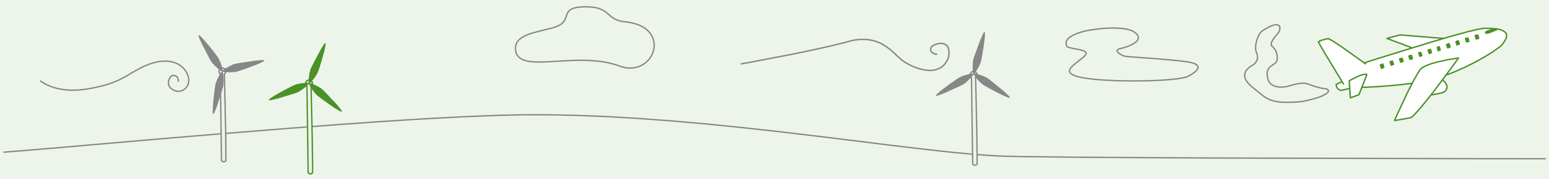


Transition to a low-carbon economy for New Zealand

Summary report

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.

Richard Bedford

Professor Richard Bedford QSO FRSNZ
President, Royal Society of New Zealand

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 emissions of carbon dioxide (CO_2) as it 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, 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 businesses.
- 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

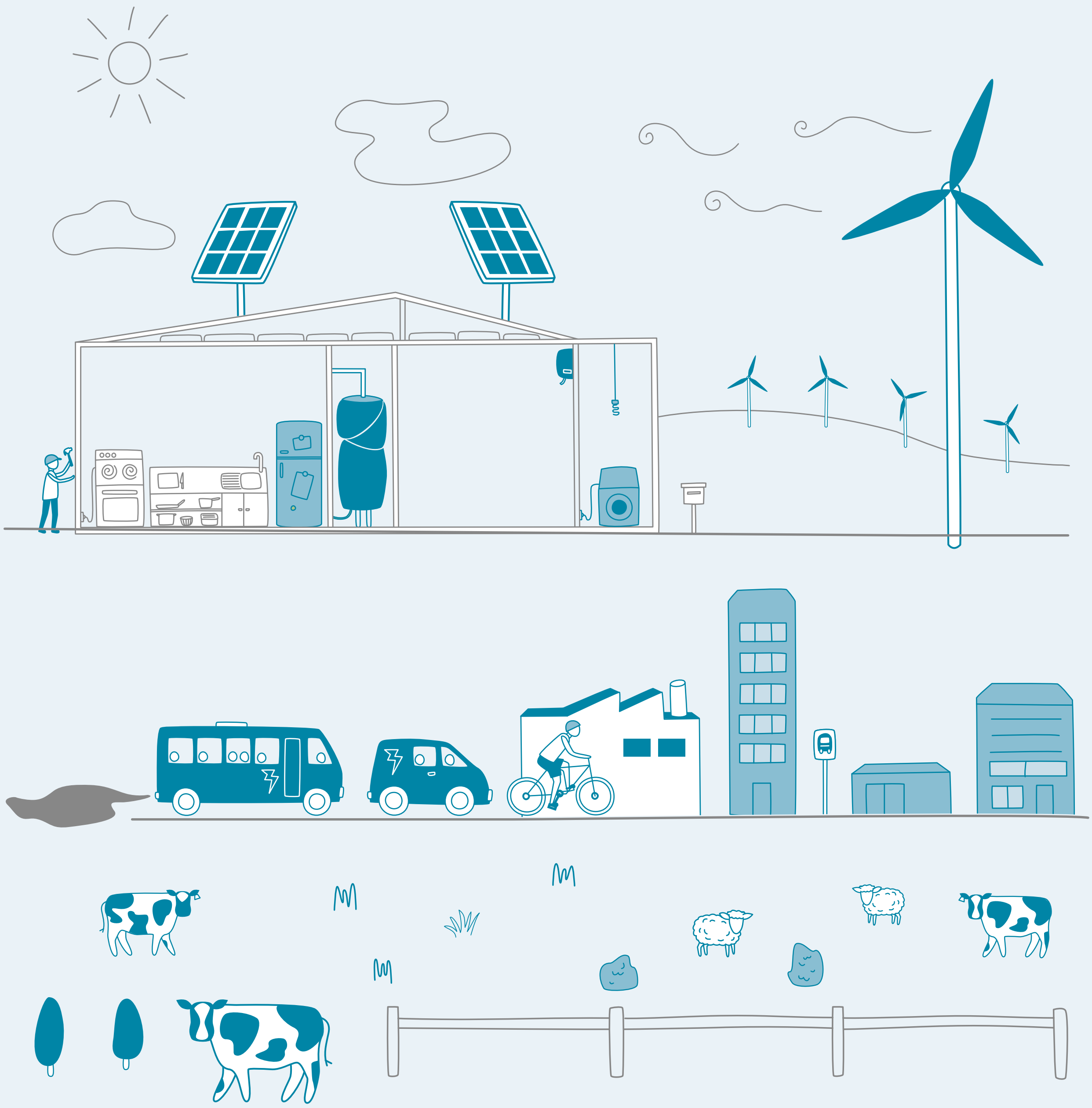
- Policies, targets, regulations, infrastructure, and market settings should be developed systematically to support low-carbon choices by businesses, cities and households.
- An independent board or entity to provide evidence-based advice to Parliament and the public would be valuable.

