Assumed appliance efficiencies in brackets.



What are the sources of space heating in New Zealand dwellings?

Space heating is a high household energy use supplied by various fuel types (Figure 5.19). Different fuels are converted to heat at varying efficiencies, so to understand the household heating market it is necessary to take account of the appliance efficiencies. Space heating in 2005 was dominated by burning wood, coal, LPG or reticulated natural gas to give direct conversion to heat. Only about a third of space heating energy came from electricity, the majority being used to power conventional resistance heaters with low efficiency.

Since the early 2000s, there has been large growth in use of efficient heat pumps which has increased the share of electricity demand and reduced solid fuels. While a resistance heater provides a single unit of heat for each unit of electricity (100%), a heat pump can provide 3 to 4 units (300-400%). Heat pumps can also be used for cooling on summer days and their rapid deployment is illustrated by the peak electricity demand in Auckland one hot day in the summer of 2016 being 10% higher than a similar day in 2015[90].

90 http://www.stuff.co.nz/auckland/76510817/aucklanders-suck-up-power-in-hot-humid-weather

Heat pumps have been actively promoted, not only due to their improved efficiency but also due to the increased emphasis on reducing local air pollution from the inefficient combustion of solid fuels in open fires or poor designs of solid fuel burners. The technology of solid fuel combustion has improved with well-designed enclosed stoves and computer controlled pellet burners, but there is still room for further improvements. Ground source heat pumps are being installed, especially in Christchurch, as a cost effective heating and cooling system for buildings. Direct use of woody biomass for space heating provides increased resilience in case of failure of electricity supply and has been argued can help to reduce peak winter power demand.

One quarter of the 400 houses surveyed in the HEEP study had living rooms with mean winter evening temperatures below the World Health Organisation recommended minimum of 16°C. Such low temperatures can lead to building fabric durability issues as well as poor health consequences which have been one of the drivers behind the Government's promotion of improving the thermal performance of NZ houses by adding roof and floor insulation.

New houses can benefit from designs which incorporate not only thermal insulation but careful integration of glass and mass. Such passive solar designs make use of orientation to the sun coupled with the use of glass to allow entry of solar heat and the use of thermal mass to store this heat with good levels of thermal insulation to reduce its escape. Added control of air leakage, external shading and ventilation to reduce overheating and maintain indoor air quality, will give a house design which is cool in summer and warm in winter. Low, or even zero-heat energy houses are technically feasible in many parts of New Zealand (Donn and Thomas, 2010). More complex technology such as air-to-air or geothermal heat exchangers may also be used.

Water Heating

New Zealand has a high proportion of electric domestic hot water systems, with 69% of houses having only electric hot water cylinder(s) and another 17% having electric plus some other form of water heating, normally a wet back supplementary heater powered by the solid fuel burner (Figure 5.20). With the shift away from solid fuel burners, this supplementary source of water heating is also being removed, thereby increasing the direct electricity requirement for hot water. Although electric air-to-water cylinder heat pumps are available, they have a relatively high initial cost.

The different domestic hot water systems illustrate one aspect of the complexity of energy use in buildings. Energy can be consumed even when the appliance is switched off and on stand-by, and also while it is preparing for use or waiting to be used, in this example as stored heat. The 'loss' component (Figure 5.21) is due to the technical performance of the hot water generation. These 'standing losses' are due both to technology (e.g. inadequate cylinder insulation) and occupant requirements (e.g. maintaining a higher water temperature in order to ensure acceptable supply regardless of the size of the tank). The 'hot water' energy lifts the water temperature from the in-coming cold supply to an acceptable washing temperature but is, in turn, driven by the volume of hot water used. The volume is a function of the demand, but this can relate to behaviour such as the taking of a bath or a shower, and also user technology such as the installation of a low-flow shower head. Solar water heaters are commonly used to supplement gas or electricity heating, with typical substitution levels around 30–50% per year depending on location and hot water use behaviour in the household.

Figure 5.20 Shares of domestic water heating system by type in New Zealand in 2005.

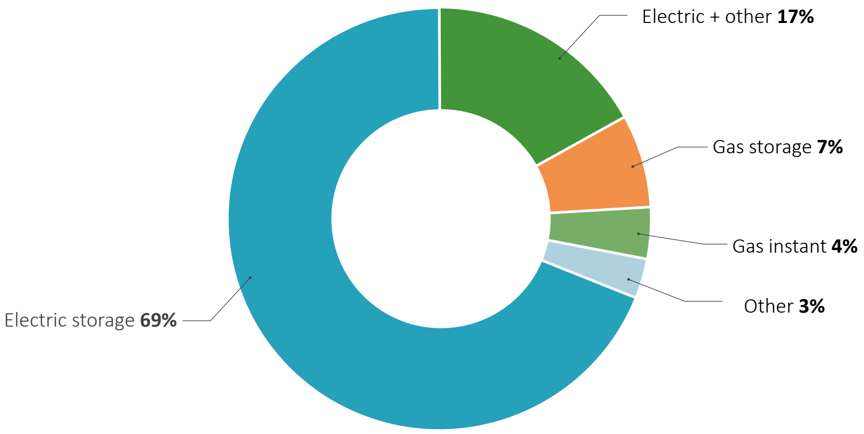
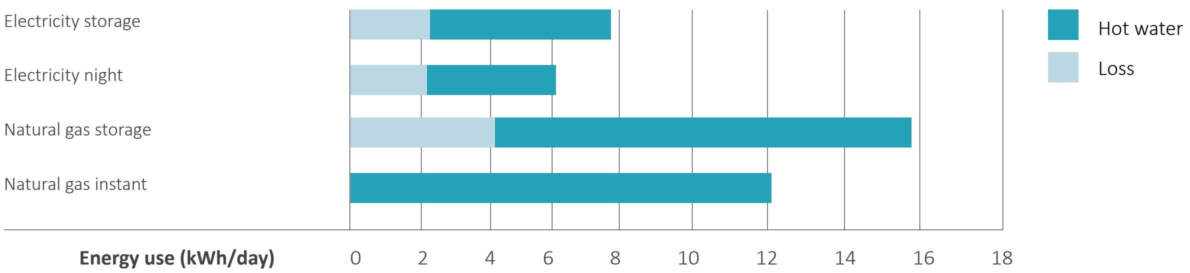


Figure 5.21 Domestic hot water energy use by fuel type and system.



Commercial buildings' energy use

How is energy used in office and shop buildings?

In New Zealand there are over 41,000 commercial buildings containing offices and/or shops, with a total floor area of 39.93 million m^2, giving an average floor area of approximately 970 m^2 per building. The size distribution is extremely skewed with around 27,000 buildings under 650 m^2 floor area and around 500 with over 9,000 m^2. Lighting consumes around 19% of total energy demand, over double the share of residential buildings, with heating, ventilation and air conditioning most of the rest.

Complexity of use makes it difficult to provide simple energy saving solutions that apply across all commercial buildings. Residential buildings are used for a reasonably similar range of purposes (eating, sleeping, socialising, entertainment etc.) whereas offices and shop buildings can vary from low energy activities (e.g.an unheated garden centre) to being very energy intensive (e.g. a bread bakery). Similarly, while the very large majority of houses fit within a reasonably narrow band of floor area and number of storeys, commercial buildings come in a wide range of sizes and designs. To add further levels of complexity, there are differences in the use of space conditioning (larger office buildings are often heated and cooled); hours of use (houses tend to be used at night while commercial buildings can be used at any time); times of use (houses tend to be used every day while commercial buildings are usually only used during work days or even only once or twice a week); and ownership (many houses are owner occupied while commercial buildings can be a combination of owner or tenant occupied, with or without specialist energy managers). Neither office and shop tenants nor building owners can be treated as homogeneous groups.

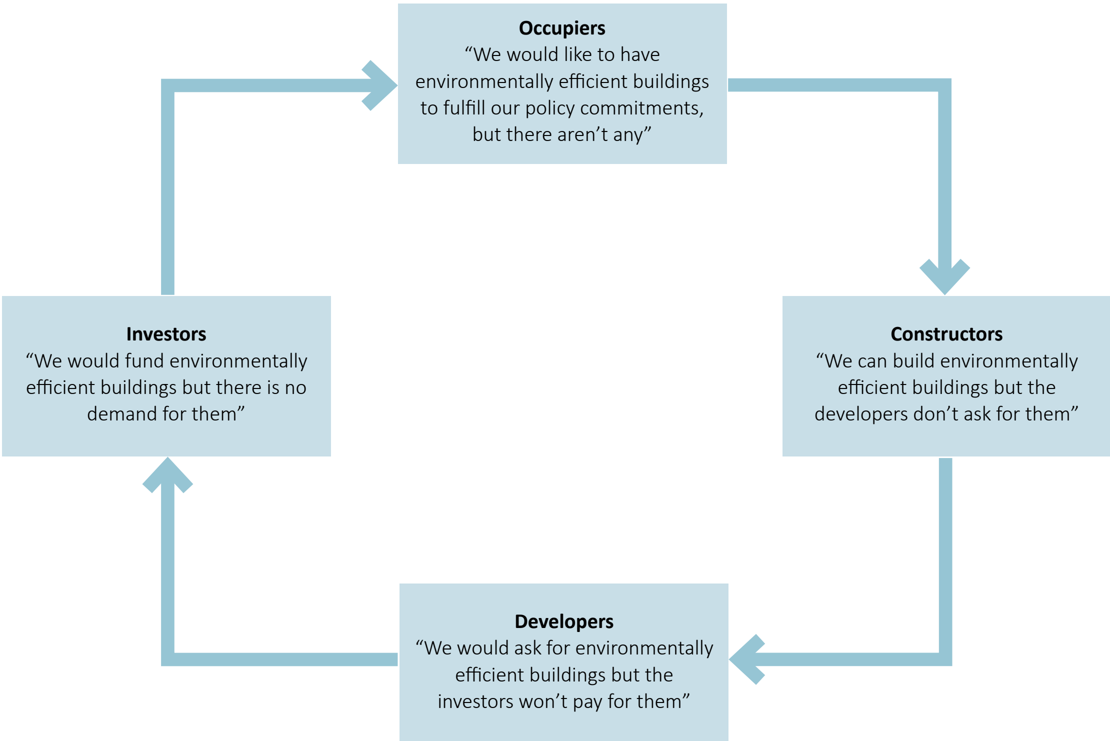
As is the case for residential buildings, the New Zealand Building Code establishes minimum performance requirements for new commercial buildings and Energy Star specifications exist for some appliances and electric light units.

The BEES survey of over 100 building owners and property managers and over fifty owner-occupiers in a recent study (Amitrano *et al.*, 2014) found that:

- Technical energy saving solutions need to be devised to provide both cost-effective new-builds and cost-effective retrofits.
- Cost-effective and easily-managed operational systems need to be developed and promoted.
- Considerable effort needs to be directed at creating awareness among building owners, property managers and tenants about innovative energy saving technologies, energy efficient building designs and carbon content of construction materials, as well as operational systems.
- Support is needed by promoting credible and tailored case studies that take into account the different imperatives that these stakeholders bring.

Each of the key groups surveyed (occupiers, constructors, developers and investors) reported interest in more environmentally efficient buildings, but each group felt unable to shift this interest into action (Figure 5.22). The EECA energy end-use survey includes the commercial building sector approximately every 4 years.

Figure 5.22 The challenge in generating stakeholder interest in efficient energy use in commercial buildings.



Influence of long term ambitions on near term actions and pathways

What are the pathways for reducing emissions from buildings?

A building can be thought of as having different layers, each with different longevity. Duffy (1990) divided the building costs for commercial office buildings into three layers: shell; services; and scenery. Brand (1997) developed this further by including a fourth category 'set', described as 'all the things that twitch around daily to monthly'. Overarching these layers is society which establishes the conditions within which buildings exist. The New Zealand Building Code has a durability clause that expects the building shell to have a life of not less than 50 years, but accepts a lesser life for other layers.

Combining these expectations confirmed that change in the building sector takes a long time for some parts, but can be quicker for others (Table 5.6) (Isaacs 2015). Globally, it is expected that approximately 80% of energy use in buildings will be 'locked in' by 2050 for decades to come, compared to a scenario where today's best practice buildings become the standard in new building construction and existing building retrofit (Lucon *et al.* 2014).

Design or construction choices can result in poor performance of the shell and services layers, so internationally minimum performance requirements have been implemented through legislation, although voluntary programmes have also had success in lifting the top end of the market. Minimum performance in the scenery and set layers are most often managed through combinations of legislation and prestige-based activities.

An attempt was made to provide an overview of estimated mitigation potentials, costs, and possible priority sequencing of mitigation actions for buildings but limited data constrained this endeavour (Annex 1).

Co-benefits

What other benefits would result from mitigation options for buildings?

Almost all actions taken to improve energy efficiency in buildings have positive financial and social co-benefits such as improved comfort. From a financial viewpoint, spending less on purchasing energy for buildings releases funding for use in more productive or desirable ways. Research has demonstrated that improved energy efficiency can result in improved productivity, improved comfort and health, improved building durability and hence increased asset value, improved individual and national energy security as reduced energy demands provide greater flexibility and disaster resilience, and reduced local air pollution as well as GHG emission reductions (Lucon *et al.* 2014).

Examples of co-benefits include:

- Experiences lead to positive attitudes to opportunities in other sectors.
- Improved comfort and potential health benefits.
- Potential for improved durability of building (e.g. through reduce disfiguring or destructive mould).
- Ability to direct financial savings to more profitable uses.
- Improved flexibility and disaster resilience.

Table 5.6: New Zealand house component expectations over time.

Layer	Longevity	NZBC Clause B2	Example	Description
Shell	Life	50 yrs.	Structure and its components	– Sub-floor (piles), Floor, Wall, Fenestration, Roof – Stone, Timber, Concrete, Steel, Glass – Fixings: nails, screws
Services	15 yrs.	15 yrs.	Cabling, plumbing, etc.	– Sanitation: cold & hot water, sewerage, toilets, basins – Distribution: pipes, wiring – Fuels: solid, gas, electricity, oil
Scenery	5-7 yrs.	5 yrs.	Layout	– Finishes: Paint, wallpaper, decoration – Built-in heaters & lighting
Set	Flexible	Not covered	Shifting of furniture	– Furniture, appliances, etc. – Space heating & cooling plant and equipment

Knowledge gaps

What else would be useful to know?

The maxim 'if you can't measure it, you can't manage it' applies very strongly in this sector. The lack of timely data for all building sectors makes planning mitigation for buildings and urban development difficult. Until this knowledge is available, the efficacy of mitigation actions within the New Zealand building sector will remain unknown.

Case studies

Are there good examples that others might follow?

The Eco Design Advisor service is operated by a number of councils around New Zealand. It provides free advice to help achieve the best use of energy, water and materials on home building projects. Through the advisors and their website they provide a wide range of factsheets to assist in the design and renovation of housing[91].

Existing home owners, landlords and tenants can receive assistance and advice from members of the Community Energy Network, a national network of community enterprises working to show leadership in the residential energy sector. As well as linking to recycling programmes, Environment Centres, skills and employment initiatives, their members operate Curtain Banks. They also provide certified Home Performance Advisors to undertake house inspections and report on opportunities to improve the performance of the home[92].

- The award winning Te Wharehou O Tuhoe[93] located in Tāneatua is the first building in New Zealand built in accordance with the North American Living Building Challenge, the most stringent sustainability criterion that can be applied to buildings[94].

It houses the Tribal offices, retail and meeting hall with a 37 kWe rooftop solar PV system. The building work in harmony with the ecosystem: the locally sourced timber structural systems, including 200 pine piles, were designed to minimize embodied energy and carbon emissions; roof water is collected and stormwater diverted to a pond with soakage hole; and treatment of the wastewater is through sedimentation pond, wetland and irrigated to land.

91 http://www.ecodesignadvisor.org.nz/
92 http://www.communityenergy.org.nz/
93 http://www.ngaituhoe.iwi.nz/te-wharehou-o-tuhoe-celebrated
94 http://living-future.org/lbc/certification

5.4 Industry

Key messages

- The industrial sector directly produces 6.3% of our gross emissions (5 Mt CO_2eq), mainly from cement and steel manufacture and HFCs from solvents and refrigerants.
- A similar amount of indirect emissions comes from the electricity consumed by industry plus fossil fuel combustion to raise process heat (with around 45% of that coming from coal).
- There are few technology barriers to the use of renewable heat energy in most instances and high potential to displace fossil fuels. For locations where biomass or geothermal resources are limited or costly, it may currently be uneconomic or there may be concerns over security of supply. Investment decisions require an evaluation of the long-term availability of the fuel required for the heat plant installed, even where biomass process residues and wastes are produced on-site.
- Industries which have large single point sources of emissions have the opportunity to consider carbon dioxide capture and storage (CCS) measures in the future if and when they become cost effective under a high carbon price. Potentially on-site bio-energy generation liked with carbon dioxide capture and storage (BECCS) could physically remove CO_2 from the atmosphere.

Sources of GHG emissions

Where do industrial GHG emissions come from?

Globally, industry's main contribution to total GHG emissions is dominated by the energy consumed in the manufacture of products, particularly fossil fuel combustion to provide process heat. Manufacturing is responsible for 98% of the total direct emissions from the industry sector (IEA, 2012a).

GHG emissions from the industrial process and product use sector are almost exclusively CO_2 emissions from the combustion of fossil fuels, although CO_2 is also produced when heating limestone during cement manufacture.

In New Zealand, industrial processes and product manufacturing emit about 5 $MtCO_2$-eq /yr (MBIE, 2015) mainly from cement manufacture and HFCs used as solvents.

Based on the emission intensities, the proportion total GHG emissions from the various fuels used to provide industrial process heat were calculated to be 45% coal, 34% natural gas, 10% oil, and 6% electricity with the remainder coming from geothermal fields and biomass supply systems.

Global GHG emission trends for the sector

What are the global trends for the industrial GHG emissions?

Global direct emissions from industry have grown steadily by 41% since 1990, from 7.1 $GtCO_2$-eq in 1990 to 10.0 $GtCO_2$-eq in 2010 (Figure 5.24). In addition, in 2010 the global industrial sector accounted for around 28% of final energy use (IEA, 2013).

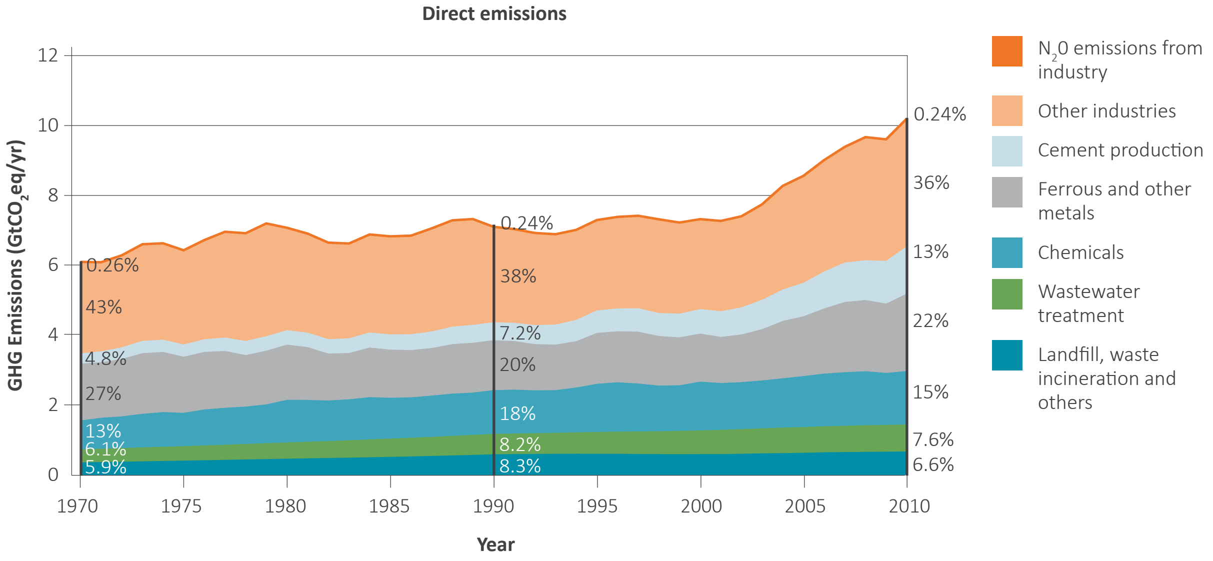
GHG emissions profile and baseline trends in NZ

What are the trends in New Zealand?

The energy consumption by the industry sector has been reasonably constant, but with a 10% increase in 2014. The sector accounted for 38% of New Zealand's primary energy demand and was the largest consumer of coal, using 39% of the total demand (MBIE, 2015).

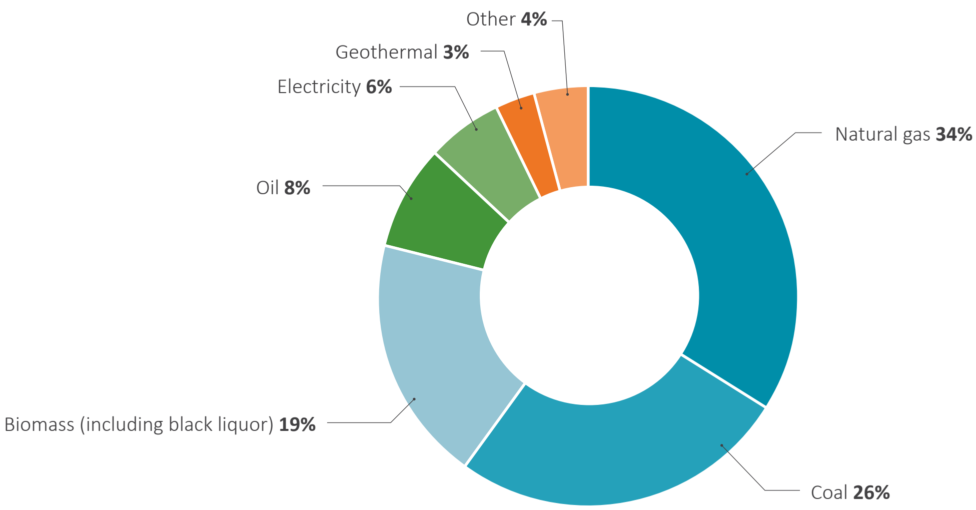
In 1990, direct emissions from this sector were $MtCO_2$-eq rising to 5.1 $MtCO_2$-eq in 2013, a 55% increase and equating to 6.3% of our total GHG emissions. In addition, fossil fuel combustion contributes around 68% of industrial heat demand. Dominant users of industrial heat are dairy processing (26% of total CO_2 emissions), petro-chemicals (21%), cement (19%) and metals processing (12%). Analysis of EECA's heat plant database (unpublished revisions, EECA, 2015) gave the fuel use shares (in energy terms) for industrial heat applications (Figure 5.23).

Figure 5.23 Growth in direct GHG emissions from global industry.



Source: IPCC (2014d).

Figure 5.24 Shares of fuels used to meet industrial heat demand in New Zealand in 2014.



GHG mitigation options

How can we reduce GHG emissions in the industrial sector?

Greater focus on energy efficiency in industry would help to lower GHG emissions. Energy intensity (MJ input/unit of product or MJ input/unit of GDP) is one potential measure of this. Across New Zealand society, there has been a 1.1% reduction in energy intensity per year on average since 1990 (Figure 3.3) but only 0.5% per year in the industrial sector. However, since 2010 this has been rising, largely due to the restarting of methanol production at the Motonui and Waitara Valley plants, steady production at the Tiwai Point aluminium smelter, and a drop in production in the wood processing, and pulp and paper industries.

Energy demand by industry was about 170 PJ/yr in 2014 with coal providing 65 PJ/yr (MBIE, 2015). Further use of renewables by the sector could provide a significant GHG mitigation option. For instance, Hall (2013) showed that 26 PJ/yr of residues from the wood harvesting and processing industries are currently available for heating fuel. This could rise to 46 PJ/yr by 2020 when woody biomass could become an alternative for coal in many solid fuel combustion applications. Furthermore, an additional 0.8 million hectares of dedicated energy forests (that mature around 25 years old) could store around 200 Mt of carbon and, on harvest, provide over 140 PJ/yr of bioenergy, resulting in GHG emission reductions of about 5 Mt CO_2-eq/yr if displacing coal. Planting at this scale would increase the plantation forest coverage in New Zealand by about 45%, but, if grown on steep hill country, could provide further co-benefits of reduced soil erosion, lower nitrogen run-off, and improved water retention, though soil and waterway damage may occur and will need to be managed when using present harvesting regimes. (Section 5.6).

Greater use of dispatchable renewable electricity (derived from hydropower and possibly biomass) to power electro-thermal technologies, or direct use of low to medium grade heat from geothermal sources, may also be options for some heat applications including heated greenhouse crop production. At the right scale, geothermal heat, including waste heat from power plants, can be cost-competitive with other thermal options[95].

Improvements in energy efficiency and greater use of renewable energy to substitute for fossil fuel combustion have the potential to reduce GHG emissions from industrial process heat demand by around 35% by 2035 (Figure 5.25). Emission reduction could be achieved by replacing or augmenting existing coal-fired or oil-fired boilers with wood-fired or co-fired boilers (wood/coal or wood/gas). Other biomass sources such as crop residues or biogas could also be utilised as could high efficiency thermo-electric heat technologies as they become more cost-competitive.

