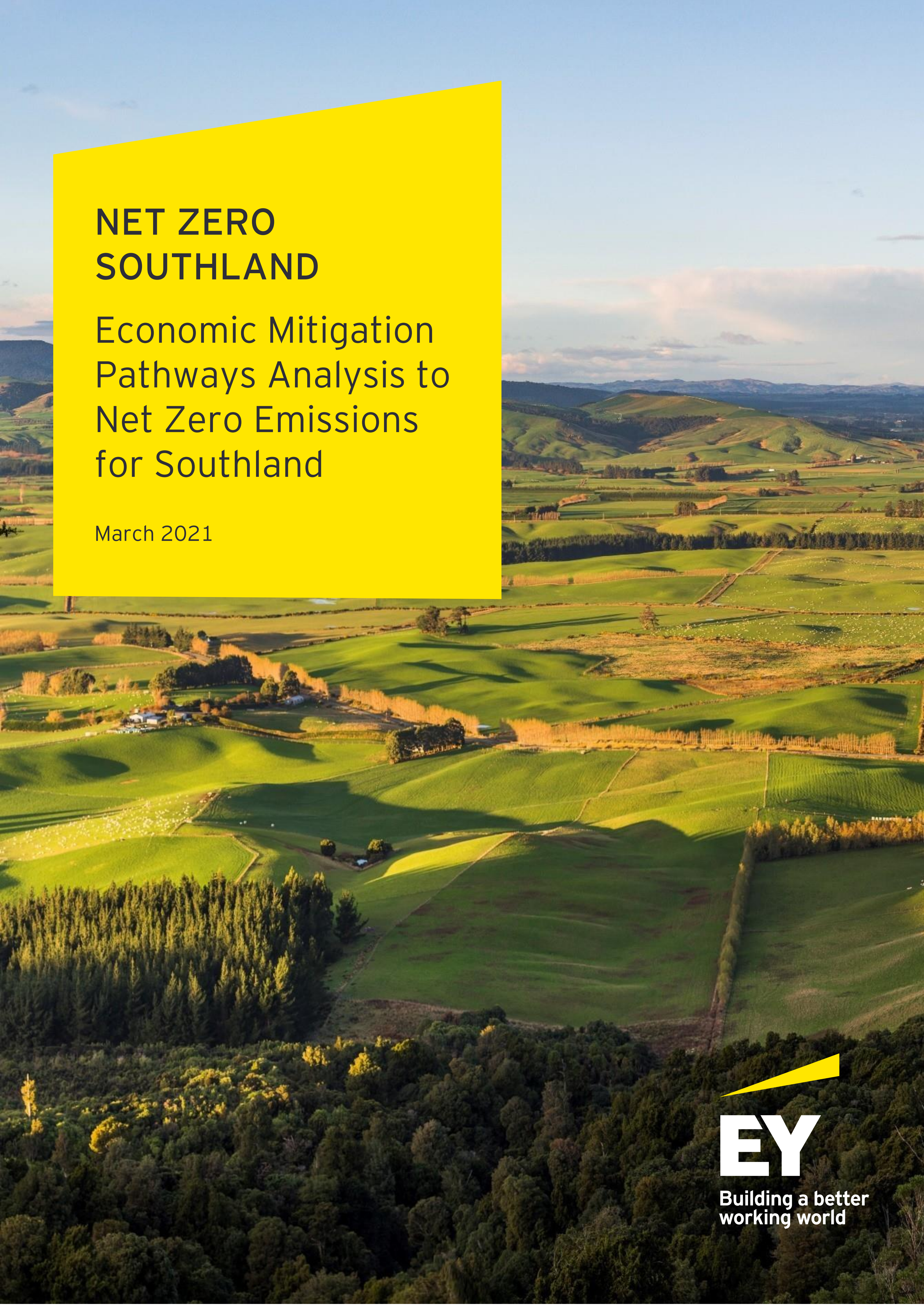
NET ZERO SOUTHLAND

Economic Mitigation Pathways Analysis to Net Zero Emissions for Southland

March 2021



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Cover page image courtesy of Great South.
Viewed from Forest Hill Reserve looking north-east