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.

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.

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.

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.

New Zealand's emissions and trends

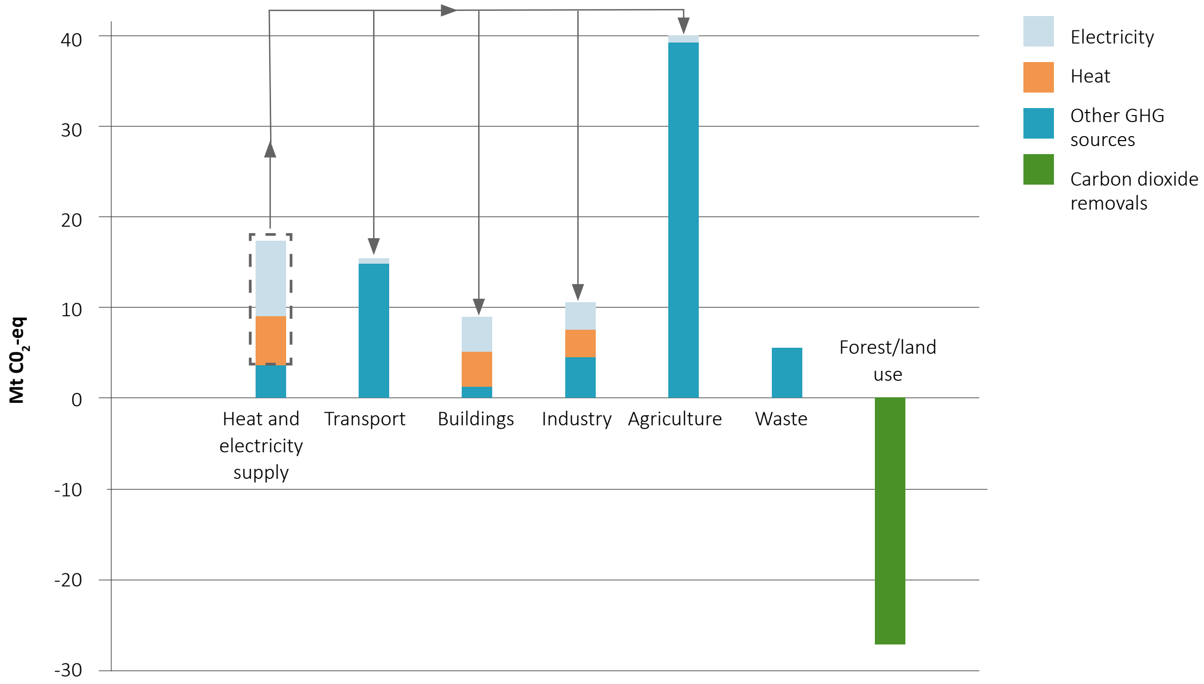
New Zealand's annual gross GHG emissions are continuing to increase. Our net emissions, after taking into account removal of CO_2 from the atmosphere by our forests as they grow, have also risen. Neither gross nor net emissions are expected to decline significantly within at least the next two decades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

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.