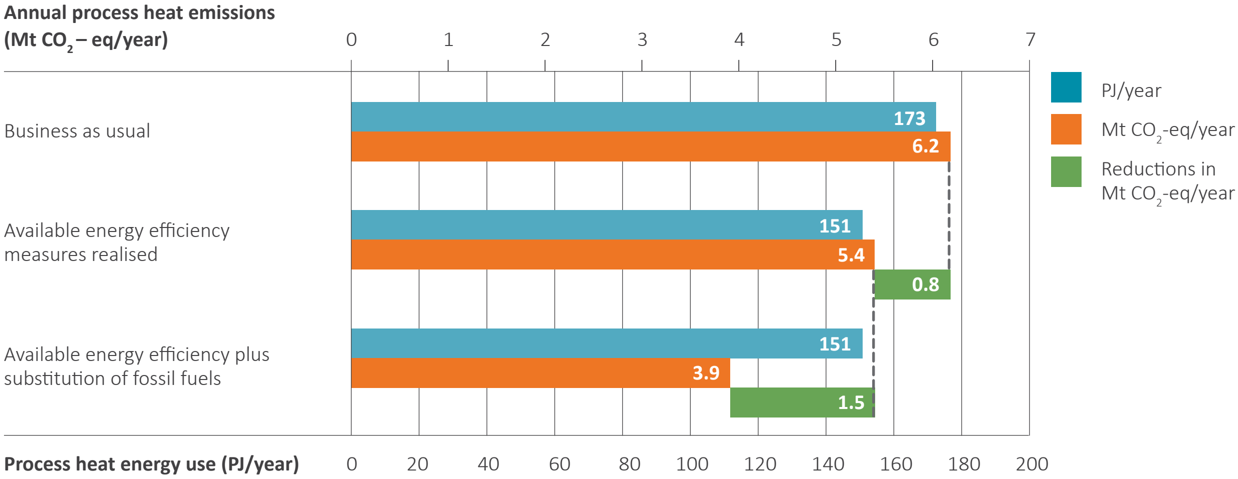
Large single-point sources of CO_2 emissions such as cement, steel and aluminium production, offer best available opportunity for carbon dioxide capture and storage (CCS) in the long term. Improvements in CCS technology are required and adequate nearby CO_2 storage sites needed before CCS can be considered, but the costs involve would require a high carbon price (around $50-100 /t CO_2 based on current CCS technology and electricity demand). A number of likely storage sites have been identified in New Zealand (Field *et al.*, 2009). Significant deployment of CCS would require current technological improvements to continue or for New Zealand to enact suitable legislation (Barton *et al.*, 2013).

Coupling bioenergy and CCS technology may offer the most likely route to achieve negative GHG emissions as will be needed before the end of this century in order to stabilise atmospheric concentrations and keep global temperature rise below 2^{o}C (Box 5.1). These options could provide a means to relax the GHG reduction requirements on sectors that are more difficult and currently costly to decarbonise whilst still moving towards net zero GHG emissions.

An attempt was made to provide an overview of estimated mitigation potentials, costs, and possible priority sequencing of mitigation actions for all sectors, including industry (Annex 1) but there was limited available data to give accurate assumptions of costs and potentials.

95 http://www.bayofconnections.com/downloads/Mike%20Suggate%20-%20East%20Harbour%20Energy%20-%20The%20Economics%20of%20Geothermal%20Heat.pdf

Figure 5.25 Reduced energy demand projections for process heat in New Zealand in 2035 as a result of energy efficiency (EE) and low-carbon fuel option scenarios in 2035.



Source: Unpublished analysis based on the EECA Energy End-Use database that contains allocations of national energy use broken down into sectors, technologies, end users and fuel types[96].

96 https://www.eeca.govt.nz/resources-and-tools/tools/energy-end-use-database

Influence of long term ambitions on near term actions and pathways

What steps could be taken to realise long-term ambitions?

GHG emissions from process heating is a key area for focussed attention to enable New Zealand to meet its GHG emissions reduction commitments. Greater focus on renewable heat as well as energy efficiency of heating and cooling systems is required, with implementation ideally taken now using commercially available technologies and leading to long-term benefits. EECA has successfully held the lead role in this area for several years but more could be achieved give higher resourcing.

Co-benefits

What are other benefits from GHG mitigation options in industry?

Reduced fossil fuel combustion can provide other environmental benefits such as lowering local air emissions to air, including sulphur dioxide, nitrogen oxide and particulates. These co-benefits depend on whether coal, gas or oil demands by industry are being reduced from improved energy efficiency, and on what form of renewable electricity or heat is used to displace them.

Biomass used to replace fossil fuels can also result in additional eco-system benefits, as well as enhanced local employment opportunities.

Insights on enabling policies

What policy interventions would be useful to encourage more rapid update of GHG mitigation options?

Currently, there are few national level mandates or incentives to promote GHG emission reduction projects in the industry sector in New Zealand. EECA may fund up to 40% of the costs of a feasibility study for industrial or commercial projects, up to a maximum of $50,000, to evaluate any technology or process that relates to energy efficiency or renewable energy uptake.

For marginal projects with too long a commercial payback period, the current price of carbon under the emission trading scheme (NZ ETS) is an insufficient driver for a business to undertake fuel switching or any other major capital investment needed to reduce emissions. The full social or national costs, risks and benefits that result from private sector investments should also be taken into account.

A factor that affects GHG emission reductions from industry is the NZ ETS, though this is only recently producing enough of a price signal to encourage industrial emitters to change behaviour in a significant way (section 4.8). A particular factor that reduces the impact of the NZ ETS on many industries is the free allocation of units to companies engaged in 'emissions-intensive trade-exposed' (EITE) activities. These include where products such as pulp and paper are also produced in countries where there is no price on carbon or where, for example, washing machines are imported from China but also manufactured in New Zealand.

A policy question currently under discussion is how long the EITE free allocation should continue, and on what terms. Industrial emissions vary enormously in their character and the activities that make up the industry sector are much more diverse than, for example, in transport. The general price signal coming from the NZ ETS has the potential to be effective in modifying economic activity in the sector (Section 4.8). Other measures, such as for energy efficiency, are harder to design and implement at a general level and each industry has its own characteristics that need to be addressed separately. Therefore, policy development is more complex than in other sectors.

Case studies

Are there good examples that others might follow?

- The Sequal Lumber timber drying kilns at Kawerau were converted from fossil fuel combustion to geothermal energy in 2014, providing a demonstration of the competitive heat supply from geothermal that can be widely used by process industries[97].
- Provision of process heat for lower temperature/lower capacity applications such as in the horticultural production sector, is significantly less challenging than some of the applications discussed above, and is easier to implement. A flower grower in Christchurch for example, uses around 100t/yr of biomass waste from its production as biomass fuel to heat the boilers to heat the greenhouses, thereby saving around $100,000 /yr from the previous purchase of coal and also avoiding around 3,500 t/yr of CO_2 emissions. The ash produced also has a nutritional value for use as a soil amendment (Grower News, 2014).
- In Austria, cement plants began to use solid waste fuels (made up of recyclable plastics, paper, textiles and composite materials) in 1993. All nine cement plants there now use solid waste fuels to a certain extent. This is being replicated across Europe using energy dense wastes as fuels, including used car tyres. (EUBIONET, 2015)
- Drax Power (4GW of installed capacity) delivers 7% of the UK's electricity demand and is in the process of switching from coal to biomass fuel. In 2014, 29% of its production was derived from biomass combustion, producing 2.9TWh of electricity and reducing lifecycle GHG emissions by 6.1 Mt CO_2-eq. Drax Power burnt 4 Mt of biomass, 95% of which were sawdust and sawmill residues, diseased wood, forestry residues and thinning wastes from the forestry/wood processing industries. Drax Power expect half of their production units to have been converted to biomass by the end of 2016, leading to a reduction in GHG emissions of about 12 Mt CO_2-eq per year (Drax, 2015).
- Charcoal has been used in Brazil, for many years, to provide the process heat for the production of metallic iron from ore – the first step in steel production. The lack of sulphur in the charcoal improves the quality of pig iron, and therefore of the steel that is produced. Today Brazil produces 10 Mt/yr of pig iron, generating an income of around USD 2 billion (FAO, 2015; UNEP, 2015c).

There are no technical barriers to replicating these case study examples. The key issues are the relative costs and the security of supply of fuels over the lifetime of the capital investment. In many instances, given the current relatively low fossil fuel prices globally, investments in low-carbon technologies are not economically viable. However, other strategic drivers such as energy security, waste treatment, product quality should be considered. As for transport and buildings, local governments have the opportunity to implement appropriate policy frameworks to encourage mitigation initiatives to be implemented by small and medium enterprises (SMEs) in their region.

97 http://sequallumber.co.nz/mt-putauaki-kawerau-new-zealand-natures-kiln-drying-boiler/

Knowledge gaps

What else would be useful to know?

There are no technology barriers to the lowering of GHG emissions by New Zealand industries and SMEs at all scales. The hurdles to increasing activity are largely economic and the availability of some reliable alternative energy supplies such as geothermal resources. The technologies and systems are mature and well proven either in New Zealand or elsewhere. The main barrier to uptake is the knowledge by businesses that such opportunities exist.

The other uncertainty is at what carbon price would the rate of deployment of low-carbon technologies and systems be greatly increased and therefore to help New Zealand exceed its present INDC target.

5.5 Agriculture

Key messages

- Direct emissions from agriculture make up almost half of New Zealand's gross GHG emissions.
- Emissions per unit of product (or emissions intensity) have fallen consistently over the past two decades owing to increased productivity per animal and improved efficiency of farm enterprises. It is feasible to reduce GHG emissions if increased productivity were to be counterbalanced by decreased animal numbers such that food production is maintained.
- Nonetheless, absolute emissions have grown because of an increase in total production, largely due to increased use of land for dairy farming and its more intensive management regime.
- Further productivity increases will reduce future emissions intensity further, but absolute emissions will continue to rise in the absence of significant policy change or permanent depression of commodity prices.
- While there are mitigation options that can be used now, most only result in small additional GHG emission reductions above business as usual trends for current agricultural and horticultural systems, although some may also offer significant co-benefits such as improved water quality and more efficient water use.
- Research on, and investment in, new mitigation technologies to address, specifically, the formation of methane in the rumen and the decomposition of animal excreta in soils, offers the potential for significant future emission reductions. However, even with such technologies being developed and deployed widely, it appears very difficult to reduce total on-farm emissions below recent levels if production continues to increase strongly, as projected in business as usual scenarios.
- Exploration of alternative land-uses to reduce GHG emissions from the agriculture sector and taking into account climate change and carbon constraints as well as other economic, social and environmental objectives, would have a major impact on reducing emissions in the long term, and is essential if New Zealand wishes to reduce agricultural emissions below 1990 levels by mid-century.

Sources of GHG emissions

Where do agricultural GHG emissions come from?

Agriculture in New Zealand directly produces GHG emissions in the form of methane (CH_4) from enteric fermentation in the gut of ruminant animals, nitrous oxide (N_2O) and some CH_4 from the deposition of both animal excreta (urine and dung) and nitrogen fertilisers on soils, and CH_4 and N_2O from manure storage. In New Zealand, about 97% of total direct agricultural direct emissions come from ruminant livestock production (mainly dairy, sheep, beef, but also deer), with non-livestock sectors contributing less than 1% total direct agricultural emissions. Overall in New Zealand, about three quarters of total direct on-farm livestock emissions are estimated to be in the form of CH_4, and about one quarter as N_2O.

Emissions of CO_2 arise directly from fossil fuels used – on-farm, such as for powering machinery and heating greenhouses, as well as indirectly from electricity demand for milking sheds, irrigation, vegetable packing sheds and post-harvest activities such as cooling, transport, and fertiliser manufacture. By convention, in national GHG accounts, these CO_2 emissions are accounted for under energy and transport rather than in the agriculture sector, but they are relevant if a lifecycle perspective is taken.

Lifecycle (cradle to farm-gate) assessments for New Zealand indicate that indirect emissions of CO_2 on – and off-farm currently amount to approximately 10% of total emissions (dependent on farm system; around 15% for dairy farms, less than 10% for sheep and beef farms). Emissions from non-livestock sectors contribute less than 1% of total direct agricultural emissions in New Zealand, although the proportion of CO_2 emissions tends to be much higher for arable and market gardens[98] (for example around 40% for arable crops). Mitigation options from improvements to agricultural transport and buildings are addressed in the transport, building and industry sections of this report.

Deforestation would have constituted a very large indirect emission from agriculture during New Zealand's initial settlement period, but this has been largely halted and partly reversed over recent decades through marginal grazing lands reverting to scrub or being actively re-planted in forests. This land-use change is not necessarily only in this one direction though. For example, Landcorp had plans to convert 25,700 ha of plantation forests to dairy farms, but this has recently been scaled back to around half the proposed area due to lower milk prices[99]. Other indirect emissions arise from off-farm production of animal feeds, although if feeds are imported these emissions are not counted against New Zealand's national emissions but may be relevant and significant if a lifecycle perspective is taken.

Post-farm gate emissions arise from processing, storage and transport to destination ports. Processing typically accounts for 10% of total lifecycle (cradle to consumer) emissions for dairy (due to the energy required for the conversion of liquid milk into milk powder and similar products), but only 2-3% for meat products. Distribution to destination ports accounts typically for up to 5% of the total footprint from the cradle to the destination port (Lundie *et al.* 2009; Ledgard *et al.* 2010; Lieffering *et al.* 2012). Mitigation options from improvements to transport and buildings are addressed in the transport, building and industry sections of this report.

Global GHG emission trends for the sector

What is happening to agricultural GHG emissions globally?

Total direct GHGs emitted from the agriculture sector were estimated to account for 10–12% of total global emissions in 2000–2010, having almost doubled since 1961 (JRC and PBL 2012; Tubiello *et al.* 2013). About two thirds to three quarters of global direct agriculture emissions come from livestock, mostly ruminants. This emissions growth reflects increasing food demand of a growing global population (which more than doubled over this period) and a shift towards more protein-rich foods, particularly per capita consumption of meat and milk products (Alexandratos and Bruinsma, 2012), as several major economies become wealthier. These general trends are expected to continue until at least the middle of the century, when the global population is expected to exceed 9 billion people, and food demand is expected to increase by about 70% by 2050 (Alexandratos and Bruinsma, 2012) and GHG emissions from agriculture to increase by almost 30% above 2010 levels (Tubiello et al 2014; FAOSTAT, 2016).

GHG emissions from ruminants are influenced both by the number of animals and feed consumption per animal. In grazing-based systems, there is a highly linear relationship between the amount and quality of feed an animal consumes from pastures or moderate amounts of supplementary feeds and the absolute CH_4 emissions it generates through enteric fermentation. The quality of feed also plays a role, but it is not linear; in New Zealand, for most animal

98 For example, Frater (2011) undertook detailed surveys of various stakeholders and calculated that 7.7 MJ of energy were consumed per kilogram of apples produced in New Zealand and delivered to Europe; 1.5 MJ in the orchard; 0.5 MJ during post-harvest and transport; 1.5 MJ from packaging; and 4.2 MJ for shipping.

99 http://www.nzfoa.org.nz/news/foresty-news/1523-080316forestrynews

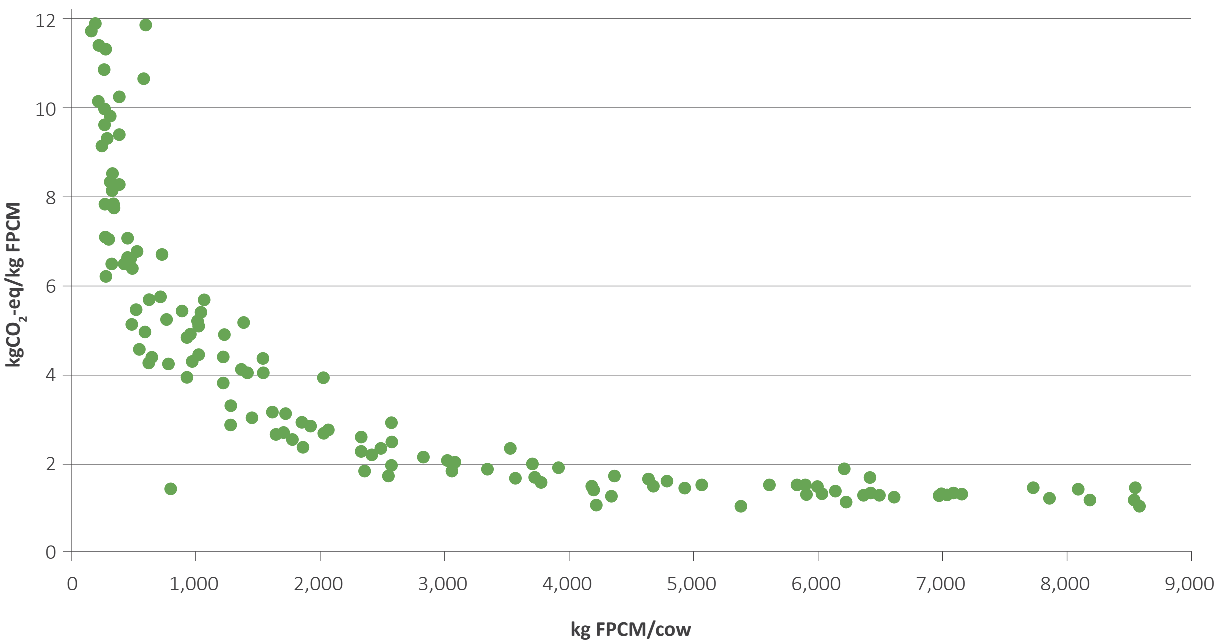
feeds the CH_4 emitted per kg of dry matter consumed shows remarkably little difference. Similarly, N_2O emissions per animal are largely a function of the surplus N that is excreted by the animal. Animals that eat more (of the same feed) generally excrete more N, mainly through urine, and hence cause higher N_2O emissions (as well as greater nitrate leaching). This means that more productive animals that produce more milk or grow faster generally produce higher emissions per animal. However, emissions per kg of meat or milk solids (so-called 'emissions intensity') tend to be lower, because a greater fraction of the total feed consumed by the animal is used to generate the desired product (growing meat or producing milk), and a lesser fraction to simply maintain the animal.

Absolute emissions and emissions intensity offer two contrasting interpretations of historical trends and future prospects for mitigation in the agricultural sector. As climate change is caused by net emissions to the atmosphere, absolute emissions are clearly a relevant metric to understand the contribution of a sector to climate change. However, most of New Zealand's agricultural products are exported to satisfy a global demand. If one assumes that New Zealand does not materially influence global demand and hence its only influence on net global GHG emissions is to provide the demanded products at the lowest possible emissions per unit of product, then the emissions intensity of production (GHG emissions per kg of meat, per tonne of corn, per litre of milk etc) is also a relevant metric.

Global emissions intensity of agricultural production decreased by around 30–50% since 1970, albeit at varying rates in different regions and production systems (Bennetzen *et al.* 2016). Since global food demand and production more than doubled during this period, absolute GHG emissions from the sector have risen nonetheless over this period, but by less than total food production.

The increasing global population and trend towards higher quality and protein rich foods makes it almost inevitable that emissions from agriculture will increase further over the next several decades. However, productivity of animals and crop production and efficiency of farm systems are also expected to continue to rise, although at potentially lower rates and with significant differences between regions and production systems. As a result of those competing trends, GHG emissions from global food production are projected to increase by about 30% by 2050 (Tubiello *et al.*, 2013; FAOSTAT 2016), which is significant but much less than the projected growth in global food demand of 70% over the same period (Alexandratos and Bruinsma, 2012).

Figure 5.26 Relationship between emissions intensity and productivity per animal for milk production.



Note: FPCM = fat and protein corrected milk.
Source: Gerber et al. 2011.

Currently, there are large differences in the productivity and associated emissions intensity of ruminant livestock across world regions (Figure 5.26 and 5.32). These differences indicate a significant potential to reduce emissions intensities simply by increasing the productivity of animals and efficiency of farm systems, particularly for regions where productivity is currently low (Gerber et. al. 2011, 2013). New Zealand appears to be amongst a group of producers with the lowest emissions intensities of enteric methane from ruminant livestock (Figure 5.27), but comparisons between individual countries are fraught with methodological difficulties. There are insufficient studies that directly compare New Zealand with other countries to support claims that New Zealand is the lowest emissions intensity producer. Ruminant meat typically has much higher emissions intensities than non-ruminant meat (chicken and pork). Ruminant milk also tends to have higher emissions per unit of protein than non-ruminant meat, although the most efficient ruminant milk production can have similar emissions per unit of protein to that of chicken and pork meat (Figure 5.28).

While business-as-usual trends indicate an on-going and increasing global demand for livestock products, there is an on-going debate that for human health, animal welfare and environmental reasons, the consumption of (mostly red) meat and milk products per capita should be reduced at least in countries with already high per capita consumption levels (which includes almost all developed countries). A parallel issue is the accelerating effort to develop synthetic meat and milk protein products in biotechnology laboratories around the world. Synthesising milk and meat proteins from plant proteins is claimed to consume around half the energy per kg of cheese or hamburgers; produce only around 4% of the GHGs per unit of protein; and use far less land and water than dairy or beef farming per unit of protein. It is also becoming cost competitive (Bosworth, 2016). Substitution of animal with vegetable based proteins could thus become viable for reducing emissions from food production in future, although acceptance of such synthetic foods by consumers will depend on price, quality and taste as well as fundamental values and trust, and is difficult to predict.

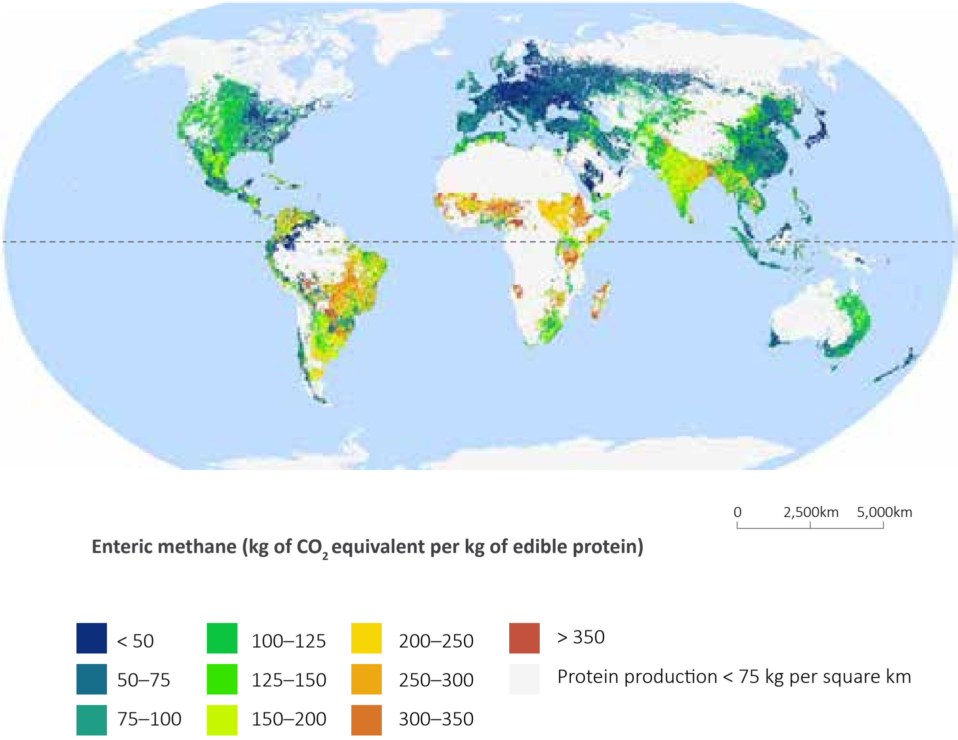
These are only two of many possible examples (along with e.g. genetic modification, biosecurity risks and food safety perceptions) of disruptive step changes in both food demand and supply systems that could fundamentally change New Zealand's competitive advantage in livestock production in the longer term and that could throw into doubt the long-term baseline production and emission trends that underpin current long-term projections for the sector (see below). However, even if there is a global shift away from livestock products (for climate change, health or other reasons), there could still be a premium market for farm-reared, grass-fed meat and milk. Given the small scale of the sector relative to global food production, New Zealand could choose to exploit niche markets if the associated GHG emissions are not seen as prohibitive by either New Zealanders or consumer markets.

GHG emissions profile and baseline trends in New Zealand

What amounts of greenhouse gases arise from agriculture in New Zealand?