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

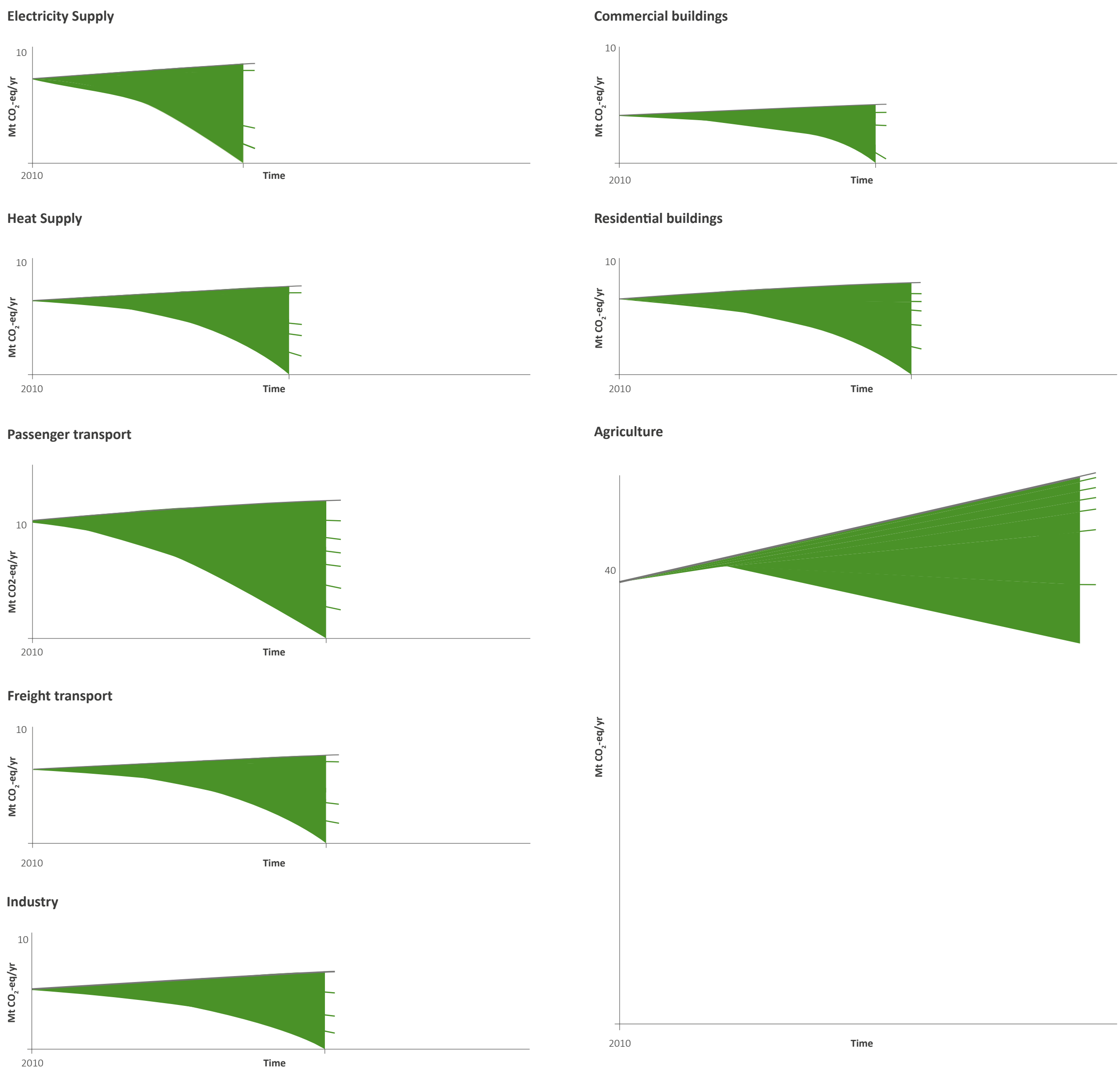
This study identifies a number of mitigation actions that New Zealand could take across each specific sector: heat supply, electricity supply, transport, building, industry, agriculture, forestry and other land use. Possible actions by individuals, businesses, local and central government are also discussed.

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. An approximation of potential emission reductions by NZ 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.