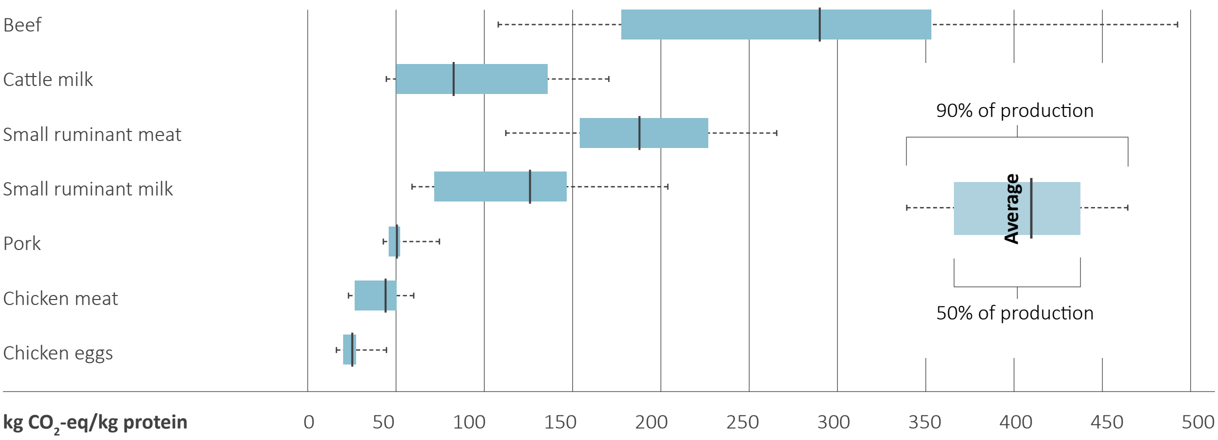
Agricultural emissions trends in New Zealand mirror global trends, with increasing absolute emissions on the back of growing total food product but declining emissions intensity. Total on-farm emissions from agriculture in New Zealand have increased about 14% from 1990 to reach almost 40 Mt CO_2-eq in 2013, with most of the increase due to an increase in dairy production, offset by a fall in sheep emissions, mostly due to reduced ewe numbers (Figure 5.29).
On an assumption of continued long-term growth in global demand for dairy products, total agriculture emissions are projected to increase by around 30% from the 2008-2012 average, to reach 45–50 Mt CO_2-eq in 2050, largely due to the continuing expansion of dairy production. Future projections are highly dependent on assumptions about global food markets (and New Zealand's ability to access those markets), as well as domestic regulations and expectations that could influence land-use changes and the intensity of livestock production; very few transparent and publicly available studies or tools are available to evaluate such projections, and most use highly simplifying if not simplistic assumptions. The current low dairy prices for New Zealand farmers will clearly limit expansion in the near term, but there is no evidence that this will reflect a fundamental change in the long-term trend.

Figure 5.27 Emissions intensity of enteric CH_4 per unit of edible animal protein.



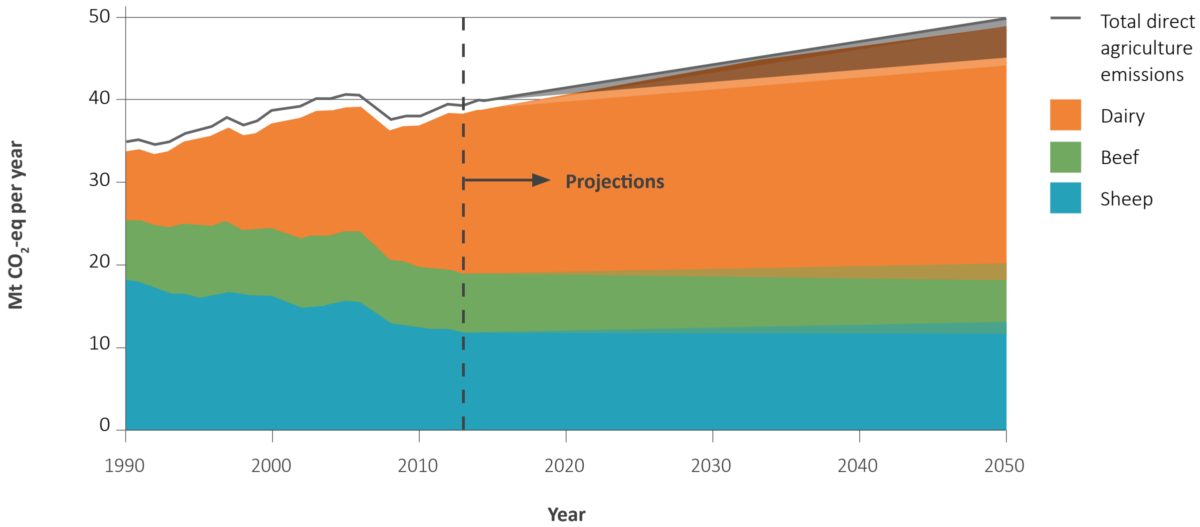
Source: Gerber et al. 2013.

Figure 5.28 Range of emissions intensities per kg protein for different livestock products.



Source: Gerber et al. 2013.

Figure 5.29 Historical and projected future emissions from agriculture, and separately dairy, sheep and beef in baseline scenarios.



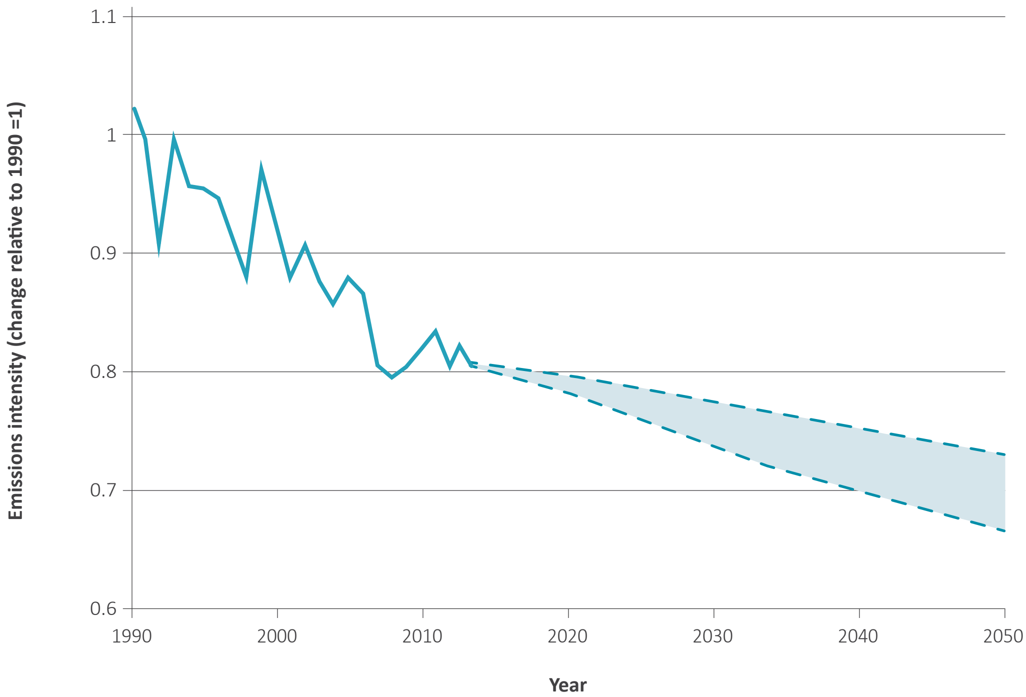
Note: Shaded wedge projections depict alternative scenarios with different rates of expansion assumed for the dairy sector, and different rates of improvement of productivity per animal.

Source: Reisinger and Clark (2015).

The trend towards more productive farm systems has resulted in about 20% reduction in emissions intensity on-farm in each of the dairy, beef and sheep sectors in New Zealand between 1990 and 2013. Emissions intensity is expected to continue to reduce, independent of additional climate policies, reflecting on-going economic drivers, along with regulatory and market drivers to continually increase the productivity of animals and efficiency of farm systems (Figure 5.30). The rate at which intensity declines in future depends on the rate at which on-farm productivity increases, but could achieve around a further 20% reduction by 2050 for dairy and beef farming and 10% for sheep (NZAGRC, 2015a).

The increasing productivity per animal and efficiency of farm systems (e.g. reductions in fertiliser use per cow) has avoided much greater increases in agricultural emissions than would have occurred otherwise. This can be illustrated through a 'thought experiment': Figure 5.31 illustrates how total on-farm agricultural emissions would have increased by almost 40% over 1990–2013 if the historical increase in production had been achieved solely by increasing the number of animals and amount of land used for livestock production in New Zealand, without any increase in animal productivity and farm efficiency. Conversely, if animal productivity had increased but animal numbers had been reduced proportionally, such that total food production was maintained at 1990 levels, absolute emissions from agriculture today could be about 20% below 1990 levels. This demonstrates that trends in New Zealand's agriculture emissions reflect economic development choices rather than a biological necessity or the absence of any mitigation options.

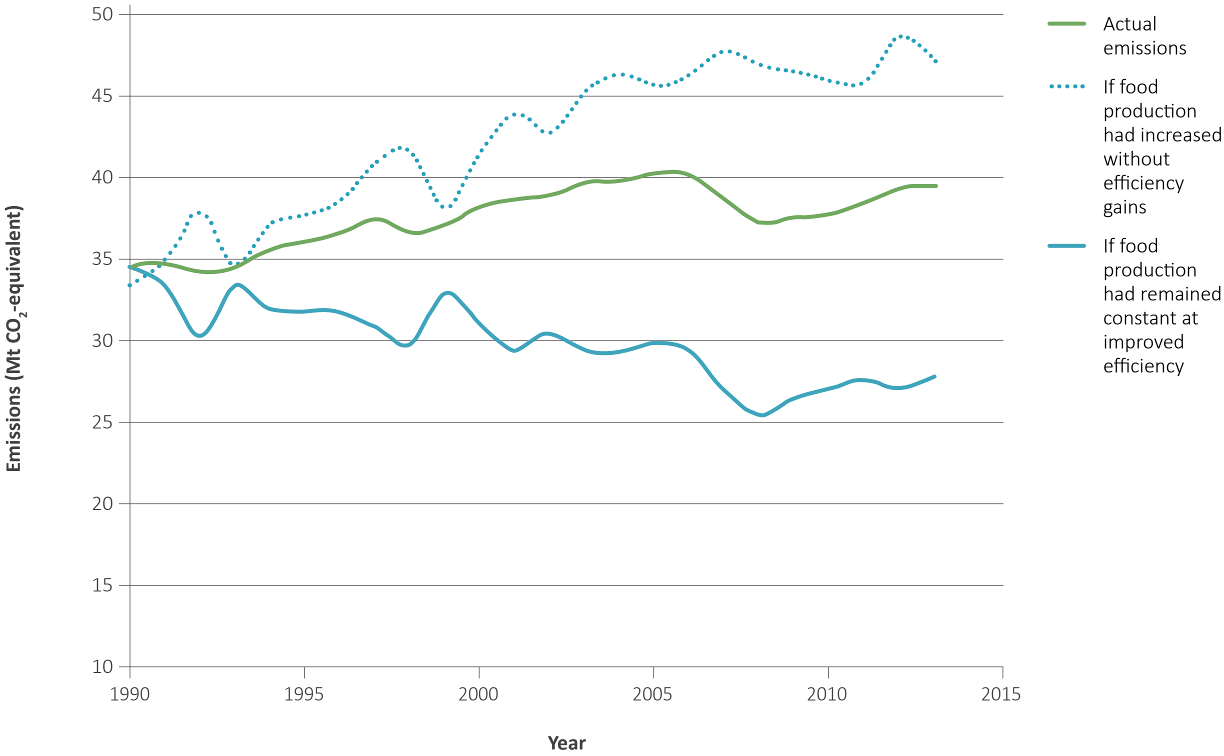
Figure 5.30 Historical and projected future changes in aggregate on-farm emissions intensity for dairy, beef and sheep meat production in New Zealand.



Note: Shaded projections are for two alternative baseline scenarios reflecting different productivity improvements.

Source: Reisinger and Clark (2015).

Figure 5.31 GHG emissions from New Zealand agriculture from 1990 to 2013, illustrating the effect of changes in animal productivity and on-farm efficiency as well as total food production.



Source: NZAGRC (2015).

Given the projected strong growth in overseas demand for protein-rich food (despite year-to-year changes in dairy prices and low dairy pay-out in the past two years), total New Zealand livestock production is projected to continue to increase in the long term in the absence of fundamental, disruptive changes to global markets. Productivity and efficiency gains using current technologies and practices can offset some of the emissions growth that would occur otherwise, but on their own they will be insufficient to avoid a further emissions increase for at least the next four to five decades.

GHG mitigation options

How can we reduce GHG emissions in the agricultural sector?

Mitigation for the agriculture sector can be classified into three broad options:

1. further increases in animal productivity and farm efficiency;
2. additional technologies that directly seek to reduce emissions;
3. constraints on the level and types of agricultural activity and movement towards low-emitting land uses.

While many technologies and practices to increase animal productivity and farm efficiency are already known and widely practiced, and many new areas are being actively researched, many of the technologies that directly seek to reduce emissions (e.g. by influencing the microbes responsible for producing CH_4 in the rumen) are still under development. A range of interventions are available or currently under development at different levels of maturity (Figure 5.32). These different approaches to mitigation are not independent and have multiple and interacting effects on emissions intensity and absolute emissions, as discussed below.

What animal productivity, and on-farm efficiency gains, can be made?

The influence of efficiency and productivity gains on emissions is complex. Measures that increase the productivity per animal (e.g. higher milk yield per cow, faster weight gain of lambs and beef cattle) will generally reduce emissions intensity but increase emissions per animal. Hence, if animal numbers remain unchanged, increasing animal productivity increases absolute emissions. However, if farm stocking rates are reduced as animals become more productive, then absolute emissions would decrease as well.

Many dairy farms use increasing amounts of supplementary feeds, many of which have lower nitrogen content and thus can help reduce the amount of N2O produced per unit of dry matter intake. However, the consequence of increased supplementation is often that more animals are kept per hectare, or that animals consume and produce more, and hence emissions intensity reduces but absolute emissions increase. Some supplementary feeds, such as palm-kernel expeller, are sourced overseas and hence emissions generated in their production are not counted against New Zealand's national emissions, but noticeably contribute to total emissions from a lifecycle perspective. Other supplementary feed may need to be produced through cropping cycles, thereby reducing soil carbon content through cultivation oxidising a part of the organic matter.

Measures that improve farm efficiency (e.g. more targeted use of fertiliser that allows reduced fertiliser use without reducing milk yield per cow) mostly reduce emissions intensity and, if animal numbers remain unchanged, also reduce absolute emissions. However, if the increased efficiency is used to grow more animal feed and achieve higher total production on the same land area, then absolute emissions may not decline or could even increase.

Experience in New Zealand to date shows competing trends, with some farmers seeking to reduce stock numbers as they move to animals offering higher yields (including to comply with water quality regulations or to take stock of low-yielding erodible land), while on other farms more productive animals are used to further increase total on-farm production.

Emissions intensity is expected to continue to reduce further even in the absence of additional climate policies, reflecting existing and on-going economic, regulatory, social and market drivers towards improved on-farm efficiency and animal productivity (Figure 5.30). The scope for reducing emissions intensity further below those business-as-usual trends is likely to be more limited based on existing technologies and practices alone. Potential opportunities exist in closing the gap between current high- and low-performing farms, and in linking climate with other environmental objectives such as water quality. One could also seek to further accelerate productivity gains across the board, given that New Zealand animals are not near any physiological limits, such that animals will be as productive in 2030 as they would have been in 2050 under business-as-usual. However, if it is assumed that the current rate of progress reflects a balance between the benefits of increased performance and the costs of achieving this, then accelerating this performance gain is likely to entail additional (but poorly quantified) costs.

Some productivity gains are linked to breeding, which is difficult to greatly accelerate without recourse to genetic modification, while others (such as more precise application of fertiliser or irrigation assisted by remote sampling and robotics) could see more rapid progress. New Zealand farms show a wide diversity of productivity and efficiency levels (Anastadiadis and Kerr, 2013a), and it is tempting to speculate that if the lowest performing farms were brought to the level of the mid – to top-performing farms, overall emissions intensity should decline further. However, as discussed above, whether this would result in a reduction in absolute emissions, depends on the way such performance improvements are implemented, and some of the differences in performance are also related to differences in soil and climate conditions.

Figure 5.32 Possible technical and management options, and their stage of development, to reduce GHG emissions in the agriculture sector by either increasing efficiency/productivity or reducing emissions per animal.

	Discovery & proof of concept	Pilot studies	Good practice
Feed & nutrition	Incorporating low GHG traits into forage plants Identification and synthesis of compounds from plants that can reduce methane and nitrous oxide	Low-methane feeds Low-nitrogen feeds	Forage crops with improved energy values and lower nitrogen content Improved forage quality
Animal genetics & breeding		Identification and selective breeding of low greenhouse gas animals	Good reproductive performance High growth rate High milk yield Breeding high-value animals
Rumen modification	Anti-methane vaccines	Testing and improving methane inhibitors	
Manure & fertiliser management	Plant effects on nitrous oxide emissions mediated by soil	Enhanced low-N plant growth (e.g. gibberellins) Optimisation of grazing/housing options	Capturing biogas from anaerobic processes Manure collection, storage and application Urease inhibitors Nitrification inhibitors Optimised fertiliser use
Increasing soil carbon content	Increased carbon supply to soil and/or increased stabilisation of soil carbon	Biochar on pasture	Maintaining carbon inputs to soil
Animal health			Prevention, control and eradication of disease Increasing productive lifetime of animals
Improved farm systems	**Developing and demonstrating profitable, practical and low GHG emitting farm systems**		

Note: The figure shows possible interventions on different aspects of the farm system (left hand column, focusing on feed and nutrition, animal breeding, rumen modification, manure and fertiliser management, efforts to increase soil carbon, and animal health). Interventions are classified based on their maturity and readiness for implementation; from right to left, this ranges from 'good practice' (meaning readily available), to pilot studies (that have been demonstrated on some farms but cannot yet be recommended as commercial practice), to discovery and proof of concept.

Source: NZAGRC (2015).

What additional mitigation options are there?

Substantial government and private research investments have been made to develop new and additional technologies and practices that could substantially reduce GHG emissions per animal further, in addition to continued improvements in productivity and efficiency. These include the development of inhibitors or a vaccine against the microbes responsible for CH_4 generation in the rumen; breeding for lower CH_4 emitting animals; and exploration and exploitation of natural compounds in plants and microbial communities in soils that could suppress CH_4 and N_2O emissions (NZAGRC and PGgRc 2015a) for an overview. The New Zealand research investment is significant even on a global scale, and places New Zealand in the position to be a technology leader rather than taker.

Promising short-term trials of inhibitors indicate that it may be possible to reduce CH_4 emissions per animal from enteric fermentation by 30% or more, while selective breeding could reduce them by up to perhaps 5–10% in the long run. However, these are active research programmes with a range of additional steps required before they can be considered commercially viable solutions. Most of the new technologies are thought to be additive (e.g. breeding plus inhibitors), but not all (e.g. a CH_4 vaccine and inhibitors would target similar groups of microbes and their effects are unlikely to be fully additive).

The total mitigation effect of novel technologies remains uncertain, even if they are developed into commercially available solutions, because their actual use depends on international market acceptance and incentives for their adoption by farmers.[100] Where new mitigation options pose net costs to farmers, their adoption would depend on whether farmers are exposed to carbon prices or other incentives that reward the adoption of such technologies. Whether new technologies are considered cost-effective solutions to climate change thus depends on both global carbon prices and domestic policy choices about the extent to which prices are passed on to farmers.

100 Since CH_4 is an energy-rich gas, it is tempting to speculate that avoiding the emissions of CH_4 should increase the energy available to the animal and hence increase its productivity. However, this effect remains to be demonstrated in practice. Whether adoption of a CH_4 inhibitor is profitable for farmers in its own right thus depends on the amount by which productivity increases as well as the commercial cost of an inhibitor and its application method.

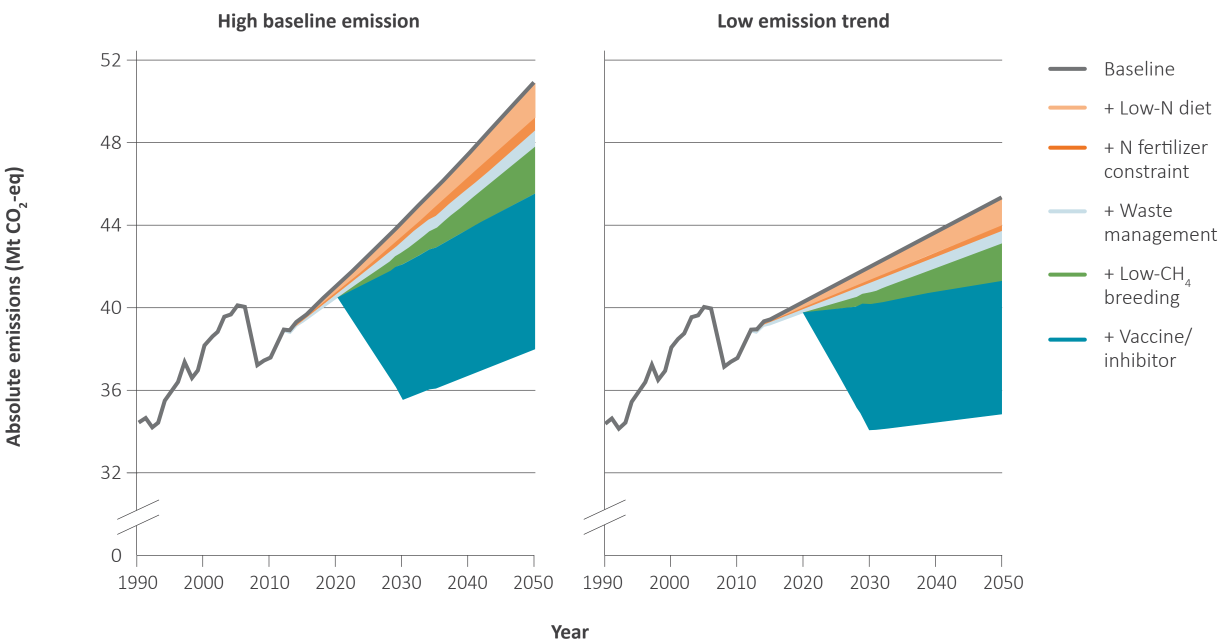
What could be the combined effect of productivity/ efficiency gains and new mitigation technologies?

The only publicly available modelling study indicates that the increase in emissions due to the increasing total production (mostly from dairy) under business-as-usual scenarios may outweigh the potential mitigation from increased animal productivity and on-farm efficiency *as well as* new technologies, such that absolute emissions in 2050 could fall below current levels but would still be above 1990 levels *even if* productivity and efficiency continue to increase and new technologies are developed quickly and adopted reasonably widely (Figure 5.33).

The mitigation potential (Figure 5.33) is indicative only and hypothetical as it depends heavily on adoption rates and availability and efficacy of new technologies that are still under development. Scenarios assuming slower scientific development, delayed commercialisation, or lower rates of adoption of new mitigation technologies, result in a smaller mitigation potential and correspondingly higher emissions.

The same modelling approach indicates that increasing animal productivity and farm efficiency, along with new technologies, could help achieve significant further reductions in emissions intensity (Figure 5.34). The gains from this approach would be particularly large if it is assumed that productivity and efficiency progress only slowly in business-as-usual, and hence accelerating this towards the upper end of what is considered feasible even under business-as-usual would significantly reduce emissions intensity.

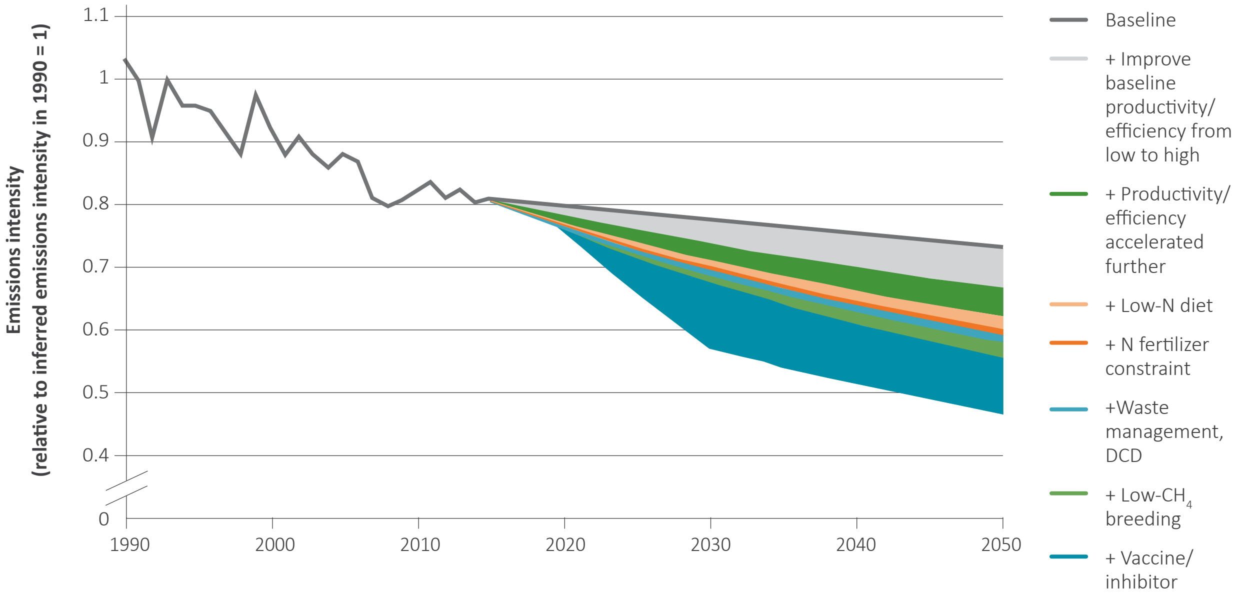
Figure 5.33 Mitigation potential for all New Zealand agriculture, against high (left) and low (right) business-as-usual emission trends.



Mitigation is shown for high adoption rates and highly optimistic assumption that new technologies are available as early as 2020.

Source: Reisinger and Clark (2015).

Figure 5.34 Packages of emissions intensity mitigation options, with results aggregated across sheep, beef and dairy production in New Zealand.



Note: In this graph, the baseline is for a low rate of productivity/efficiency improvement under business-as-usual. Mitigation options consist of improving the baseline productivity from low to high, accelerating this improvement further such that productivity in 2030 is as high as it would have been in 2050 under an already optimistic business-as-usual scenario, plus additional mitigation options as in Figure 5.33.

Source: Reisinger and Clark (2015).

What are the constraints on animal numbers/land-use?

Existing modelling studies indicate that, even with optimistic assumptions about productivity/efficiency gains and development and adoption of new technologies, absolute direct emissions from agriculture are unlikely to decline below roughly 1990 levels by 2050, and could be substantially above in scenarios where total production continues to increase but mitigation is less effective, available, or adopted.

This suggests that if it is considered desirable to reduce agriculture emissions substantially below 1990 levels by 2050, either global market demand (or New Zealand's ability to supply this market) would have to reduce significantly, or active constraints would have to be imposed on the level and types of agricultural activity in New Zealand. The extent to which this would have economic costs depends on the existence of alternative, lower-emitting land uses (see below).

Very few studies have actively considered national-scale mechanisms to impose such constraints, their effectiveness and economic or social implications. The main regulatory policy options appear to be imposition of a price on GHG emissions from farms, constraints on total nitrogen loading on a catchment basis, or to limit the ability to convert land-uses to activities that imply higher emissions per hectare. The purpose of this report is not to analyse these options in detail (including because of the lack of relevant, publicly available and peer-reviewed literature that would allow an objective assessment). Voluntary options would include industry benchmarks and voluntary standards/reporting. All such options would rely on development of new tools to allow sufficiently robust monitoring, reporting and verification of emissions and policy development to manage and avoid perverse incentives and outcomes.

Imposing limits on total nitrogen loading on a catchment basis would have strong synergies with policies to limit and reduce negative effects of livestock farming on water quality. However, the extent to which such an approach would limit GHG emissions would vary strongly from catchment to catchment depending on baseline water quality and the overall level of ambition for improving water quality, especially where this might appear in conflict with rural economic development and well-being.

Other proxies that might be used to limit agricultural production, such as limiting animal numbers, would require frequent revision as they could prompt a counterproductive move towards heavier breeds, thus resulting in an increase in absolute emissions, and would make it difficult to change land-use where this may be a more cost-effective solution. A variation to such an approach would be to limit total liveweight per hectare, but such measures further increase the required complexity of reporting.

Any of the above constraints on agriculture production would imply a significant opportunity cost relative to business-as-usual. The question whether it is feasible to strategically move to other land-uses that rely less on milk or ruminant meat production has seen very little evaluation in New Zealand. Some pastoral land at routine risk of drought or erosion has already been afforested, converted to viticulture, let return to scrub or indigenous forest, or used for tourism purposes. However, the areas where such options are readily feasible appear limited if the land is to return similar profitability per hectare or require significant capital investments with a high risk profile. Hill country is difficult to put into other land uses except forestry, whose profitability depends on carbon prices and the extent to which agriculture is exposed to those, and requires a much longer-term investment strategy.

As the New Zealand agriculture sector currently responds mostly to international rather than domestic demand for food products, any domestic incentives to encourage a long-term move away from animal farming would have to balance economic export drivers and market premiums with alternative land uses and domestic emission reduction targets. Nonetheless, growing carbon constraints imply that diversification of New Zealand's land-use towards lower-emitting activities could be of critical importance if we wish to achieve significant reductions in our net GHG emissions of 50% below 1990 levels by 2050, and even lower levels beyond.

This long term picture sharpens the tension between two contrasting characterisations of the climate goal for agriculture in New Zealand, namely either a focus on reducing emissions intensity without constraints on absolute emissions and agricultural production, or a focus on reducing absolute emissions by constraining further growth in emissions-intensive ruminant-based food production *as well as* reducing emissions intensity. These two approaches would have very different economic implications in the near term but also intersect with other goals with regard to environmental outcomes and rural development and resilience. A long-term goal to reduce absolute emissions appears to require a very active, long-term programme to diversify land-use, support the exploration of alternative climate-smart land-based activities and manage potential negative social and economic implications of this transition. Whether such a shift is in fact feasible at national scale and consistent with economic growth and rural regional development expectations is debatable and deserves dedicated attention so that it can become part of a national conversation on New Zealand's low-carbon future.

Influence of long term ambitions on near term actions and pathways

What are the pathways for reducing emissions from agriculture?

From a physical science perspective, it is defensible to delay reductions in CH_4 emissions compared with reducing CO_2 or N_2O emissions, because CH_4 is a much shorter-lived gas and hence does not accumulate in the atmosphere in the same way as CO_2. Thus there is a physical justification for focusing on the development of cost-effective ways of reducing CH_4 emissions in future, rather than putting efforts into reducing emissions today. This is in strong contrast to CO_2, where today's emissions contribute to future warming, and hence mitigation of long-lived gases is as important today as it will be later this century. However, the Paris Climate Agreement to keep the rise in temperatures to significantly below 2 °C, and even aim to hold it at 1.5 °C, means that reductions of the short-lived gases have now become more rather than less urgent.

From a socio-economic perspective, the land-use changes between forestry, agriculture, different livestock sectors and other land-uses that has been observed over recent decades indicate that land use does change in response to changing profitability, albeit sometimes slowly. Hence, in theory, there is ability to change away from emissions intensive land-use in future in response to external policy or market signals (Kerr and Olssen, 2012).

The main exception is where significant capital investment in intensive dairy farm systems, including animal housing or large-scale water storage and irrigation systems with long payback times, might constrain future land-use changes away from such emissions-intensive land-uses, as the locked-in capital investment could present significant socio-economic consequences if carbon prices rise rapidly, or if domestic policies or international market signals shift fundamentally. This is already becoming evident in New Zealand where significant dairy conversions occur during periods of high dairy pay-outs, but there appears to be little conversion back to sheep or beef systems during periods with low pay-outs.

An attempt was made to provide an overview of estimated mitigation potentials, costs, and possible priorities of mitigation actions across all sectors including agriculture (Annex 1). Limited data and analysis meant this could only raise issues for consideration, not a definitive assessment.

Co-benefits

What other benefits result from reducing agricultural GHG emissions?

There would be strong co-benefits from reducing total animal numbers in some catchments in terms of improved water quality where this has deteriorated or is set to become a problem due to livestock farming. Demand on water resources could also be reduced through such constraints, especially where catchments are at, or already over, their allocation and constrained by minimum flow rates of waterways.

In the absence of a fundamental change in domestic climate policies in the short term, it is likely that some GHG mitigation would arise as a co-benefit of non-climate policies and drivers for changes in farming practices, such as caps on total nitrogen loading in some catchments. New Zealand could benefit from joining these separate narratives and policy developments into a coherent whole that would then allow the joint evaluation of climate and water benefits of farm system improvements and climate-smart land-use choices. Increasing soil carbon stocks can also play a part but the high level of spatial and temporal variability is a major constraint (Box 5.4)

Insights on enabling policies

What policy interventions could encourage changes?

Some measures to improve animal productivity and increase farm efficiency may not imply significant additional costs and some, in fact, improve profitability, or some are necessary to ensure compliance with other environmental regulations. However, if performance were to be accelerated significantly beyond historical rates of improvement, then this could entail a more marked cost increase. The cost of new technologies to directly reduce emissions is not known until they are commercialised, but unless a reduction in CH_4 emissions improves the productivity of animals, then most of the new technologies will not be cost-free to farmers. This implies that significant further reductions in emissions intensity below business-as-usual trends will occur only if farmers are exposed to additional costs for their emissions or provided with other incentives to apply available mitigation options.

There are significant variations in productivity per animal, farm efficiency and profitability across New Zealand farms. Some of these variations can be explained by differing climate and soil conditions, but some can be attributed to the skills and priorities of farm managers and land owners. This suggests that policies to up-skill the lowest performing farmers could achieve significant reductions in emissions intensities for some farms. However, the best measures to achieve this are outside the scope of this report. Given that farms are already exposed to very similar economic drivers around the country, a simple nation-wide price-based GHG mitigation measure (such as by including agriculture in the ETS) may be ineffectual if the goal is to lift the game of the lowest performing farms. An additional price measure would likely make the lowest-performing farms entirely uneconomic rather than providing an effective incentive to improve their performance.

If agriculture is to be included in the ETS, there is fairly broad sector-level consensus that the point of obligation should be at the individual farm level to allow the price signal from the ETS in order to ensure the emissions price signal is retained to the farm level to spur innovation and productivity gains (AgTAG,2009; KPMG, 2012). However, the compliance costs of accounting for GHG emissions on-farm could be prohibitively high and increase the total cost of mitigation per unit of emissions avoided. Further development of appropriate tools to report GHG emissions on New Zealand farms that have sufficient credibility with industry, farmers and regulators and do not require costly additional data collection would appear to be a logical and necessary step. Any such tool will need to strike a balance between accurate and detailed reporting of farm-level activities and mitigation measures, and costs to provide input data and report and verify estimated emissions, especially if used in a regulatory context.

Studies that can help demonstrate the low emissions intensity status of New Zealand agriculture relative to its key competitors in international markets could help enable a more proactive marketing approach, although there is very little evidence about a price premium that consumers overseas would be prepared to pay for 'climate-friendly' milk and meat products. However, the focus of such an approach would inevitably be on emissions intensity, not on absolute emissions.

Knowledge gaps

What else would be useful to know?

There are only a few modelling studies that robustly assess assumptions and uncertainties around future commodity prices (including their variability) and their effects on animal numbers, animal performance and the interaction of such numbers with other environmental, social or economic objectives such as water quality, carbon pricing on forestry, and irrigation schemes. The absence of robust and transparent scenarios limits the ability to discuss future agriculture emissions and options to limit their growth. Development of a transparent and flexible tool to represent the different drivers and pressures on New Zealand agriculture and their potential evolution in future would help foster a more informed debate, including about the potential for alternative land-uses and aid decisions that reflect multiple objectives.

Development of a credible and cost-effective tool to estimate, report and verify GHG emissions/emissions intensity on-farm, and to reflect a range of possible mitigation actions, could help engage farmers in mitigation policies. The OVERSEERTM software tool, designed to inform farmers and growers about their nutrient use (http://overseer.org.nz), has some potential to do this but, without further development, the range of mitigation actions it could reflect is limited. Experience with its use in support of water quality policies and catchment limits also indicates its limitations in a regulatory context or to inform catchment-wide nutrient caps.

5.6 Forests and other land-use

Key messages

- New forest investment can make a significant contribution to New Zealand's strategy on climate change mitigation, but should not be viewed as an alternative to implementing other direct mitigation actions.
- Reporting rules for forest and land use under the UNFCCC govern estimates of carbon stock changes, whereas accounting rules define what are the eligible mitigation actions, as in the NZ ETS.
- Increasing the area of planted forest can increase carbon sequestration (trees absorb CO_2 and store the carbon as they grow) and hence provide further offsets for CO_2 emissions from future combustion of fossil fuels and other GHGs arising from agricultural emissions.
- Planted forests also provide ecosystem services such as improved water quality, recreational benefits, shelter and reduced erosion particularly when planted on marginal land.
- Establishing new forests is currently the only large-scale mitigation option that can be easily implemented to sequester large amounts of carbon dioxide from the atmosphere.
- Recent new forest planting rates in New Zealand have been too small to significantly offset future CO_2 emissions.
- Given that much of our post-1989 plantation forests are approaching maturity age, future emissions are likely to significantly increase when they are harvested, and hence our net GHG emissions over the next decade will also increase.
- Over 1 million ha of suitable land has been identified for further afforestation in New Zealand, but because there are ultimate land area limits due to land-use competition, the mitigation potential for forest removals in the long-term is unknown.
- Woody biomass residues from forest harvesting and wood processing operations can be combusted to provide useful heat, often cost competitively with coal or natural gas depending on location. In future, some of this resource could be converted to advanced liquid biofuels or chemical polymers.
- Soil carbon stock changes arising from land use change (such as from pasture to forest) are variable, poorly understood and difficult to assess, so are not easily incorporated within a carbon accounting system.

The terrestrial biosphere contains carbon stored in growing plants (biomass), dead organic matter and the soil. Forest ecosystems generally hold more carbon per hectare than grasslands, savannah, scrub land or degraded land. Reducing atmospheric concentrations of CO_2 can therefore be achieved through artificially planting of tree seedlings into such lands (*afforestation*) or by the re-establishment of forest cover either or naturally by allowing pasture or degraded marginal land to revert back to native forests (*reforestation*). Therefore, depending on the relative land-use economics, converting land used for pasture and grazing livestock to forests can positively affect a nation's economy and ecological status, and have an impact on the national GHG emission profile over the period where new forests are growing to maturity.

Sources of greenhouse gas emissions and sinks

What human activities on land (excluding agriculture) affect atmospheric CO_2 content?

A forest is a reservoir of carbon stored in the biomass, being usually around 50% of the total dry weight of a tree. A forest may be a net carbon sink if the annual amount of CO_2 removed from the atmosphere and stored as biomass via the process of photosynthesis is greater than annual losses from the forest due to decay and harvesting, or it may be a net carbon source if the opposite is true. A natural forest is usually in carbon balance as some trees die but others grow naturally to take their place. However, it can lose stored carbon if it becomes degraded, for example as a result of damage from possum browsing. New Zealand's regenerating natural forests are currently sequestering around 6 Mt CO_2 per year (MƒE, 2015a). A mature planted commercial forest may also be in carbon balance, assuming that as trees are harvested, others are planted and then grow to replace them.

Land use changes can affect GHG emissions accounting by:

a. direct changes in carbon stocks at the time of land conversion and on-going changes in stocks due to sequestration, decay, burning and soil carbon changes;

b. changes to emissions from the new land use compared with the old; for example afforestation of pasture reduces emissions from livestock grazing and nitrogen fertiliser application on that land;

c. energy used by machinery to undertake the land use conversions;

d. possible long-term storage of carbon in wood products such as those used in building construction;

e. substitution of more GHG emission-intensive alternatives by wood products such as displacing concrete blocks or plastic furniture; and

f. substitution of fossil fuels by using biomass from woody vegetation clearance and other biomass sources.

The GHG impacts of land use change are included as one of the sectors in GHG inventory reporting (MƒE, 2015a). Any change in land use gives rise to both a direct impact caused by the land conversion process and ongoing differences in net GHG emissions arising from different uses for that land. While stock changes within and between all land uses can contribute to changes in atmospheric CO_2, changes involving forests make the biggest contribution. The land use emission sources reported in the UNFCCC inventory other than agriculture are relatively minor in New Zealand and include open biomass burning through wildfires and controlled burns, soil drainage, non-CO_2 emissions from drainage of soils and wetlands, fertilisation of forests and other land, and N_2O mineralisation associated with land use change.

Cutting down forests eventually releases the carbon stored in the biomass into the atmosphere, either during combustion of the harvest residues to clear the land, as it decays over time, or in the longer term once any wood products reach their end-of life. This *deforestation*, whether of a natural or a planted forest without replanting it, represents a one-time addition of CO_2 to the atmosphere, because the land area with a high level of carbon stocks per hectare is converted to one with a lower level of carbon. Forest fires and harvesting also release stored carbon to the atmosphere, but unless followed by land use change, the CO_2 will be reabsorbed as the forest regenerates or is replanted and grows.

Conversely, *afforestation/reforestation* results in carbon uptake, whether a new forest is planted into pasture, scrubland or degraded land, or results from indigenous regrowth. This provides a one-time removal of CO_2 from the atmosphere. The amount of carbon held in a commercial forest, and in the soil, may fluctuate over time as it undergoes periodic harvesting with the harvested area subsequently replanted. Pastures in New Zealand typically have more carbon stored in the soil than do forested lands, the average carbon stock on that land area outweighing the slightly lower soil carbon content in forests (Box 5.5). The carbon content of soils also often steadily changes after a land use change, but the rate of change and stabilisation of the soil carbon level reached vary with soil type and local climate (NZAGRC, 2015b).

"The default assumption in New Zealand's Greenhouse Gas Inventory is that soil carbon does not change where land remains in a constant land use over time. Changes in carbon are only taken into account when there is a change in land-use. Following land-use change, the soil carbon is assumed to transition by the same amount each year to its new steady state value (depending on the new land-use) over a default period of 20 years. After 20 years, and in the absence of further land-use change, the soil carbon stocks are assumed to remain at the steady state level for the new land-use class. Carbon is accounted for in this way because of uncertainties and technical difficulties of deriving accurate national estimates within land-use classes, and the requirement to estimate only those changes that are occurring directly as a result of local human activities" (NZAGRC, 2015b).

The soil carbon content can also decrease following erosion, cultivation or drought. Increasing the carbon content of soils by incorporating organic matter, adding biochar[102], or minimising cultivation, under some circumstances can store carbon that would otherwise have entered the atmosphere. However, further research is needed to better understand this process and its potential in New Zealand where the arable land area is limited, most of the land is under pasture, and our average soil organic carbon content is relatively high compared with many soils in Australia, USA and the UK.

102 Biochar is charcoal incorporated into the soil as an amendment that being porous, under some circumstances can hold water and nutrients and hence increase crop productivity. http://www.biochar-international.org/biochar/benefits

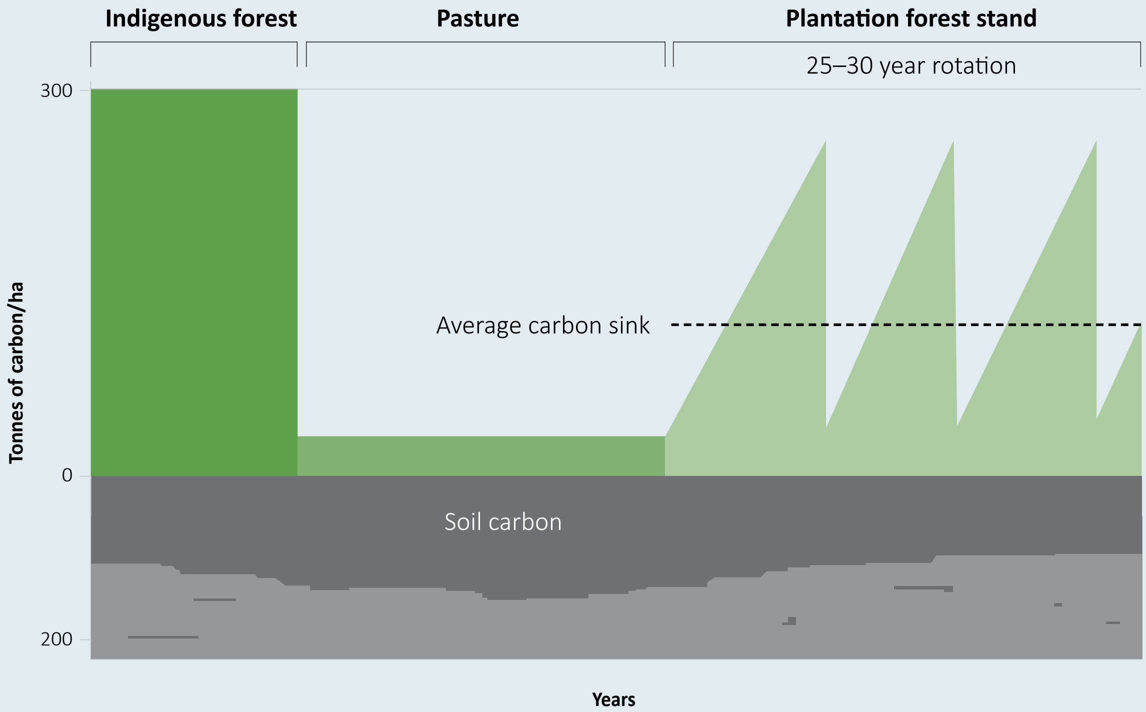
Box 5.5: How the process of land use change can affect carbon stocks over time

As an example, taking one hectare of land in New Zealand under natural forest last century, when it was cleared for conversion into pasture, the carbon stock was depleted significantly (Figure 5.35). When a commercial forest was later planted into this pasture land, CO_2 was absorbed as the trees grew and matured and the carbon stocks (t C/ha) steadily increased.

At harvest time, most of the stored carbon in the biomass will eventually be oxidised to CO_2 and released to the atmosphere. For illustration purposes here, all the carbon can be assumed to be oxidised and released as CO_2 immediately after harvest. In practice, some residues left on-site decay slowly or alternatively may be burned on-site as soon as the logs are removed and the C converted to CO_2 during combustion; some biomass may be stored then later burned for useful bioenergy; paper and cardboard products may have a lifetime of a few months before being disposed of; and the carbon in building construction wood materials could be locked-up for decades until the building is demolished or catches fire.

When harvested land is replanted and the next rotation of trees is grown, CO_2 is steadily reabsorbed as the trees mature and again stored as carbon. This can be repeated with continuing rotations over time. The average long term carbon stock of 1 ha of land under commercial forest is around 100-200 t carbon, (excluding any carbon stored in long-lived wood products). The amount of carbon stored in the soil as organic matter varies with land use change after deforestation and replanting, either increasing or decreasing depending on the soil type and its land use history. Soil carbon tends to increase under pasture and decrease after afforestation, but due to biological variations, the amounts of carbon involved are uncertain and hard to measure (NZAGRC, 2015b).

Figure 5.35 Indicative changes to the carbon stocks in the biomass growing on 1 hectare of land when indigenous forest is converted to pasture land which is then later planted in a commercial forest stand that is then harvested and replanted over several rotations.



Note: this excludes decay of harvest residues left on the land and any carbon stored in wood products that would increase the carbon sink.

The annual net carbon uptake by a forest is influenced by the distribution of age classes and the annual harvest rate. Large changes in net uptake are therefore possible over a short period of time, which means that the rate of net uptake in a given year is not necessarily indicative of a wider trend. This is one reason why the Kyoto Protocol was based around commitment periods of several years (2008-2012 and 2013–2020) rather than having a single target year when looking at national net emissions.

Global greenhouse gas emission trends for forests and other land use

Can atmospheric CO_2 be removed by growing forests?

Estimates of emission fluxes from global deforestation and other land use changes in recent years cover a large range of around 5–6 Gt CO_2-eq /yr (IPCC 2014b, Chapter 11). This is similar to the volume of annual agricultural GHG emissions (Section 5.5), and accounts for around 10% of total global emissions. Most analyses indicate a decline in annual net CO_2 emissions from forests over recent years and project continuing declines in the longer term, largely due to decreasing deforestation rates and increased afforestation.

Reporting and accounting of land use change and forests internationally has become complex because of different rules between the UNFCCC and the Kyoto Protocol. Under UNFCCC rules, New Zealand reports annual carbon stocks and stock changes under broad land uses. A subset of stock changes may count towards meeting a net emissions target under the Kyoto Protocol when all stock changes due to deforestation must be accounted for, but only stock changes in forests first planted after 1989 into non-forest land (such as pasture or cropland) are included. For pre-1990 natural and planted forests, accounting under the Kyoto Protocol is with respect to a reference level. The carbon stocks in these forests are expected to fluctuate over time, and only deviations from 'business-as-usual' stock changes enter the accounts.

In December 2015[103], New Zealand ratified the Doha Amendment which created a second Kyoto Protocol commitment period 2013–2020, but New Zealand did not elect to take a binding commitment under this second commitment .Our current position is to apply the Kyoto Protocol rules under the Framework Convention to the 2020 target of 5% emissions reduction below 1990 levels[104]. The Paris Agreement did not fully clarify accounting rules for forestry and it is anticipated a work programme will be convened by the UNFCCC over the next few years (Section 2.2). Meanwhile, the present intention for New Zealand is to continue a Kyoto-like approach to forestry and land use accounting after 2020, but revised to better reflect the cyclical nature of our production forests by accounting for afforestation up to its long term average rather than accounting for all removals and emissions as they occur[105]. This results in crediting and debiting post-1989 forests over subsequent rotations, rather than focusing credits on new forests. It also accounts for temporary fluctuations in carbon, whereas using the average carbon stock would better reflect the long-term permanent sequestration potential of a new production forest.

103 http://news.xinhuanet.com/english/2015-12/01/c_134873122.htm

104 *Application of Kyoto Protocol accounting rules for New Zealand forestry (Mason, 2015).* The Kyoto Protocol includes two methods of forest reporting and accounting:

Article 3.3 concerns afforestation, reforestation and deforestation of post-1989 'Kyoto' forests (plus any deforestation of pre-1990 forest);

Article 3.4 concerns land use, land use change and forest management of pre-1990 forests (both natural and exotic plantations using the categories of forest management; cropland management; grazing land management; and re-vegetation plus wetland drainage and re-wetting).

Different reporting/accounting rules apply:

For Kyoto's 1st commitment period (CP-1) of 2008-12, parties were obliged to account for article 3.3 activities but it was optional whether or not to account for article 3.4 activities. New Zealand elected not to.

For Kyoto's 2nd commitment period (CP-2) of 2013-20, reporting of forest management under Article 3.4 became mandatory, whereas for the other categories, reporting remains voluntary. NZ elected not to report.

The mandatory requirement to report/account for forest management of pre-90 forest comes under Article 3.4. Accounting is against a 'business-as-usual' reference level – if nothing changes and actual net emissions remain as predicted, there is nothing to account for.