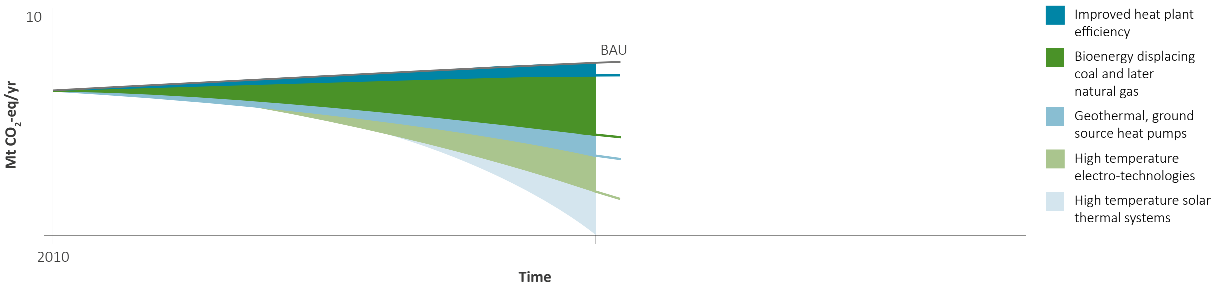


Sectoral mitigation options

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

Heat Supply
Zero emissions by medium to long term



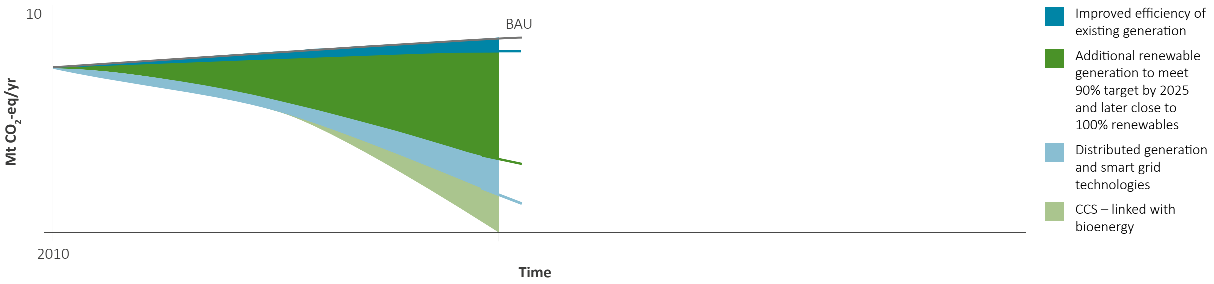
Cost effective options to reduce or avoid GHG emissions have not been fully realised to date. These options include the greater uptake of biomass, solar thermal, and geothermal resources to displace coal and natural gas in the heat sector. The technical mitigation potential for renewable heat is high 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.

Electricity supply

Electricity Supply
Zero emissions by medium term

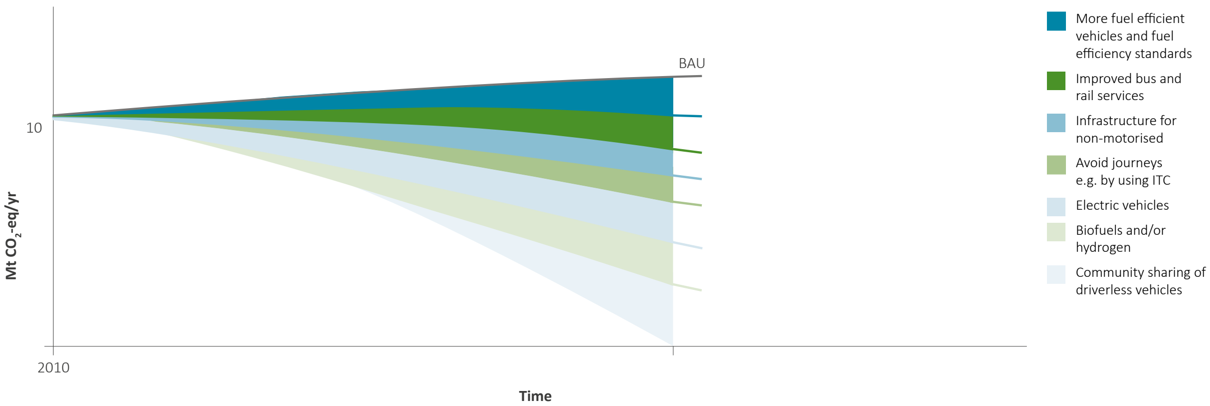


Around 80% of New Zealand's electricity is generated from renewable sources, primarily hydropower. This can be further increased cost effectively to reach New Zealand's renewable electricity target of 90% by 2025. Eventually, it will be technically possible to reach close to 100% zero carbon generation (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.