105 http://www4.unfccc.int/submissions/INDC/Published%20Documents/New%20Zealand/1/NZ%20INDC%20Addendum%2025%2011%202015.pdf

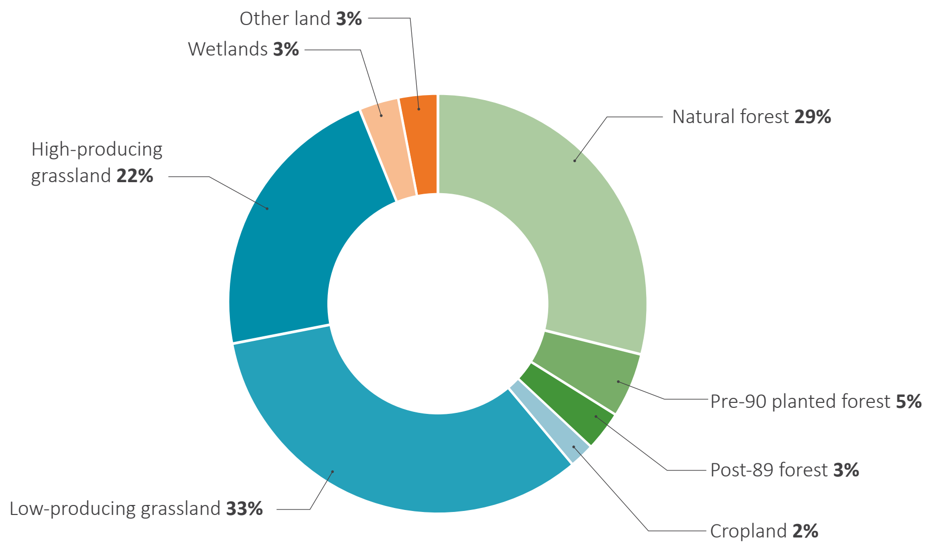
GHG emissions profile and baseline trends in New Zealand

How quickly has land use in NZ changed in recent years?

Almost 30% of New Zealand's 26.9 million hectare total land area remains under natural forest (Figure 5.36) largely protected for conservation and recreation. Over half the total land area is under high-producing and low-producing grasslands; around 8% grows commercial planted forest stands; 2% is arable land used for growing permanent and annual crops; with around 3% used for urban settlements, roading etc. (MƒE, 2015a). In 2000 the plantation forest area was 1.77 million ha but had declined to 1.72 million ha by 2015, an average reduction of 3267 ha per year, and with a further 9,300ha awaiting a decision from the landowner whether or not to replant[106].

Between 1990 and 2013 there were net changes in land use that affected around 756,800 ha (3% of total land area) mostly through afforestation after 1989 (Table 5.7). While there were expansions of human settlements (18,600 ha) and croplands (35,300 ha), especially kiwifruit and grapes, the most significant changes involved the afforestation of low producing grassland and the loss of 168,000 ha of total forests. In addition to the conversion of grassland to planted forests there has also been significant intensification within grassland categories. In 2015, new forest plantings totalled around 3000 ha but the total planted forest area fell by approximately 16,000ha[107].

Figure 5.36 Land use shares in 2013 of New Zealand's total area of 26.9 Mha.



Source: Based on MƒE (2015a).

106 http://www.nzfoa.org.nz/news/foa-news/foa-media-releases-2016/1520-230216foanews

107 http://www.nzfoa.org.nz/news/foa-news/foa-media-releases-2016/1520-230216foanews

Table 5.7 Summary of land use changes in New Zealand, 1990–2013[108] (based on MfE, 2015a, Table 6.2.6)

	Net area lost (ha)	Net area gained (ha)
Natural forest	62,200	
Pre-90 planted forest	82,800	
Post-89 planted forest	22,900	682,200
Annual cropland		16,800
Perennial cropland		35,300
High producing grassland	106,000	
Low producing grassland	345,800	
Grassland with woody scrub	134,000	
Wetlands (open water)		3,900
Wetlands (vegetated)	1,000	
Human settlements		18,600
Other land uses	2,500	
Total hectares	**757,200**	**756,800**

New Zealand's natural forests have been estimated to be a carbon sink because significant areas are regenerating as they recover from previous disturbances such as logging and land clearance activities. Assuming the carbon stored in the biomass of a mature native forest is around 300 t C /ha, if deforestation takes place it will eventually all be released (Box 5.5). Whether the forest biomass is burned, used for paper, furniture or building materials, or left on the forest floor to decay, most of the carbon content will ultimately be oxidised and hence add around 1000 t CO_2 /ha to the atmosphere.

New Zealand forests provided net carbon sequestration that offset about one-third of our gross GHG emissions in 2013, including 6 Mt CO_2 annual removals from regenerating natural forest (MfE, 2015a). Future sequestration is possible but will eventually be constrained by land competition and hence land availability for more forest plantings. As an indication of land area needed, to offset the annual GHG emissions from grazing 80 cows on around 30 ha would need approximately 10 ha of forest to be planted out of pasture every year. This assumes one hectare of land used to grow pasture for feeding cows at a stocking rate of 2.8 per hectare would result in total GHG emissions of around 6.5–7t CO_2-eq /yr, arising mainly from around 100 kg of enteric methane emitted by each cow; N_2O coming from animal urine and the use of nitrogenous fertilisers; and some CO_2 emitted from fossil fuel based energy sources or electricity consumed on the farm (Landcare Research, 2009; Section 5.5).

The net stocked forest area currently under planted forest stands (mainly *Pinus radiata*) is around 1.8 Mha of which over two thirds was planted before 1990. As more CO_2 is released from the continual burning of fossil fuels in New Zealand, or more non-CO_2 emissions arise from agricultural production, more pasture land would continually have to be planted into forests, (or fenced off to revert to permanent forest), in order to offset those emissions. For example, if a 100 MW gas-fired power plant generates 700 GWh / yr of electricity, around 420 kt CO_2 would be produced as a result that could be offset by planting around 12,000ha of land into forest every year the power plant operated.

108 These data are subject to a review due to the methodology and accounting method used, so may need to be adjusted in future.

Once a new forest planting reaches a steady mature state, in most cases there is little or no economic benefit to the forest owner from participating in the ETS. So while forest sinks can permanently offset part of our historic fossil fuel emissions, they are not a long-term solution to mitigating our on-going emissions. The potential total land area available for afforestation is finite, so once covered in mature trees at equilibrium, no more direct carbon offsets are possible.

Land use changes from 1974 to 2008 have been evaluated, and projections made to 2020, with assumptions made for future farming intensities of dairy and sheep/beef farms in New Zealand and a carbon price of \$25 /tCO_2 (Figure 5.37) (Anastadiadis and Kerr, 2013b). Dairy and planted forest land areas were projected to continue to increase as the sheep/beef area further declines (Section 5.5) with a higher carbon price supporting a faster rate of conversion. However, with price fluctuations for agricultural commodities and crude oil, plus changes in currency exchange rates, it cannot be assessed how much deforestation might increase in future, what land might actually be reforested for carbon, and what tree species would be most appropriate as a truly long term C sink and when taking all ecosytem services into account. Scion calculated that on 28,000ha of land, forestry would produce on average \$161 million /yr of export revenue plus \$31 million for carbon credits whereas dairy (and meat) on the same land area would have \$193 million /yr revenue but decreased by GHG and leached nitrogen costs of \$18 million (Parker, 2016)

Removal of CO_2 emissions by New Zealand forests increased between 1990 and 2013 (Table 5.8), but was more than offset by a nearly five-fold increase of emissions from grassland production activities (MƒE, 2015a). In 2013, under the current accounting method (IPCC, 2014b), deforestation of almost 9000 ha (including pre-1990 planted forests) resulted in around 4.9 Mt CO_2 added to the atmosphere but this was offset by around 17 Mt CO_2 absorbed by post-1989 planted forests. So around 12.1 Mt CO_2 of removals were reported. Further removals by improved forest management, including by reducing the emissions from land and through wood products, equated to around 8.3 Mt CO_2 (MƒE, 2015a; Table 11.1.1).

Figure 5.37 Historic land use shares in New Zealand till 2008, then projected out to 2020 as baseline (solid lines) and with a \$25 /t CO_2 price (dashed lines partly obscured).

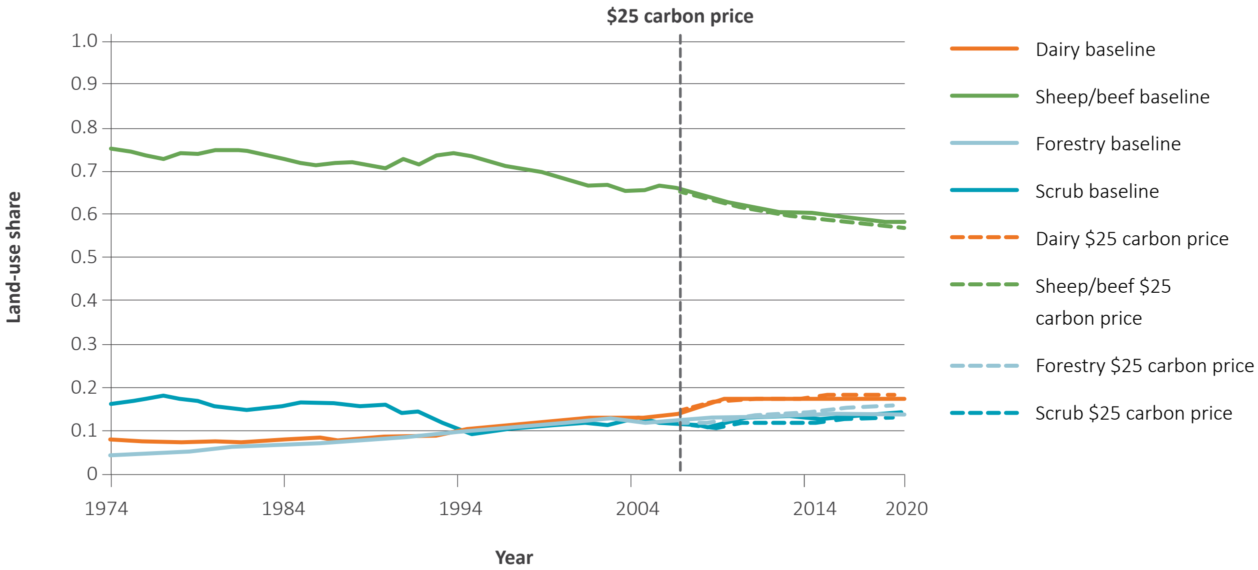


Table 5.8. GHG emissions and removals from land use in New Zealand in 2013 and compared with 1990 as reported to the UNFCCC for all forests included (MƒE, 2015a)

Category	1990 (Mt CO_2–eq)	2013 (Mt CO_2–eq)	Percentage change
Forest land*	-30.2	-33.7	11%
Cropland	0.4	0.4	-7%
Grassland	1.1	6.5	486%
Total emissions	**-28.7**	**-26.8**	**-7%**

*Removals shown as negative

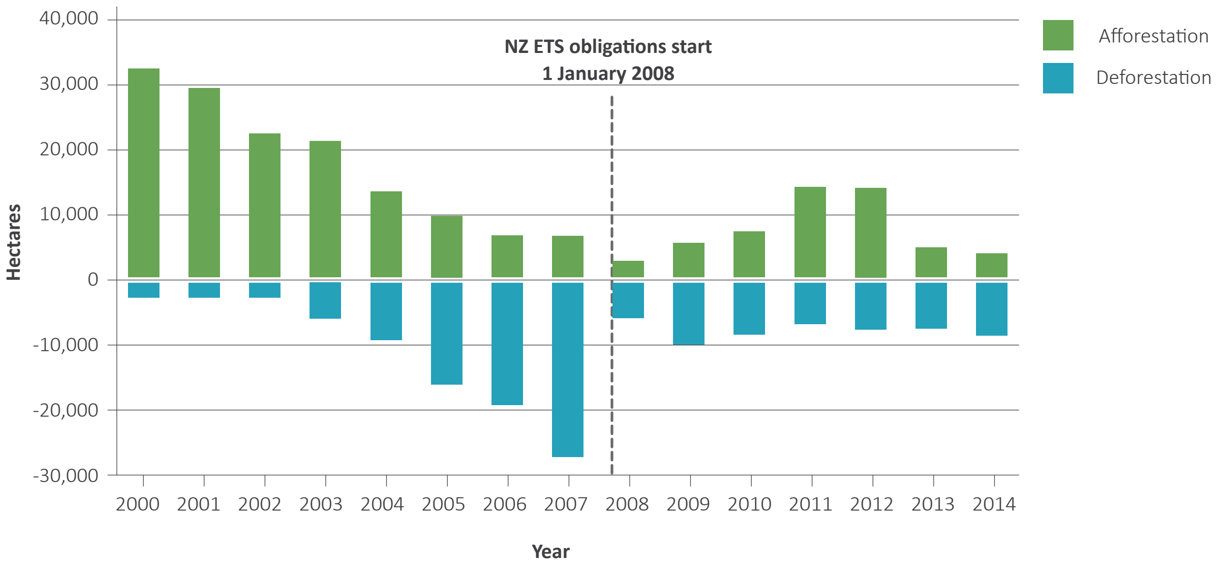
After 8 years of operation of the emissions trading scheme (NZ ETS) (Section 4.8), more than 95% of emission units surrendered in 2014 by participating companies were not from New Zealand's forest sinks but had been purchased from offshore, mainly emission reduction units (ERUs) from projects in Ukraine and Russia for around $0.10/t (EPA, 2015). As a direct result of introducing the NZ ETS, no sectors have been shown to have actually reduced emissions to date except 'waste' (MƒE, 2015a).

In addition, during 2014 around one hundred companies in 'trade exposed' industries received as their allocation 4.4 million New Zealand units (valued at around $4–5/NZU and paid for by taxpayers), hence reducing any obligation to reduce their emissions.

Many of these ETS participants have banked a total of around 150 million NZUs whilst using cheap ERUs purchased from overseas to meet their commitments. Importing ERUs is no longer allowed, so the banked NZUs will now have to be used to meet the future commitments of these companies.

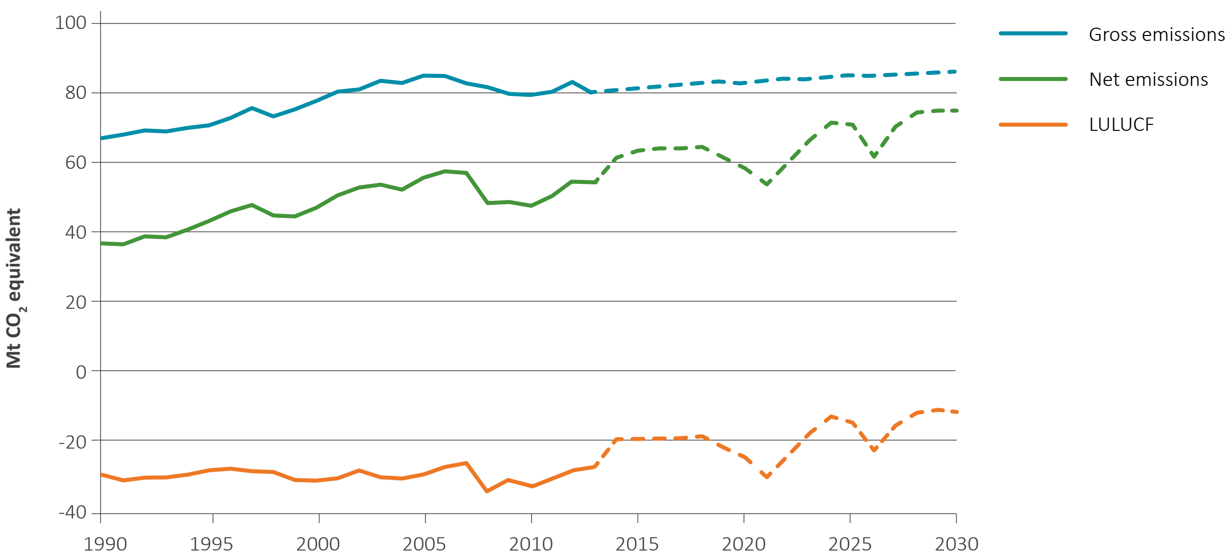
The reduction in new forest plantings and the increase in deforestation (Figure 5.38) was possibly influenced by imports of the cheap credits. This trend explains why net emissions have risen in recent years (Figure 5.39)

Figure 5.38 Afforestation and deforestation in New Zealand from2000 to 2014.



Source: M*f*E (2016).

Figure 5.39 Historic GHG emissions in New Zealand from 1990 to 2013 under UNFCCC accounting rules with projected trends out to 2030 showing growing net emissions in New Zealand as existing planted forests are harvested and not always replanted.



Source: Based on M*f*E (2015e).

Greenhouse gas mitigation options

Is planting more forests a feasible mitigation option?

Planting forests in marginal pasture land presents New Zealand with an opportunity to contribute to mitigation of climate change emissions through carbon sequestration combined with other benefits such as displacing land uses with relatively high emissions (such as sheep/beef production on hill country); production of wood products with low-carbon footprints; the provision of environmental services such as land stability and flood risk minimisation; and the supply of renewable bioenergy systems using biomass residues.

In the future, it may be that high carbon and fossil fuel prices imposed on energy users, coupled with low pulp and timber prices, could encourage forest owners to harvest their trees for sale as biomass fuel for conversion to heat, electricity, or transport biofuels and hence to displace more costly fossil fuels. Assuming the harvested land is soon replanted, the biomass is deemed to be a relatively low-carbon fuel since although CO_2 is produced during its combustion (as for the combustion of fossil fuels), the CO_2 is, in effect, reabsorbed as the replanted forest grows.

Even with full replanting, forests could be a net source overall due to a function of age class distribution and harvesting. It may also be that some planted forests are not harvested due to steep terrain or low log prices.

If the maximum reforestation rate achieved during the 1990s could be repeated and sustained until 2030, just over 1 million ha of new planted forest would be established. Total carbon sequestration by such new plantings would be at least 23 Mt CO_2 /yr. Hence, assuming revised accounting rules are agreed internationally after 2020 (MƒE, 2015b, Addendum), these new plantings could, by 2030, offset over half of our non-agricultural gross CO_2 emissions, or a quarter of total gross GHG emissions[109]. Forest biomass from residues could also displace coal and gas for renewable heat (Section 5.1).

In May 2015, the NZ Government announced the Afforestation Grant Scheme that, for a range of reasons including storing carbon, aims to encourage 15,000 ha of new plantings over the period 2015–2020 by providing a $1,300/ ha grant[110]. Under Kyoto rules, the existing post-1989 plantation forest estate may become a net source of CO_2 as it matures and particularly when harvesting the 1990s peak planting area that will commence around 2020[111] (Figure 5.39). This means the CO_2 absorbed by our planted forests would be unable to even partly offset the CO_2 emitted from our continual burning of fossil fuels. This is exacerbated since, under the UNFCCC reporting convention, and hence the ETS requirement, it is assumed that at harvest, all carbon stored in the wood is immediately released as CO_2. As a result, New Zealand's net emissions (total gross emissions minus CO_2 removals) are projected to rapidly rise for the next decade or longer (Figure 5.39). Harvested wood products are included in all UNFCCC and Kyoto reporting under accounting rules since 2013 and also being considered further in the current review of the NZ ETS (Section 4.8).

Several studies have quantified the area of marginal land potentially available in New Zealand for afforestation (see for example Trotter *et al.,* 2005). Watt *et al*. (2011) analysed three scenarios of afforesting 0.7 million, 1.1 million and 2.9 million ha, based on a variety of spatial datasets and exclusion criteria. In all cases, arable land and land with potential for high value grazing were excluded, as were indigenous tussock and scrublands. The scenarios differed in the erosion severity of the land targeted:

- ***Severe to extreme*** for scenario 1 (mainly North Island East Coast and Manawatu-Wanganui regions).
- ***Moderate to extreme*** for scenario 2.
- ***Slight to extreme*** for scenario 3.

109 2030 emissions from *New Zealand's 6th National Communication on Climate Change*; Scion's forestry calculations.

110 https://www.mpi.govt.nz/funding-and-programmes/forestry/afforestation-grant-scheme/

111 Pre-1990 planted forest removals have fallen from ~22.2 Mt in 1990 to almost zero in 2013 due to increased maturity and harvesting. (MƒE, 2015a Table 6.4.2). Post-89 forest will probably become a net source when the forests planted in the mid-1990s boom start to be harvested, by which time pre-1990 planted forests should be a sink again.

If the highest estimate of 2.9 million ha of afforestation is to be achieved in practice, it would largely displace low intensity agriculture, but could meet public resistance for aesthetic, local environmental constraints, and increased water demand reasons. Other trade-offs from expanding the planted forest area include higher risks of pest damage from growing monocultures, forest fires, and the spread of wilding pines, which need to be considered against the positive ecosystem services provided by forests.

A ‘Rapid Afforestation Scheme’ has also been proposed to encourage planting of 50,000 ha per year from 2015 to 2040 leading to a total conversion of around 1.3 M ha of low producing land (Mason, 2015). This estimate was based on the Land Cover Database that was produced later than that used by Watt et al., (2011) with most of the identified area being low producing grasslands in the South Island (Table 5.9).

Table 5.9. Potential low producing land area available that could be used for a Rapid Afforestation Scheme (ha) with land above 900m above sea level (ASL) in the North Island excluded, and above 700m ASL in the South Island.

	North Island	South Island	Total for New Zealand	% share
Depleted grasslands	163	84,337	84,500	6%
Gorse and/or broom cover	67,159	119,328	186,487	14%
Low-producing grasslands	219,758	850,905	1,070,663	78%
Mixed exotic scrub-lands	7,178	29,974	37,152	2%
Total	**294,258**	**1,084,544**	**1,378,802**	

Source: Mason, 2015. Land Cover Database v. 4.

However, if afforestation of this entire land area occurred, it would not necessarily provide a net public benefit. Barry *et al.* (2014) used an integrated spatial economic model to assess the net private and public benefits from converting marginal agricultural land into planted forests in New Zealand. Results suggested that with a low carbon price per tonne CO_2, little of the total 1.38 Mha potential area would be economically viable for landowners to convert to forestry. But where land use change is uneconomic, additional net public benefits would justify payment of government incentives to increase the rate of forest planting and natural regeneration.

Where marginal pasture land on hill country can be fenced off and planted or left to regenerate naturally to native forest over time, carbon credits can be awarded to the landowner under the ETS for post-1989 forests or the Government’s ‘Permanent Forest Sink Initiative’[112]. Reforestation to native forest can achieve annual carbon uptake of around 15t C / ha (Whitehead *et al.*, 2001). Regeneration of existing natural forests through pest control was recently assessed at around 2tC /ha (MƒE, 2015a). Pinus radiata plantation forests were assessed to have a higher annual average carbon removal potential of 19–22.5 t C /ha (Hollinger, 1993) though a loss in soil carbon may occur and eco-system services are often less than for native forests.These can then be sold to businesses or individuals wishing to offset their carbon footprints. The rate of carbon fixation by regenerating natural forests is lower than planted forests and therefore would not be a satisfactory option where a rapid increase in carbon stocks is the aim.

112 http://www.mpi.govt.nz/funding-and-programmes/forestry/permanent-forest-sink-initiative/

Encouraging further land use change from pasture and scrubland to planted and natural forests will remove more CO_2 from the atmosphere as well as provide other GHG emission offsets. This could be achieved by a higher carbon price for an NZU and the desire of GHG emitters to trade directly with landowners who can offset their emissions.

While New Zealand's planted forests have been used in the past to offset increasing GHG emissions from fossil fuels and agriculture, the most appropriate role for large-scale new plantings (or reversion of pasture to indigenous forest) would be in conjunction with a well-thought out and widely understood strategy to reduce New Zealand's gross carbon emissions. This could include consideration of the temporal benefits of focusing on low-cost forestry mitigation opportunities in the near term, while other sectors still lack deployment of technological mitigation solutions. Once this has been formulated and agreed, a large scale planting programme would allow New Zealand to reach its target for reduced emissions much earlier.

What are the opportunities and barriers for these mitigation options?

The opportunities for taking up mitigation options for forestry and other land-use include:

- Revenue per hectare may be increased after planting forests on marginal pasture land.
- Design and construction of wooden buildings to lock-in carbon with possible export potential (Section 5.3).

Barriers to these options being taken up include the following:

The carbon price remains too low to drive new forest plantings. Although the New Zealand Unit (NZU) price under the ETS has risen to around $12/NZU (as at April 2016), it is still deemed too low to encourage forest planting.

- Some planted land may prove unsuitable for harvesting due to excessively steep terrain or high water table.
- There is inequitable competition for land use if not all land uses (as for agriculture) are liable for their emissions.

There is uncertainty of UNFCCC accounting for forest sinks after Paris COP 21 and hence the future ETS rules and government intervention in the carbon market are unknown.

The current ETS reporting treatment of forests at time of harvest assumes instantaneous emissions of all carbon embodied in harvested wood. If the ETS reporting convention changes to include the carbon embodied in harvested wood products, then the assumed impact at harvest of post-1989 forests may be reduced.

An attempt was made to provide an overview of estimated mitigation potentials, costs, and possible priority sequencing of mitigation actions across all sectors including forestry (Annex 1) although data scarcity limited the analysis.

Co-benefits

What other benefits exist when reducing GHG emissions in forestry and other land use?

There are a number of benefits that can result for undertaking mitigation options for forestry and other land use:

- Land stabilisation of hill country and minimisation of flood risks.