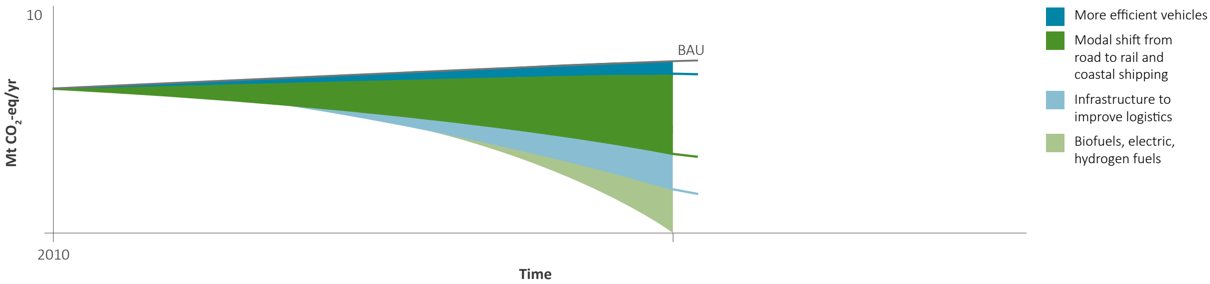
If there is a high proportion of variable renewables in the mix of electricity generation, specifically designed equipment will be needed along with collaboration from stakeholders to ensure frequency fluctuations can be controlled to provide grid stability in the wholesale electricity market. Distributed 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.

Transport

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



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



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.

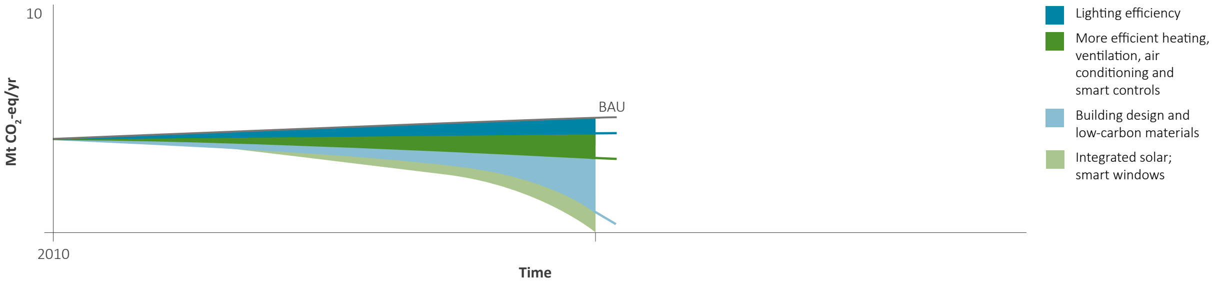
The declining retail prices for EVs (including E-bikes, E-cycles and E-buses) and hydrogen fuel cell vehicles, coupled with the carbon price reaching a high level, could drive the large scale adoption of low-carbon mobility choices. To speed up development of EVs will require policy instruments and other 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.

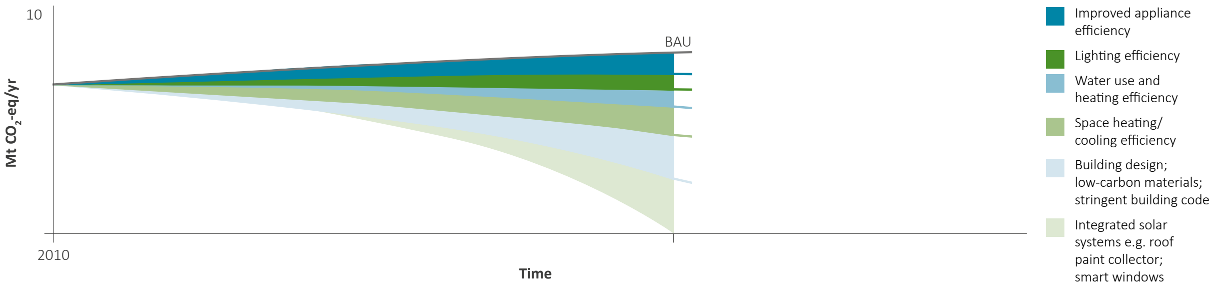
Domestic biofuels based on by-products from food processing (such as ethanol produced from whey, biodiesel from tallow or used cooking oils, and biogas from organic wastes) avoid competition for land use and can be competitive with petroleum products. These are currently being utilised only at a small 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.