Economic return and employment from commercial forestry and wood processing.

- Production of wood materials and products with low-carbon characteristics.
- Biomass resources used for bioenergy applications.
- Contribution to improved water quality (due to lower N and P additions compared with more intensive farm systems) and aquatic biodiversity.

Provision of habitat for native species that prefer forest environment to farmland.

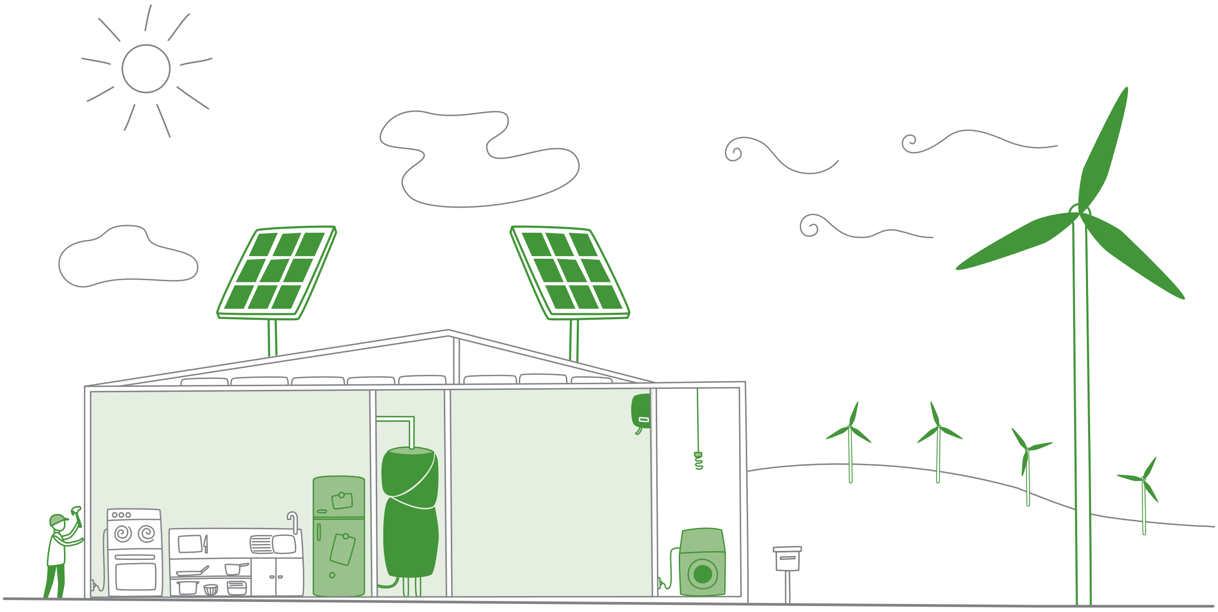
Knowledge gaps

What else would be useful to know?

- Reporting rules govern estimates of carbon stock changes, whereas accounting rules define what are eligible mitigation actions. International accounting methods for assessing carbon removals or emissions by forests and land use change are complex and may evolve under the post-2020 Paris Agreement. How these rules will be reflected in the revised NZ ETS is uncertain and will continue to require continuous improvement and development to ensure that they are as efficient as possible and meet the new reporting requirements.
- A carbon mitigation strategy based on afforestation requires an understanding of the potential impacts on other ecosystem services (both positive and negative).
- Accounting for harvested wood products requires better information on the carbon content of products and the appropriate discard rates for different types of products in different markets.
- The role of soil carbon as a sink or a source is uncertain under both constant land use or in association with land use change.
- The effect of future climate change on forest and soil carbon stocks and processes, together with adaptation options, need further investigation. Methods for disseminating information to decision makers are required, such as planning tools for landowners, managers and policy analysts to quantify the GHG impacts of alternative land uses and mitigation options on their properties.

Section 6: Emission reduction pathways

There is a strong case for immediate mitigation based on existing, well-proven low-carbon technologies and systems whilst research continues and innovative solutions emerge. Analysis of alternative mitigation pathways is lacking but delaying action whilst new knowledge is sought is not an option. If we wish to commence on a smooth and rapid transition to a low-carbon economy, there is potential to achieve deep cuts in greenhouse gas emissions and to gain the co-benefits from so-doing over the next several decades and across all sectors. The exception is agriculture that will move relatively slowly along a transition pathway towards zero emissions.



Key messages

- A transition to a low-carbon economy is possible over the next few decades if we start now and include coherent aspirations and actions across agencies and businesses as well as by communities and individuals.
- If New Zealand wishes to take domestic actions to significantly reduce our current GHG emissions, households, cities, commercial enterprises and land-users will all need to make changes in order to reduce their GHG emissions significantly.
- Although there have been some useful studies of future mitigation pathways for New Zealand, information to enable quantitative and realistic pathways to be produced is scarce and there is a lack of detailed data to enable further analysis to be undertaken to fill the knowledge gaps.
- The term 'pathways' suggests that there are a number of different ways to proceed towards approaching net zero emissions around the second half of the century. However, all routes that might achieve this goal include implementing all feasible means of avoiding activities, products and services that involve releasing CO_2 from the burning of fossil fuels.
- Models developed for emission reduction pathways elsewhere could be adapted for use by New Zealand assessments, given time and resources.
- Judgements based on current knowledge of innovative technology development and assumptions on future costs, deployment rates, and carbon prices, can be used to provide at least an indication of future mitigation trajectories in each sector.
- All sectors have good potential to reduce emissions and gain the many co-benefits including cost savings, although for some sectors, the mitigation costs in terms of \$/t CO_2-eq avoided, are unknown.
- To support immediate and short-term mitigation actions, especially those relating to behavioural changes by households and businesses, an effective carbon pricing regime would increase the rate of mitigation.
- The more uncertain or politically difficult GHG reductions, such as agricultural emissions, can evolve over the longer term whilst other sectors move more rapidly along a transition pathway towards zero emissions.

6.1 Review of approaches to producing mitigation pathways

What has been undertaken elsewhere to enable emission reduction pathways to be assessed?

The Paris Agreement invites parties to submit long-term mitigation pathway plans by 2020. Mitigation pathway analyses elsewhere, often led by non-government organisations, have included a range of emission reduction options that can be simply classified as:

1. feasible at low-carbon prices, especially if justified by valuing the many co-benefits or by removing other barriers to adoption;
2. requiring fundamental shifts in values and strategic signals, thereby indicating a need for cross-societal change that cannot be achieved simply by disseminating a low-carbon price through the economy; or
3. requiring high carbon prices to justify and motivate an early transition to mitigation options rather than waiting to be regulated.

Such analysis has not been undertaken in New Zealand due to a shortcoming in government-led analysis to date so it was not possible to undertake this task for this study, also partly due to a lack of readily available data on costs and potentials for most sectors. The lack of publicly available data seriously hampers having informed discussions about long-term pathways and debate about near-term goals for mitigation that may or may not be consistent with our longer term ambitions. This is a key knowledge gap that will be hard to fill without government taking responsibility and leadership to help furnish such data. Filling data gaps will enable the outputs from future analyses to underpin good insight, discussion, and policymaking.

Detailed integrated assessment modelling to analyse possible emission reduction pathways and hence develop a strategy for immediate and future GHG emission reductions is a useful approach taken by many countries, and globally by the IPCC (2104b). From such analysis, emission reduction actions can be prioritised. An outline of several analytical approaches used in New Zealand and elsewhere is given below, with commentary on possible New Zealand applications where appropriate.

1. **The UK '2050 Calculator'**

   The UK Department of Energy and Climate Change (DECC) has produced an on-line calculator[113] to enable users to create their own preferred mitigation pathway making choices and trade-offs that will be realistically faced when reducing GHG emissions across the energy supply, transport, building and industry sectors. Agriculture and land use are specifically covered in this calculator under the levers *'Land dedicated to bioenergy'* (including four land-use scenarios that include options for growing 1st and 2nd generation crops for biofuels, agriculture, food crops and forestry) and *'Livestock and their management'.*

   The calculator has since been adapted for use by many other nations including China, Japan, South Africa, India and Belgium, and a global version has recently been launched[114]. It is included here as although perhaps more of a communication tool, the detailed spreadsheet behind the visual presentation has value for undertaking detailed analysis in order to compare a range of possible mitigation pathways. In New Zealand, the National Energy Research Institute (NERI), in association with Victoria University, has started to adapt the Calculator for New Zealand conditions but the task has not been fully completed. This work was unable to include any cost analyses to the degree that was achieved for the UK Calculator, because limited cost data exists for New Zealand.

   The Calculator has been successfully adapted by NERI for use by the Wellington City Council[115] to assess how the city might meet its emission reduction targets of 30% below 2001 levels by 2020 and 80% below 2001 levels by 2050 (Fig. 6.1 and Box 6.1). However, cost analyses were again not included due to a lack of available data, and land-use change and forests were not evaluated in detail.

113 http://2050-calculator-tool.decc.gov.uk/#/guide

114 http://tool.globalcalculator.org/

115 http://climatecalculator.org.nz/#/home

Figure 6.1. Screen shot of one section of the Wellington City Council 2050 Pathways Calculator showing just a few of the many variables that can be changed to assess the technical mitigation potential for the city. Changing each variable as a "pathway action" reduces or increases the total annual GHG emissions

Box 6.1: What might a low-carbon future look like for a city?

Note this case study is purely an illustration of what the Calculator can be used for and is simply presenting one of many possible sets of solutions. All pathway options identified by users of the calculator will involve an extensive range of choices for the many aspects of residential, industrial, commercial and land use activities.

The Wellington City Council has a target of reducing GHG emissions to 80% less than 2010 levels by 2050. Using their on-line climate calculator, one set of actions which would achieve this reduction target is outlined below. The list gives a good idea of how widespread the changes need to be to reach this target, but, at the same time, shows that many of the changes are both technically and financially feasible today. Some can be achieved quickly, while others need a longer lead time, especially where they involve long-term investments in infrastructure. (While this calculator is designed for Wellington City's emissions, it recognizes that some sources of emissions are at a national level, such as electricity generation distributed through the grid.)

Supply

- 100% of electricity is generated from renewable resources.
- National biomass supplies, including from forest residues, are undergoing significant growth as outlined in the NZ Bioenergy Strategy.
- 50% of food waste and all sewage sludge are used for production of biogas for energy.
- Most of the other available biomass, such as garden and park residues, is converted to liquid fuels and/or biogas.
- 50% of local biogas is used for electricity generation, the remainder displaces LPG and CNG.
- 50% of houses have solar PV, plus there is another 71,000 m2 of larger-scale PV panel installations.
- 50% of houses have solar hot water, plus there is another 70,000 m2 of additional collection panel installations on commercial buildings.
- Food waste is reduced by 20% from 2020 levels

Demand

Travel:

- Travel demand per person is 40% lower.
- 80% of car travel is in zero emission vehicles, 20% is in plug-in hybrids.
- 5% of trips are by cycling, 3% by walking.
- 12% of trips are by bus and 10% by electric train.
- Bus and train designs are 20-40% more fuel efficient.
- Diesel buses are replaced by electric buses by 2035.
- Buses are higher capacity and carry an average of 60 passengers per trip.
- Aviation fuel consumption is 25% less due to efficiency gains.
- The share of freight using rail increases from the current 14% to 25%.
- Freight movements are 45% more energy efficient per tonne kilometre.

Households:

- The energy demand of space heating reduces at 0.4% a year, and water heating by 0.8% per year due to greater technology efficiencies and improved building designs.
- All new houses and half of existing ones use electricity for space and water heating and cooking.

Industry:

- Production output grows at 0.5% per annum.
- The energy intensity of industry improves by 2% per annum.
- There is considerable substitution of electricity for fossil fuels in industrial processes and heat.
- GHG emissions from HFCs from solvent and product use declines at 5% per year.
- Commercial:
- Energy used for space heating reduces at 0.3% per year, and for water heating by 0.4% per year.
- Commercial space heating is 74% electric, and water heating is 82% electric, mainly from heat pumps.
- More efficient lighting systems means electricity demand reduces to 81% of 2012 levels.
- 75% of commercial cooking uses electricity or biogas.

Land use:

- In the Wellington City region, national cattle numbers remain constant and sheep numbers decline by 2% per year; methane emissions per animal remain constant after 2020
- The area of native vegetation in Wellington increases by 9ha per year
- Pine plantations are all replanted after harvest, and an additional area is planted annually.

2. **New Zealand analyses.**

   Recently, Motu has been developing a creative *Low Emission Future Dialogue* by working back from the assumption that an attractive low-emission future has been reached (Motu, 2016). The aim is to generate as many ideas for specific actors and actions that could be undertaken to contribute to 'milestones' likely to be important parts of a transition to low emissions.
   The milestones are then grouped within broader sector categories (Table 6.1). This approach presented a positive image for the future and the study concluded that New Zealand's approach should:

   i. focus on a long-term climate change mitigation goal that everyone can agree on;
   ii. consider current actions compatible with achieving this goal;
   iii. implement many actions and policies that will be needed to meet this goal;
   iv. identify a variety of different roles for a multitude of actors to produce society wide change;
   v. prepare to be agile since the shape of a low-carbon emission future is uncertain with many pathways possible and numerous novel technologies and systems yet to be developed;
   vi. take a positive approach to an uncertain future: experiment, fail early and keep evolving. Engaging with an uncertain future involves being prepared to fail, although the risk of 'failing early' is usually avoided by politicians and policy advisers.

'Pivot points' have also been generated that, if happen, such as the rapid implementation of a disruptive technology, would force society to shift from one possible mitigation pathway to another. Such 'adaptative pathways' would involve stopping doing some things whilst putting more emphasis on others.

A range of other models exist in New Zealand or could be adapted from international sources that could support better quantification of sectoral or economy wide mitigation pathways, including their costs and interactions with other societal objectives.

For example, the electricity supply sector (Section 5.1) can utilise the Electricity Authority's 'GEM' optimisation Interactive Electricity Generation Cost Model – 2015 (MBIE, 2016). This tool enables future demand growth to be assessed and potential costs of new generation capacity to be evaluated and compared prior to construction. Sensitivity analyses can be made using various assumptions for future fuel prices, carbon prices, currency exchange rates, etc. The long-run marginal costs[116] of a range of possible individual projects can be assessed to enable them to be ranked and compared. Various transport models also exist (Section 5.2) and for the building sector (Section 5.3), modelling of future household demand is in process (Jack et al., 2016).

116 The average wholesale price a generator needs to receive to recover investment and operating costs plus earn an economic return on investment.

Table 6.1. Milestones to be reached by 2050 across sectors as part of the transition to a low-carbon future for New Zealand as presented in the Low Emission Future Dialogue.

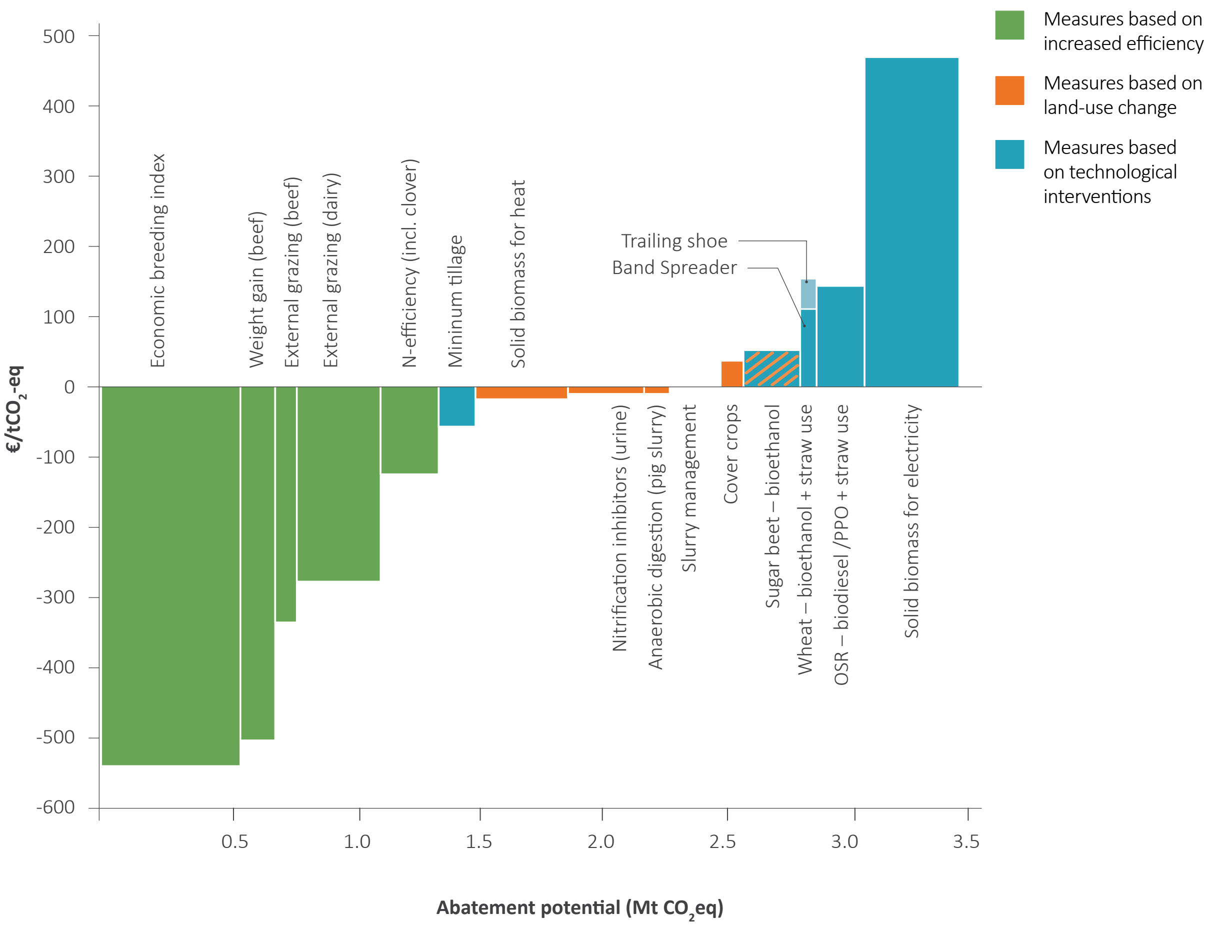
2050 vision	Sector category	Possible sector characteristics
New Zealanders have access to secure, resilient and affordable zero-net-emission energy to power their homes and businesses.	Electricity and heat supply	Utilities supply nearly 100% renewable generation.
		Distributed renewable generation displaces some utility generation.
		Heat for industrial production and buildings is primarily produced with renewable electricity or other non-fossil fuels.
		Emissions from fossil fuel or biomass combustion are removed by CCS.
		Disruptive technologies transform the supply of power and heat.
	Electricity and heat demand	Enhanced energy efficiency and energy conservation generate multiple benefits.
		Disruptive technology transforms demand for power and/or heat.
New Zealand's transport system ensures efficient, resilient and affordable zero-net-emission mobility for people and goods*.	Transport fuel supply	Transport is powered primarily by electricity.
		Transport is powered primarily by bioethanol, biodiesel, biogas*.
		Disruptive technology transforms transport energy supply.
	Vehicle fuel demand	Vehicle fuel efficiency increases significantly.
	Passenger transport demand	Private motor vehicle use is heavily displaced by public, other shared or active transport modes.
		Private motor vehicle use is significantly reduced by urban planning and/or culture change.
	Freight transport demand	Freight shifts significantly from road to rail and coastal shipping.
		Freight transport demand declines significantly due to changes in technology or consumer demand.
New Zealand operates a highly efficient, low GHG emission food production system.	Food supply	NZ operates an ultra GHG-efficient livestock sector.
		NZ produces zero-CH_4, low-N_2O nutrition.
	Food demand	NZ reduces food waste across the chain of food production and consumption.
		Consumers demand low-emission food

* Transitional use of gas-derived fuels (CNG, LNG) as an alternative to petroleum fuels was not included.

Source: Motu, 2016.

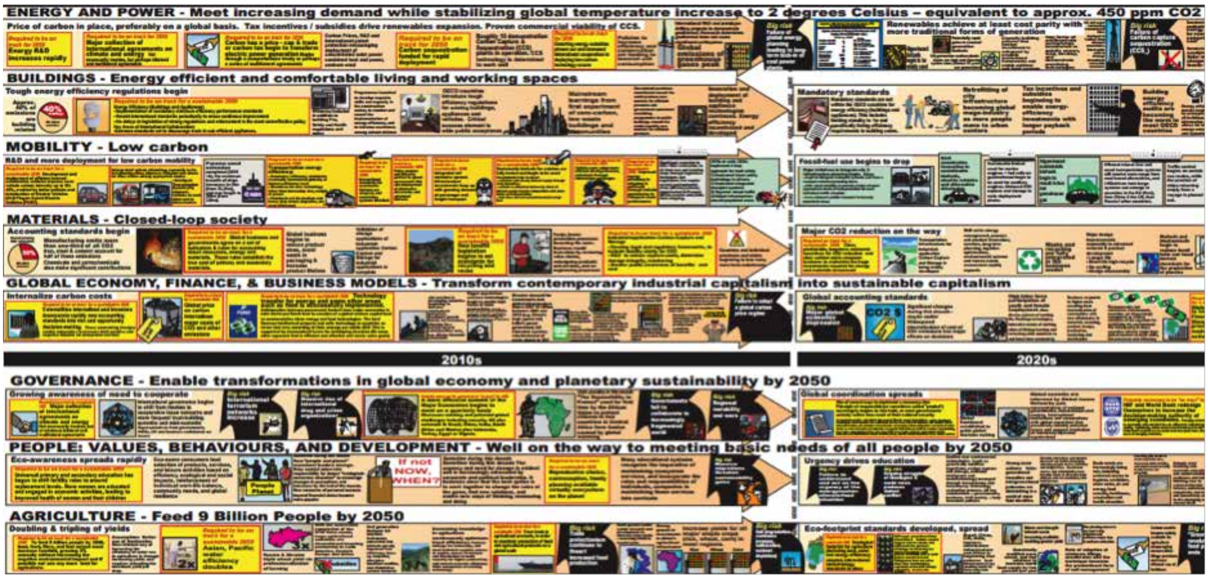
3. **Marginal abatement cost (MAC) curves.** Also known as McKinsey curves, these have been used for many analyses internationally to provide a snapshot of relative costs and potentials for a range of mitigation options. One example is the abatement potential for the Irish agricultural sector (Figure 6.2). The width of each bar indicates the estimated annual abatement potential of each technology. Bars below the zero line (to the left) represent mitigation technologies or systems that are considered to be economic to deploy (even in the absence of any carbon price) since they can reduce GHG emissions whilst also saving costs. The bars for mitigation technologies or systems above the zero line (to the right) are economic only if a carbon price is applied with the height of a bar representing the carbon price (as shown on the y-axis here as EUR/t CO_2-eq) that would be needed to give cost-effective uptake of the technology or system.

Figure 6.2 Marginal abatement cost curve for Irish agriculture showing emission reductions from increased efficiency (dark green), land use change (light green) and technological interventions (blue). The width of each bar represents the annual abatement potential (Mt CO_2-eq/year).



Source: Schulte and Donellan (2012).

Figure 6.3 Screen shot of a small section of the World Business Council for Sustainable Development's infographic mural showing some of the 10 sector pathways towards sustainability for the 2010s and 2020s (ENERGY AND POWER, BUILDINGS, MOBILITY etc.).