Buildings

Commercial buildings
Zero emissions by medium to long term



Residential buildings
Zero emissions by longer term



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 the 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.

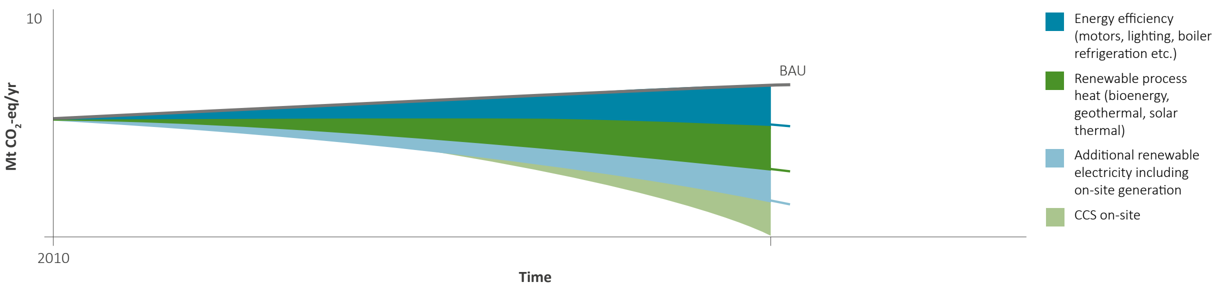
Appliances have a shorter life than buildings but often continue to consume energy 15 to 20 years after purchase. The application of minimum energy performance standards (MEPS) have helped remove the most energy inefficient appliances from the market. *'Doing better'* type labels such as *EnergyStar*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

2 www.nzgbc.org.nz/Category?Action=View&Category_id=112

Industry

Industry
Zero emissions by longer term



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.