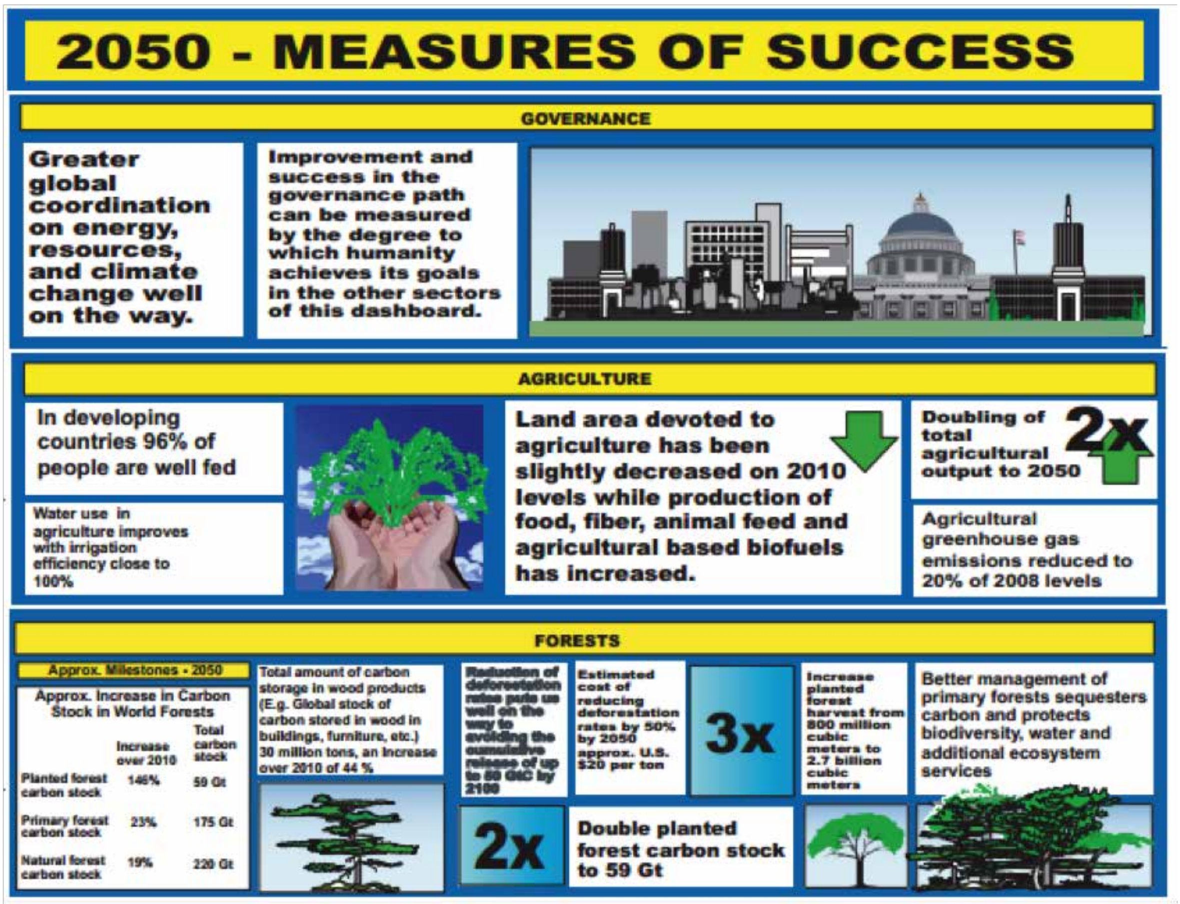
MAC curves can help identify priorities for a nation or a city and provide a comparison between mitigation options, but they do not account for the costs and abatement potential changing over time as new and improved technologies are developed, nor for the limited lifetime of investments and their contribution to an overall pathway towards a low-carbon future. This omission is important for investment in long-lived infrastructure. For example, fuel switching from coal to gas in a heat plant often seems to be a cost-effective way of reducing emissions, but if the goal is to become carbon neutral within a few decades, then the gas infrastructure will have to be leap-frogged. This is because once investments are 'sunk' then the financial imperative is to keep using the plant, but this could be for decades longer than is consistent with the need to rapidly lower emissions.

There are also open questions regarding why, in the MAC curve, apparent mitigation potentials that are cost-effective even in the absence of a carbon price, are, nonetheless, not taken up in practice. For a business this can be due to lack of understanding, behaviour issues, staff culture, psychology, and how firms make financial decisions. It also raises questions about the feasibility of additional mitigation options given the introduction of a carbon price. For some businesses, perhaps there is a lack of knowledge on energy efficiency opportunities since they are not related to core business. For others, the payback period may be too long compared with making other investments to increase production.

The absence of any published MAC curve for key sectors in the New Zealand economy hampers technical analysis and public discussion about feasible mitigation options and pathways. They can provide a very useful means of gaining a better and quantitative understanding of New Zealand's options and choices towards a low-carbon future and could also be a useful tool to assist prioritising areas for R&D investment by government. However, given the short-comings of MAC curves, it is not suggested that they should dictate policy decisions about mitigation priorities.

4. **'Pathway Towards a Sustainable 2050'** was published in 2010 by the World Business Council for Sustainable Development (WBCSD).[117] Compiled by representatives from 29 companies, it provided a vision for a world moving towards sustainability and provided milestones at 2010, 2020, 2030, 2040 and 2050 for each of the 10 tracks of energy and power; building; mobility; materials; global economy, finance and business models; governance; people: values behaviours and development; agriculture; forests; ecosystems; and biodiversity. An infographic (Figures 6.3 and 6.4) identifies 40 risks and 350 milestones including 40 that are 'must-haves' and must be achieved in the near term if the world is to reach the sustainable vision envisaged.

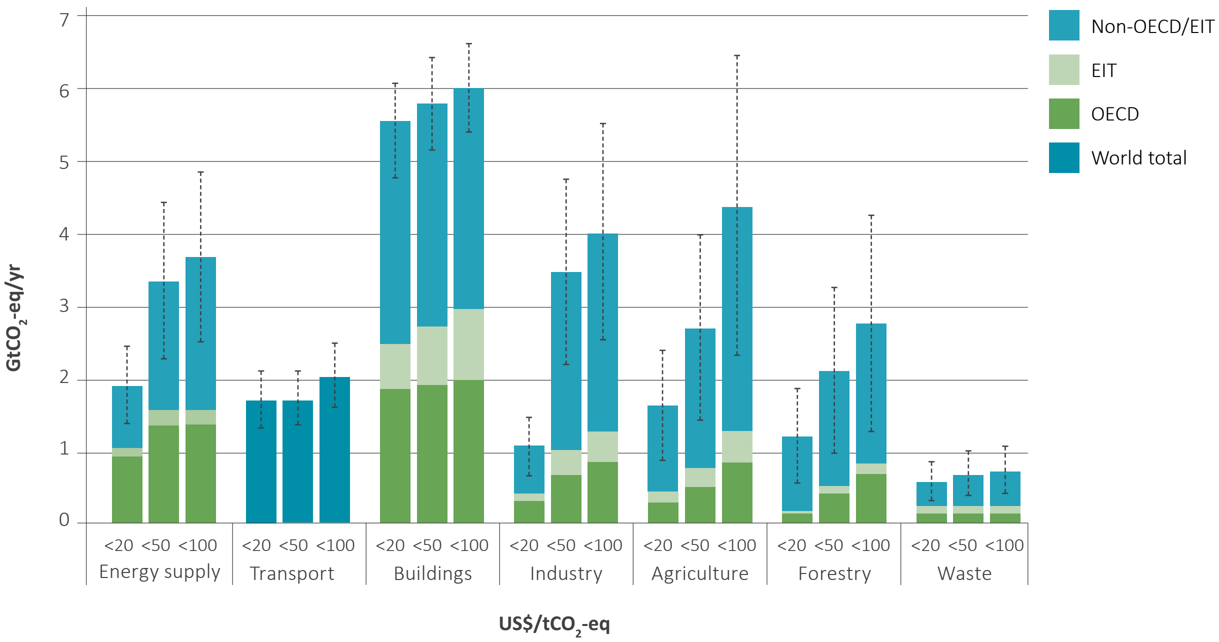
Figure 6.4 Screen shot of details from a small section of the World Business Council for Sustainable Development's infographic mural showing some measures of success by 2050 for sector pathways aiming to reach greater sustainability.



5. **Intergovernmental Panel on Climate Change.** Co-ordinating lead authors of the IPCC 4th Assessment Report, Mitigation (IPCC, 2007) jointly developed a detailed spread sheet for use by Chapter 11 Mitigation from a cross-sectoral perspective. It enabled global and regional mitigation potentials for all sectors to be produced for various future costs of carbon (Figure 6.5).

The complex spreadsheet is available and could be used to produce a similar analysis for New Zealand. However, because of the time and resources needed to make the necessary data inputs and amendments to better suit New Zealand conditions, it was not possible to undertake this task as part of this study.

Figure 6.5 Estimated sectoral economic potentials for global mitigation for different regions as a function of carbon price in 2030 compared to the respective baselines assumed in the sector assessments.



Note: EIT = economies in transition

Source: IPCC (2007.)

However, this was not a systemic approach since it ignored inter-sectoral interdependencies such as competition between sectors for the same resources. For that reason the IPCC chose a different approach in the 5th Assessment report (IPCC, 2014b).

6.2 Mitigation pathways for New Zealand

What are the options for New Zealand to reduce its GHG emissions over the next few decades?

It has not been possible in this study to produce detailed pathways for a range of mitigation options out to 2050 and beyond. Undertaking comprehensive studies to fill these knowledge gaps is needed, but were not possible for this study partly due to time and resource constraints but mostly due to lack of available data due to a dearth of analyses of mitigation potentials, costs, co-benefits and trade-offs associated with their implementation, and the inability to combine discrete measures into comprehensive packages that would enable a gradual transition over time.

The various tools listed above from IPCC, WBCSD and DECC took considerable time, effort and resources to produce. Adapting them to New Zealand's circumstances would capitalise on this work and provide valuable insights for future pathways. In this regard, to have adapted parts of the DECC 2050 Calculator for Wellington City Council was a commendable effort, even though it is still lacking in key components such as costs and benefits.

In parallel with this study, a group of New Zealand industry associations and organisations (including renewable energy technology associations, energy management groups, business councils, and representative local governments), has come together to contribute to designing a low-carbon future. Under the brand *'Yes we can'* their aim is to present the technical and economically viable renewable energy and energy efficiency opportunities that can contribute to reducing GHG emissions. The members are actively involved in developing an analysis of practical and realistic mitigation opportunities that can be either implemented immediately or in the foreseeable future. In addition, policy recommendations will be made to ensure the various government targets (90% renewable electricity by 2025; 11.2% reduction of GHG emissions below 1990 level by 2030, and 50% reduction below 1990 level by 2050) can be met in practice. Being industry led, the cost effectiveness of such mitigation options will be presented in their forthcoming report and related Symposium planned for the end of May, 2016. This work should help to fill in some of the cost gaps in the knowledge as identified in this study.

Although 'pathways' suggests that there are a number of different ways to proceed towards net zero emissions over the next few decades, the evidence makes it clear that there is only one main highway that will achieve it. This would be by *implementing all feasible means of avoiding the burning of fossil fuels* and compensating for unavoidable emissions through afforestation and, in the longer-term, bioenergy combined with CCS. The highway includes displacing the use of coal, oil and gas (in that order of importance) with renewable heat, renewable electricity, biofuels, and possibly 'green' hydrogen. A strong focus on reducing demand and increasing efficiency is imperative.

The *main highway* diverges from business-as-usual in some respects, but in others it picks up on a pathway that is already being taken by many businesses, councils, communities and individuals who are consciously reducing their GHG emissions whilst enjoying positive economic, social and environmental outcomes.

There are no technical reasons why moving along the *main highway* towards a lower dependence on fossil fuels cannot start immediately by undertaking changes that are no longer in need of further debate (Figure 6.6). Delaying action makes the whole transition more difficult, more costly overall, and with higher resulting total GHG emissions to reach the same end-point (Box 2.2). In order for New Zealand to rapidly move along the core transition highway, there is an urgent need to develop strong targets and present coherent aspirations and actions across agencies, businesses, municipalities, communities and householders across all sectors (Annex 1).

There are many additional low-carbon actions that can also be undertaken, but they may require further information, engagement and/or debate. Some are choices about the precise route of this *main highway* and will determine whether it reaches the goal faster or slower. These choices include having a greater or lesser focus on:

- Reducing methane and other emissions which affect New Zealand's ability to reduce overall GHG rather than only CO_2 emissions.
- Using afforestation to offset fossil CO_2 and other emissions.
- Reducing HFCs, other F-gases, and black carbon emissions.
- Achieving on-going economic growth (assuming less growth results in less emissions), as opposed to a broader focus on societal well-being.
- Reducing forms of consumption that result in GHG emissions.
- Long term costs and benefits on the basis that investing for a low-carbon future requires a long-term strategy, particularly for long-lived investments.

Other determinants of the precise *main highway* are, as yet, unknown and will become clearer over time, but action cannot wait until they are fully understood. Such uncertainties include:

- The future financial viability of various forms of carbon dioxide capture and storage (CCS).
- The cost trajectories for innovative low-carbon technologies, some of which may be disruptive.
- The future price of carbon.
- Broader societal concerns about the climate change performance of New Zealand and other countries.
- The response of markets to either climate-friendly or climate-polluting activities and products.
- The speed at which climate change impacts will eventuate and increase global concerns such as the rate of sea level rise and the frequency of extreme weather events.

These uncertainties lead to negotiable and fungible aspects to the goal of achieving a future low-carbon economy.

If moving along the *main low-carbon highway* is implemented immediately, it will give time for decisions to be made about additional variants to the pathway which are more uncertain, under-researched or require time for engagement and negotiation. These variants can then evolve and contribute to the momentum and speed of the transition pathway over time. For example, strategic long-term transitions for the agricultural sector differ from other sectors in that reaching zero emissions within several decades is unlikely but also not strictly necessary. This therefore involves a choice being made by New Zealanders between either:

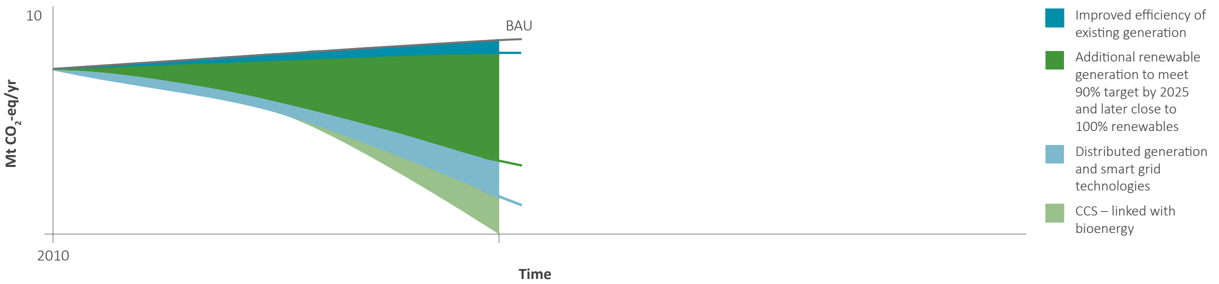
- shifting away from current growth trajectories for meat and dairy production to alternative climate-smart land-use scenarios with a lesser focus on ruminant livestock as the dominant land-use; or
- accepting that, even with large and successful R&D investment and implementation of new technologies using all practical solutions available, reducing non-CO_2 emissions from agriculture is unlikely to decline to below 1990 levels. This assumes current industry growth trajectories and targets will be maintained and that there is no movement towards changing current land uses and agricultural production to lower GHG-emitting alternatives per hectare than for current enterprises. In the long term, New Zealand would acquire an even more unusual emissions profile and, *inter alia,* would be unlikely to be able to meet the long term target of reducing net GHG emissions in 2050 to 50% below 1990 levels. In addition, any spillovers would mean that some food production could shift to other parts of the world and result in higher emissions per unit of product with no benefits to the global commons and the overall food security reduced.

Realisable mitigation trajectories for each sector in New Zealand have been developed based on expert evaluations and wide ranging assumptions (Fig. 6.6). The wedges are approximations that serve to indicate a number of major actions that could make the greatest impact on GHG emission reductions for each sector, largely based on assumed costs where these were not available and 'realistic' potentials. Each sector wedge also indicates the time in the future when zero-carbon emissions could possibly be achieved. Improving data analysis would enable more precise projections to be developed but large uncertainties will always remain. However, a more precise analysis of carbon budgets, target dates and timeframes for reaching zero net emissions in each sector is needed, enhanced by including probabilities.

Figure 6.6 Indicative illustrations of selected mitigation pathways for each New Zealand sector starting from 2010 emission levels and based on assumptions for business as usual (BAU) growth; rate and scale of deployment of major low-carbon technologies and systems; and a future time when zero emissions could be achieved.

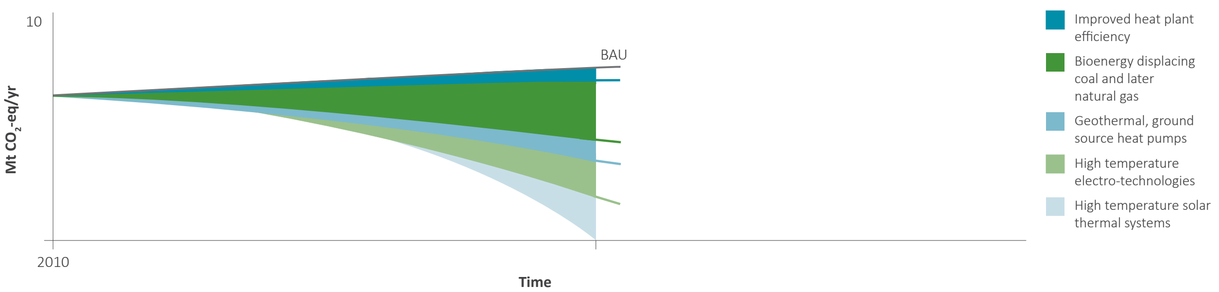
Electricity Supply

Zero emissions by medium term



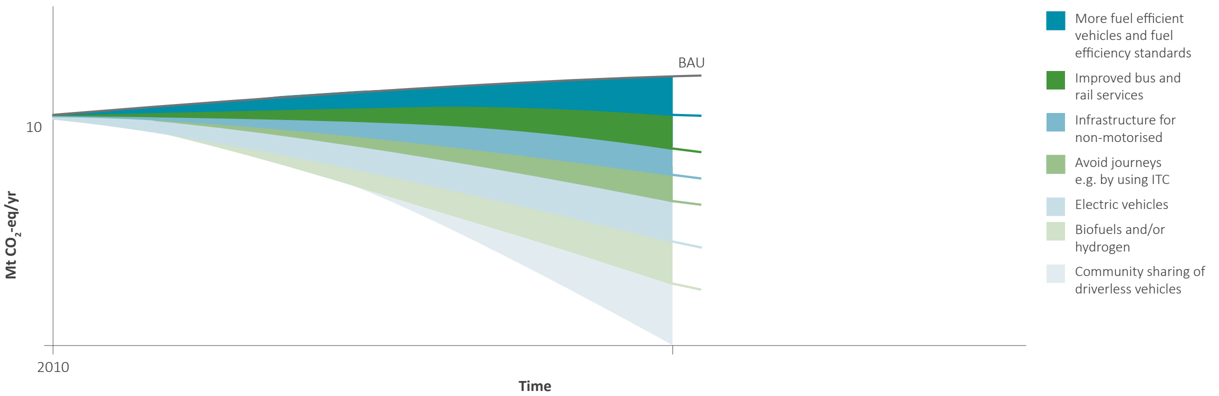
Heat Supply

Zero emissions by medium to long term



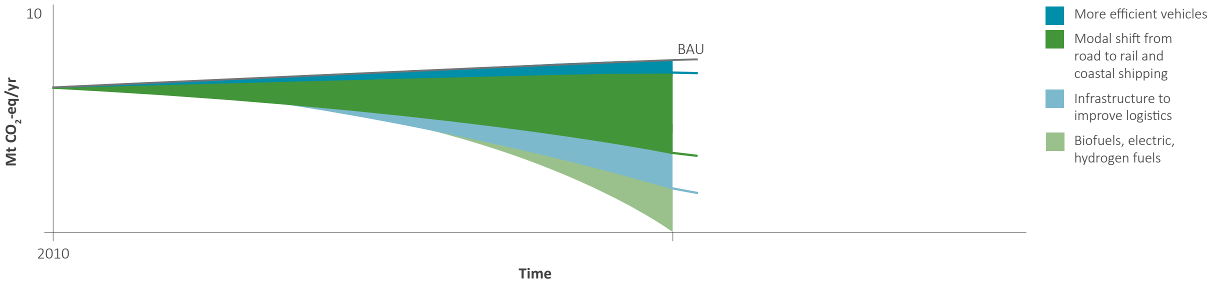
Passenger transport (domestic excluding international aviation)

Zero emissions by long term



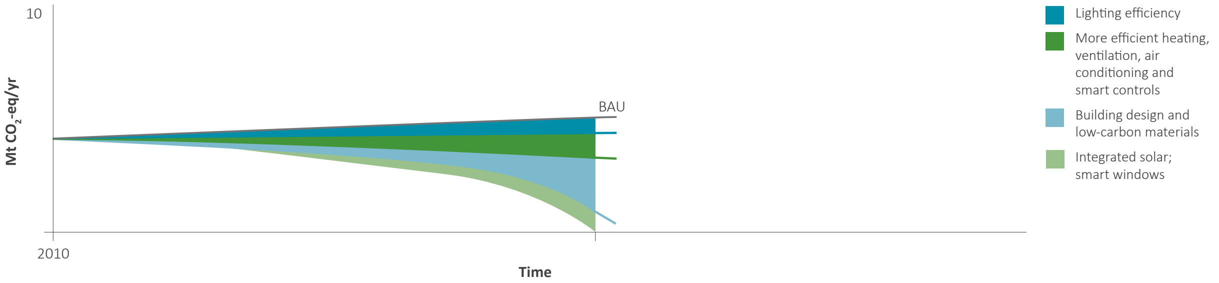
Freight transport (domestic excluding international shipping)