Agriculture

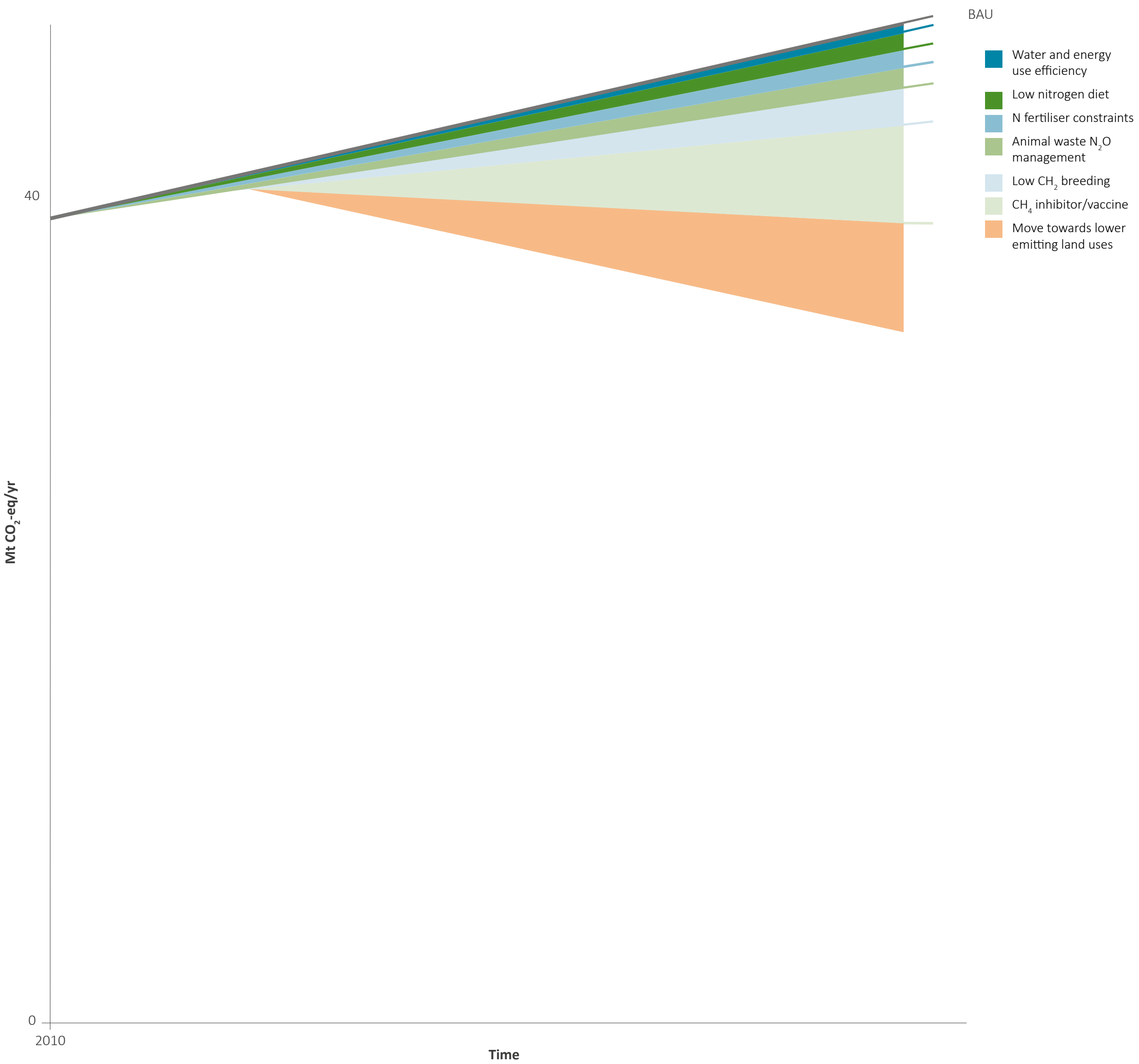
Direct emissions from agriculture make up almost half of New Zealand's gross GHG emissions. These are mainly CH_4 emissions from ruminant animals, N_2O from animal wastes, with CO_2 emissions related to energy demand on farms for electricity, greenhouse heating, crop drying, tractor fuels, water pumping 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 un-forested 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 of our 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 publicly 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 Emissions 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 post-agreement negotiations.

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 CO2 accumulate in the atmosphere so reducing or capturing emissions as soon as possible is preferable to waiting for future advancements.

3 http://newsroom.unfccc.int/.

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.

Achieving *a low-carbon economy* for New Zealand involves taking low-risk climate mitigation actions now and planning for more ambitious GHG emission reductions in the future. This can be done as we gain greater scientific understanding of the potential actions, costs and trade-offs of the many additional mitigation options available.

Authors of this review

Professor Ralph Sims (Chair):
School of Engineering and Advanced Technology, Massey University.

Professor Barry Barton
Te Piringa Faculty of Law, University of Waikato.

Dr Paul Bennett
Science Leader, Clean Technologies, Scion Research.

Dr Nigel Isaacs
Senior Lecturer, School of Architecture, Victoria University of Wellington.

Dr Suzi Kerr
Senior Fellow, Motu and Adjunct Professor, Victoria University of Wellington.

Associate Professor Jonathan Leaver
Associate Professor of Civil Engineering, Unitec Institute of Technology.

Dr Andy Reisinger
New Zealand Deputy Director (International), New Zealand Agricultural Greenhouse Gas Research Centre, Wellington.

Dr Janet Stephenson
Director of the Centre for Sustainability, University of Otago.

Acknowledgements

The Panel would like to thank the Society's expert advice (Dr Marc Rands and Dr Roger Ridley) and communication and outreach (Ms Nancy de Bueger and Ms Joy Gribben) teams for their valuable support and assistance. The Panel would also like to thank the many experts who have contributed to the report (Annex 2), with special thanks given to Dr Robert Schock, Dr Timm Zwickel, Dr Morgan Williams and Professor Gerry Carrington for reviewing the report for the Society.

For further information

Please contact info@royalsociety.org.nz

or go to the Royal Society of New Zealand web page:
www.royalsociety.org.nz/climate-change-mitigation-options-for-new-zealand

ISBN 978-1-877317-18-7

Except for figures & the RSNZ logo,
Emerging Issues papers are licensed under a
Creative Commons 3.0 New Zealand Licence.