Zero emissions by long term



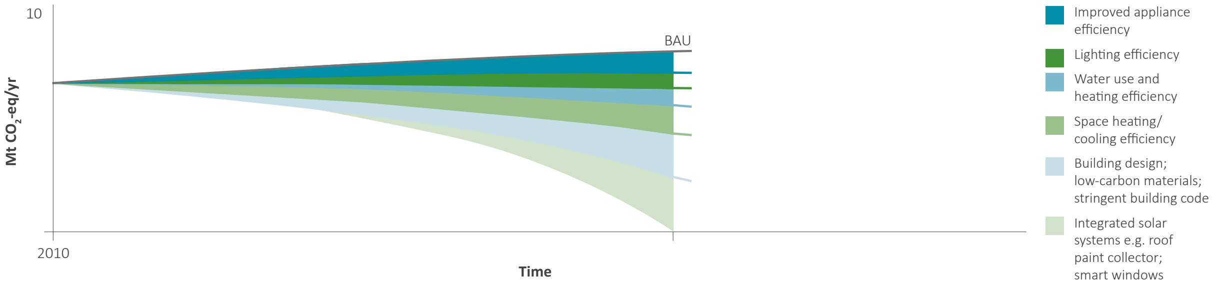
Commercial buildings

Zero emissions by medium to long term



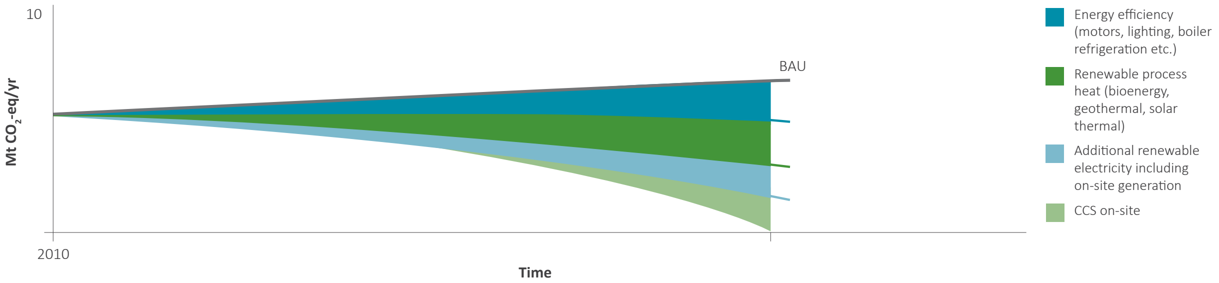
Residential buildings

Zero emissions by longer term



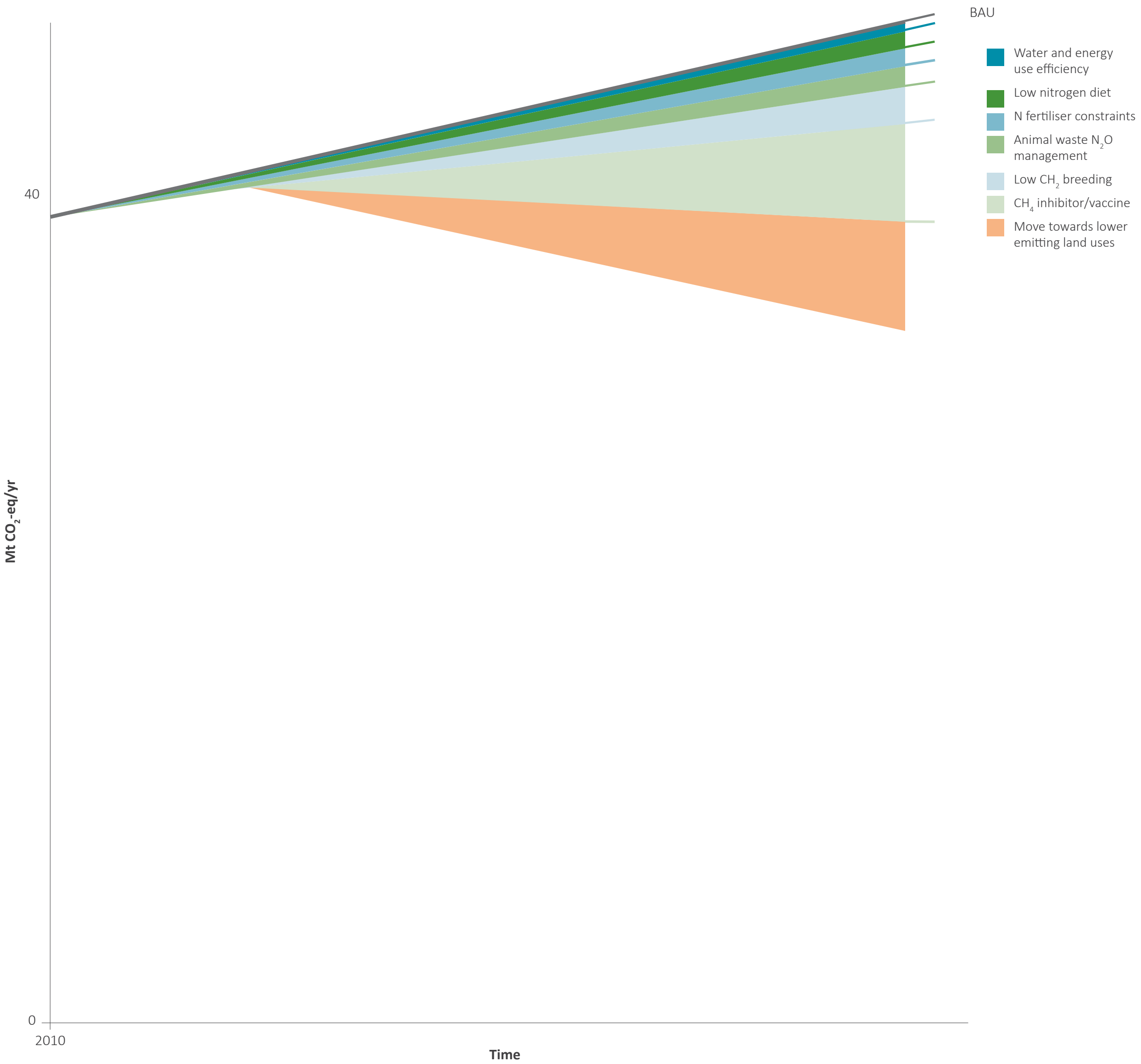
Industry

Zero emissions by longer term



Agriculture

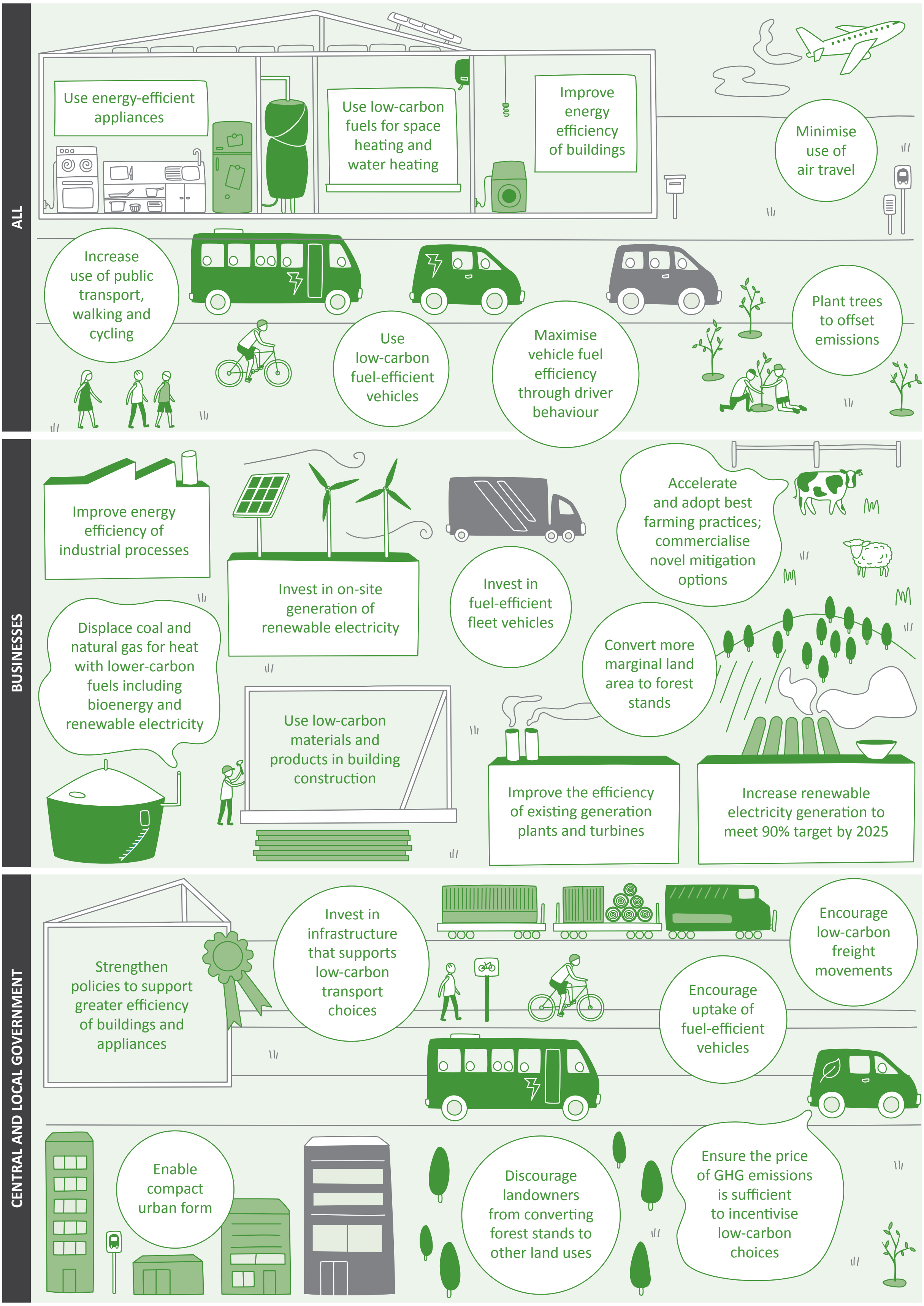
Zero emissions not considered possible even in the long term especially for livestock based systems.



The transition pathway to a low-carbon economy for New Zealand in the future suggests moving along a pathway that should begin immediately since delaying action will make the whole transition more difficult, more costly overall, and with higher total GHG emissions resulting when reaching the same end-point (Box 2.2).

To reach a low-carbon economy in New Zealand after the next few decades implies the need for aspirational targets across all sectors, coherent ambitions, and strong actions being taken now and going into the future. Government agencies, businesses, municipalities, communities and householders will all have to play a part.

Actions we can take now towards a low-carbon future for New Zealand – by individuals, businesses and central and local government



Annex 1: Summary of possible mitigation actions for New Zealand

This Annex provides a summary of possible mitigation actions for New Zealand by institutions, organisations and individuals with an indication of sequence priority, level of mitigation potential and costs per tonne of CO_2 avoided. More details can be found in the relevant sections of the main text.

The Annex identifies a number of actions that New Zealand could take as outlined in the text, but the study was unable to make a detailed assessment of these in terms of their social and economic impacts with any great accuracy. It is recognised that, when identifying the sequence of potential mitigation actions as below, understanding the trade-offs, risks and challenges as well as the opportunities for specific actions would be necessary to provide full information of the implications of those actions. This table of actions is purely indicative and further analysis is required.

Possible sequence of actions	Relative levels of annual GHG mitigation potential. L = Low M = Med H = High	Cost	Possible mitigation actions by sectors Coloured dots indicate approximate relative costs in terms of $/t CO_2-eq avoided, based on existing technologies and systems, expert opinion, and assumptions on future developments. **● Green = low cost ● Blue = medium cost ● Orange = High cost** Note: These costs, potentials and sequencing priorities are only indicative. They will vary widely with the specific circumstances, rate of technological development, trade-offs, and consumer behaviour, choice and perceptions.
Immediate			**Industry**
	M	Green	Greater focus on energy efficiency in industrial processes.
			Buildings and appliances
	M	Green	Labelling of appliances to better inform consumers.
	M	Green	Standards implemented to encourage 'doing better'.
	M	Green	Removal from the market of the most inefficient appliances through the use of minimum energy performance standards (MEPS).
			Forest and land use
	H	Green	Convert additional land area, especially marginal land, to plantation forest stands. Reduced erosion and cleaner waterways can be co-benefits.
			Agriculture
	M	Green	Increase and accelerate development and adoption of best practices that increase productivity of animals and greater efficiency of farm systems.Whether this approach reduces absolute emissions depends on whether the gains are used to increase total production, or to increase profitability with retirement of less productive land and farm system.
			Support research on novel technologies to reduce CH_4 from enteric fermentation, N_2O from soils, and enhance soil carbon storage.
			Transport for individuals
	H	Green	Purchase the most fuel efficient vehicle suitable for mobility needs and consider car-pooling, taking the bus, and for short journeys, walking or cycling to also improve health.
			Transport for businesses
	M	Green	Select fuel efficient vehicles for fleets and adequately maintain them.
	L	Green	Avoid journeys by tele-conference meetings.
	H	Green	Encourage freight movement by rail or coastal shipping in preference to road.
			Transport for local and regional government
	M	Green	Encourage use of comfortable and time-efficient transit through buses and light-rail.
	M	Green	Develop infrastructure to encourage cycling and pedestrians.
			Transport for central government
	H	Blue	Encourage urban densification and provision of economically viable inter-city low-carbon transport options.
			Electricity
	M	Green	Increase shares of renewables towards meeting the 90% target by 2025
			Heat
	H	Green	Expand uptake of bioenergy (wood, biogas etc.) to displace coal for heat.

Short term			**Industry**
	H	●	Increase use of renewable heat (solar thermal, geothermal, bioenergy) to displace coal and gas.
			Buildings
	M	●	Promote more efficient appliances through programmes such as Energy Star.
	L	●	Enable new building designs to incorporate passive solar systems and energy efficiency above current Building Code levels.
	H	●	Provide training and education for everyone involved in designing, manufacturing, installing and using low-energy buildings and equipment.
			Forest and land use
	H	●	Incorporate more wood materials and products for building construction giving stored carbon benefits and lower carbon footprints than using steel or concrete.
			Transport for individuals
	L	●	Avoid journeys through use of electronic social media, better planning of trips, internet shopping, combining trips.
	L	●	Use public transport, especially trains, where available.
	M	●	Maximise vehicle fuel efficiency by good driving skills and behaviour, vehicle maintenance, correct tyre pressures, etc.
			Transport for businesses
	L	●	Do not provide free car parks for staff and encourage car-pooling with incentives such as preferential parking or use of public transport.
	L	●	Allow flexible working hours to minimise travel times during congested periods and enable employees to work from home when practical to do so.
	M	●	Monitor fuel efficiency and distance travelled in work vehicles with possible rewards for above average performance by drivers.
			Transport for local government
	H	●	Develop compact urban form to incentivise non-motorised transport.
	M	●	Prioritise provision of more public transport infrastructure.
	L	●	Encourage car-pooling by staff and citizens and community car-sharing
	L	●	Support installation of electric vehicle public recharging points.
			Transport for central government
	H	●	Encourage purchase of fuel efficient and low emission vehicles by introducing vehicle fuel efficiency standards across the fleet.
	M	●	Provide education on fuel efficient and non-motorised low-carbon transport technologies, electric vehicles and promote the co-benefits such as improved health, reduced traffic congestion, staying connected to electronic devices etc.
	H	●	Encourage freight movement by rail and coastal shipping in preference to road or air.
	M	●	Support development and deployment of advanced biofuels from ligno-cellulosic feedstocks.

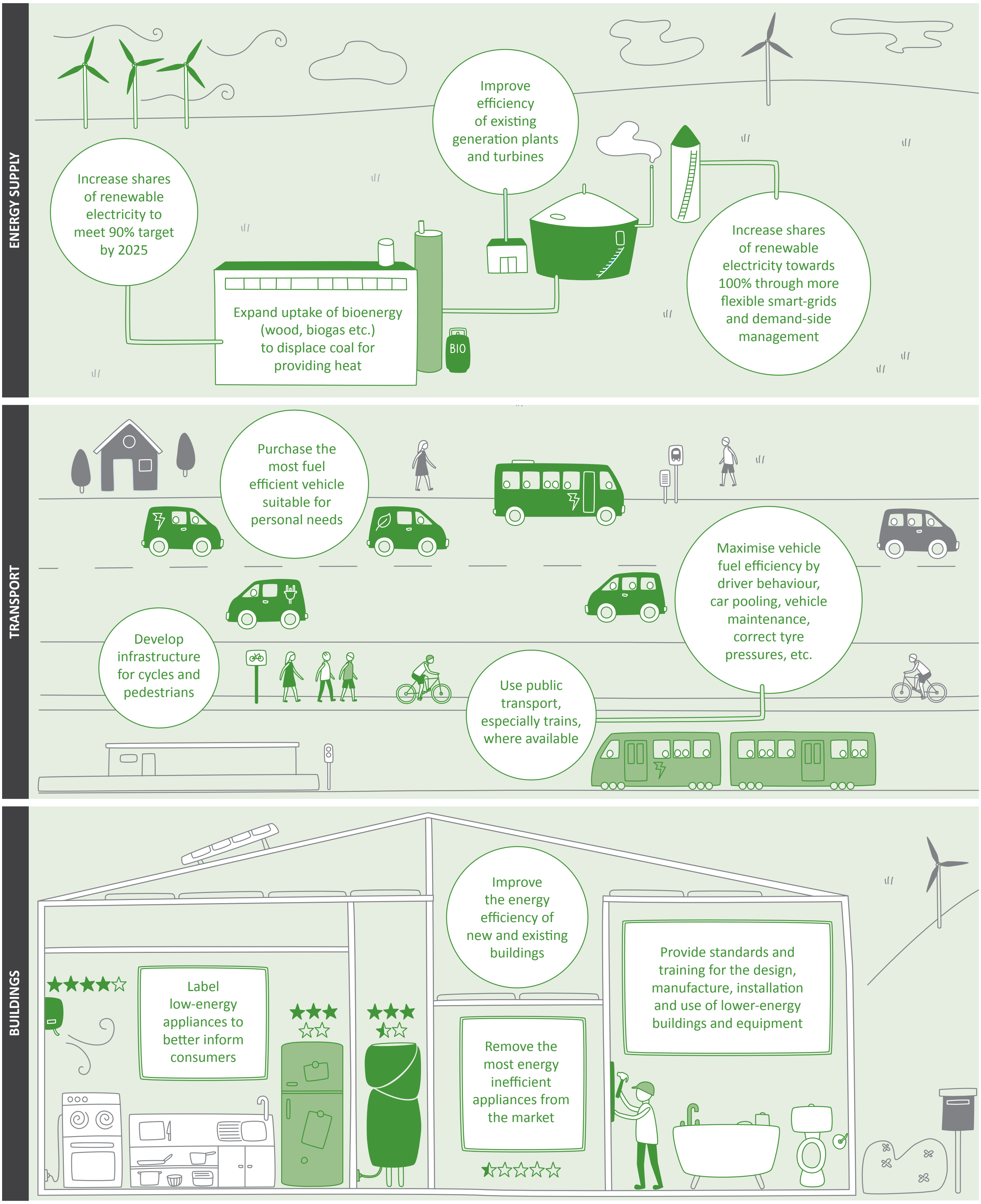
			Electricity
	M	●	Improve efficiency of existing generation plants and turbines.
			Heat
	M	●	Expand uptake of bioenergy, geothermal, to displace coal and gas.
Short to medium term			**Buildings**
	H	●	Promote more efficient new and existing buildings through programmes such as Greenstar and NABERSNZ and use of low-carbon materials.
	L	●	Develop appropriate minimum building performance levels for implementation in the New Zealand Building Code.
	M	●	Undertake regular surveys (5 – 10 years) of energy use and end-uses in order to identify new and untapped opportunities for energy savings.
			Forest and land use
	M	●	Use more woody biomass residues for bioenergy applications.
	M	●	Continue to plant forests on marginal land and reduce pests in natural forests to further encourage regeneration
			Transport for individuals
	L	●	Encourage personal contacts to minimise their transport emissions by, for example, minimising the use of air-conditioning in vehicles.
	L	●	Service your vehicle and engine regularly in accordance with manufacturers' recommendations.
			Transport for businesses
	L	●	Encourage low-carbon modal choice by employees and provide education on fuel efficient driving vehicle operation.
	M	●	Locate business offices and work spaces close to public transport, especially rail, to minimise transport emissions of freight and staff.
			Transport for local government
	M	●	Deploy electric buses and bus rapid transit systems
			Transport for central government
	L	●	Incentivise efficient load-carrying capacity freight vehicles and back-loading.
	M	●	Increase the proportion of renewables in the electricity system to minimize emissions from recharging battery and plug-in hybrid electric vehicles.
			Electricity
	L	●	Encourage deployment of smart-grids and local distributed generation.
			Heat
	M	●	Expand uptake of electro-technologies for process heat applications.
	L	●	Use efficient wood pellet stoves for domestic and small business application.

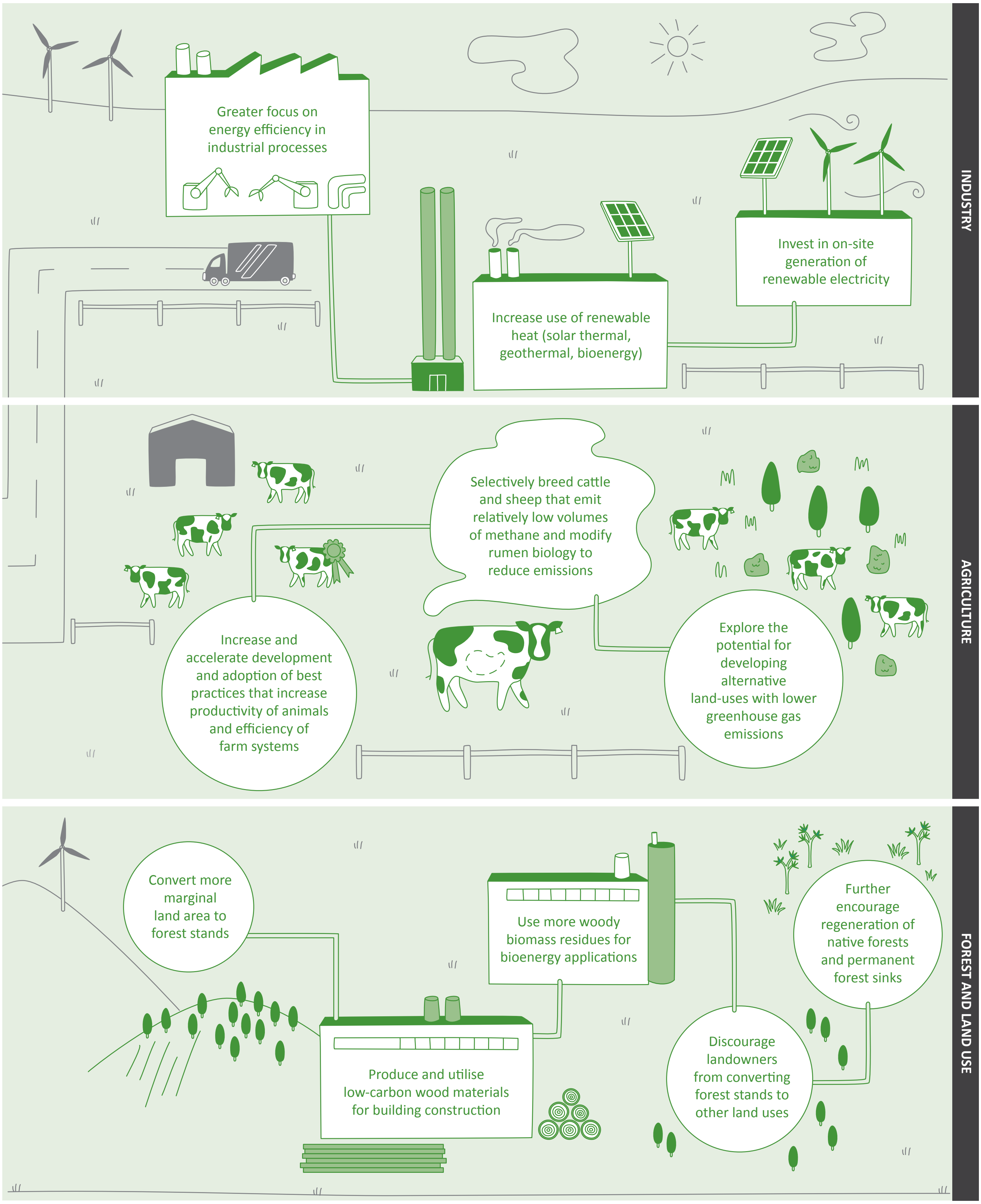
Medium term	**Industry**		
	H	●	Invest in generation of renewable electricity or heat for on-site use.
	Forest and land use		
	M	●	Discourage landowners from converting forest stands to other land uses.
	Agriculture		
	M	●	Select supplementary feeds with a lower GHG emissions based on life-cycle analysis; integrate manure and feed management to minimise use of nitrogen fertiliser.
	L	●	Enhance manure management and biogas production from pigs, poultry, dairy and use organic waste feedstocks where available in horticulture.
	M	●	Selectively breed cattle and sheep that emit relatively lower volumes of methane
	Transport for individuals		
	L	●	Avoid driving, especially in rush hour traffic and consider not owning a car.
	M	●	Use biofuels, LPG, CNG and biogas where available in preference to gasoline and diesel fuels.
	L	●	Minimise particulate emissions from diesel fuel by substitution with renewable hydrogen, biofuels, or improved battery electric hybrid vehicles.
	Transport for local government		
	L	●	Monitor passenger flows and optimise public transport options.
	M	●	Install smart-control systems for road transport management, freight logistics and efficiency at airports and ports.
	L	●	Implement congestion charging in major cities using number plate recognition.
	Transport for central government		
	M	●	Require regular vehicle emission testing to ensure vehicle fuel efficiency is optimised and black carbon emissions are minimised.
	L	●	Evaluate national infrastructure for renewable hydrogen.
	M	●	Encourage smart-control systems for road transport management, freight logistics and efficiency at airports and ports.
	Electricity		
	M	●	Increase shares of renewables closer to 100% by improved integration of variable generation through more flexible grids, demand-side management with back-up generation in the mix for dry years.
	L	●	Assess potential for CCS based on latest technologies in place overseas.
	Heat		
	M	●	Encourage more solar water heating installations on commercial buildings and air-to-water heat pumps.

Medium to long term			**Industry**
	H	● (orange)	Explore potential to couple bioenergy with CCS technology to achieve negative GHG emissions in future.
			Forest and land use
	L	● (orange)	Plant more trees on farms, with complementary land uses and eco-services.
			Electricity
	L	● (orange)	Evaluate and demonstrate potential for a) ocean energy technologies and b) CCS for any remaining thermal power stations such as gas peaking plants
			Heat
	L	● (orange)	Displace all remaining coal combustion heat plant with low-carbon alternatives.
			Transport for central government
	L	● (orange)	Encourage installation of national infrastructure for renewable hydrogen.
		● (blue)	Encourage port facilities to accommodate larger maritime freighters
Long-term			**Agriculture**
	M	?	Introduce new nitrification inhibitors on pasture having tested for no side-effects or food contamination.
	H	?	Deploy methane inhibiting technologies for ruminant animals (inhibitors, vaccines, selective breeding).
	H	?	Move towards low-emitting land-uses. Note the cost of this would critically depend on the profitability and viability of alternative land-uses.
			Agriculture, forestry and land use
	M	● (blue)	Increase soil carbon by improved management practices.
			Transport for individuals
	L	● (orange)	Live near work place and tele-commute where possible to minimise travel.
			Transport for local government
	H	● (orange)	Develop very rapid electric vehicle recharging and hydrogen infrastructure.
	L	● (blue)	Provide real-time information on travel times, congestion, public transport timetables, recharging and hydrogen refilling stations.
			Transport for central government
	L	● (blue)	Support research on novel low-C emission technologies.
			Transport for individuals
	H	● (orange)	Use community owned, driverless vehicles
			Transport for central government
	M	● (orange)	Encourage use of biofuels in transport for domestic aviation.
	L	● (orange)	Build fast-rail infrastructure.

NOTE: Establishing an effective carbon pricing regime to support these immediate and short-term changes, especially those relating to behavioural changes by householders and businesses, would increase the rate of mitigation, as would simplifying the resource consenting process to make it less challenging and expensive for low-carbon projects and potentially more incentivising.

Actions we can take now towards a low-carbon future for New Zealand – by sectors





Greater focus on energy efficiency in industrial processes
Increase use of renewable heat (solar thermal, geothermal, bioenergy)
Invest in on-site generation of renewable electricity
INDUSTRY
Selectively breed cattle and sheep that emit relatively low volumes of methane and modify rumen biology to reduce emissions
Increase and accelerate development and adoption of best practices that increase productivity of animals and efficiency of farm systems
Explore the potential for developing alternative land-uses with lower greenhouse gas emissions
AGRICULTURE
Convert more marginal land area to forest stands
Use more woody biomass residues for bioenergy applications
Further encourage regeneration of native forests and permanent forest sinks
Produce and utilise low-carbon wood materials for building construction
Discourage landowners from converting forest stands to other land uses
FOREST AND LAND USE

Annex 2: Individuals consulted as part of the Review

Individuals consulted

Simon Arnold, National Energy Research Institute

Paul Atkins, National Energy Research Institute

Professor Peter Barrett, Antarctic Research Centre, Victoria University of Wellington

Rachel Brown, Sustainable Business Network

Andrew Campbell, EECA

Harry Clark, New Zealand Agricultural Greenhouse Gas Research Centre

Brian Cox, Bioenergy Association

Anders Crofoot, Federated Farmers

Dr David Evison, New Zealand Institute of Forestry

Liz Halsted, Auckland Transport

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Chris Kerr, Ministry for Primary Industries

Catherine Leining, Motu

Dr Adrian Macey, Institute for Governance and Policy Studies, Victoria University of Wellington

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Dr Mike Reid, Local Government New Zealand

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Gerald Rys, Ministry for Primary Industries

Ralph Samuelson, Ministry of Transport

Richie Singleton, Greater Wellington Regional Council

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Elizabeth Yeaman, EECA

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Staff from the Ministry for the Environment, Ministry of Business Innovation and Employment, and Ministry of Foreign Affairs and Trade also provided comments on a draft version of this report.

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