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Glossary

Term	Definition
Abatement	A reduction in level, especially of something that is harmful.
AECOM	An infrastructure firm providing in climate change and environmental consulting services.
Aerobic Digestion	A process which uses bacteria and oxygen to break down organic and biological waste.
Baseline	A starting point used for future comparisons.
BAU	Business as usual.
BEV	Battery electric vehicle.
Bioenergy	Renewable energy produced by living organisms.
Biofuel	A fuel derived from living matter.
Biogas	Gas (methane) derived from the fermentation of organic matter.
Biogenic	Produced or brought about by living organisms.
Biosequestration	The net removal of carbon dioxide from the atmosphere by plants and micro-organisms and its storage in vegetative biomass (trees, plants) and in soils.
Carbon Sequestration	The process of capturing and storing atmospheric carbon dioxide.
CCC	He Pou a Rangi – Climate Change Commission
CH_4	Methane.
Climate Change	A change in global or regional climate patterns such as temperature, precipitation, wind patterns.
CO_2	Carbon dioxide.
Decarbonisation	To remove or reduce the carbon dioxide emitted in the economy.
EECA	Energy Efficiency and Conservation Authority
Effluent	Liquid waste or sewage.
Euro6	A vehicle exhaust emissions standard for petrol and diesel vehicles developed by the European Emissions Standards.
FCEV	Fuel cell electric vehicle.
Fossil Fuel	A fuel formed by natural processes of buried dead organisms of biological origin.
GDP	Gross Domestic Product.
Greenhouse Gas	A gas that contributes to the greenhouse effect by absorbing infrared radiation.
ICE	Internal combustion engine.
IPCC	(United Nations) Intergovernmental Panel on Climate Change.
IPPU	Industrial processes and product use.
kWh	Kilowatt hour (measure of energy over time).
LULUCF	Land use, land use change, and forestry.
Marginal Abatement Cost	The comparison between the financial costs and benefits associated with the implementation of mitigation options and their emissions abatement potential.
Mitigation	The process or result of making something less severe, serious, or painful.
Mitigation Pathway	The resulting pathway modelled from the mitigation option.
$MtCO_2e$	Megatonnes of carbon dioxide equivalent.
NO_2	Nitrogen dioxide.
NDC	National Determined Contribution

Net Present Value	The difference between the present value of cash inflow and the present value of cash outflow over a period of time.
Net Zero Emissions	The balance between the amount of greenhouse gas put into the atmosphere and those taken out.
NIWA	National Institute of Water and Atmosphere.
PCL	Public Conservation Land
Renewable	(of a natural resource or source of energy) not depleted when used.
tCO_2e	Tonnes of carbon dioxide equivalent.

1. Executive summary

The New Zealand Government has committed to reaching net zero emissions of long lived gases by 2050, and to reducing biogenic methane emissions by between 24-47% by 2050 (Climate Change Commission, 2021). In 2018, Great South in partnership with the Ministry for the Environment and the Tindall Foundation, established the Carbon Neutral Advantage project with the key objective of providing a commitment to supporting Southern industries and communities towards establishing a competitive carbon neutral advantage and creating a sustainable environment for generations to come.

The purpose of the *Economic Mitigation Pathways Analysis to Net Zero Emissions for Southland* report (hereon referred to as the *'Net Zero Southland Report'*) is to establish a baseline for carbon abatement and a high-level economic assessment of achieving net zero greenhouse gas emissions at regional scale. Key outcomes from this report will be the identification of implementable mitigation options for the Southland region, and the economic effect of these options towards achieving net zero emissions by 2050, which is in line with the mandated government directive of achieving net zero emissions by 2050 on a national scale.

A baseline emissions profile has been established for the region showing Southland contributes 9.7% to New Zealand's gross emissions. This equates to 8.9 megatonnes of carbon dioxide equivalent (MtCO2e) of total emissions. Agriculture contributes 69% of gross emissions, and 27.5% of Southland's gross emissions are offset by exotic and native forestry.

Two emission reduction themes were developed and modelled in this analysis reflecting different focus areas: Technology and Innovation, and Land Use and Agriculture. Corresponding mitigation options were identified and modelled to show the mitigation pathway to achieving net zero emissions with an economic analysis undertaken to provide the marginal abatement costs associated with these options.

Marginal abatement cost analysis evaluates the financial costs and benefits of implementing the identified mitigation options, and compares this to the mitigation option's emissions abatement potential, where abatement is the reduction in carbon dioxide equivalent. Figure 1 illustrates this relationship. Simply, the width of each column in the graph represents the potential reduction in carbon dioxide equivalent (expressed as kilotonnes of carbon dioxide equivalent per year), with the height of the column representing the cost of implementing the mitigation option. Negative marginal abatement costs (such as mode shift and industrial boiler fuel switch) indicate an overall financial benefit for implementing the mitigation option.

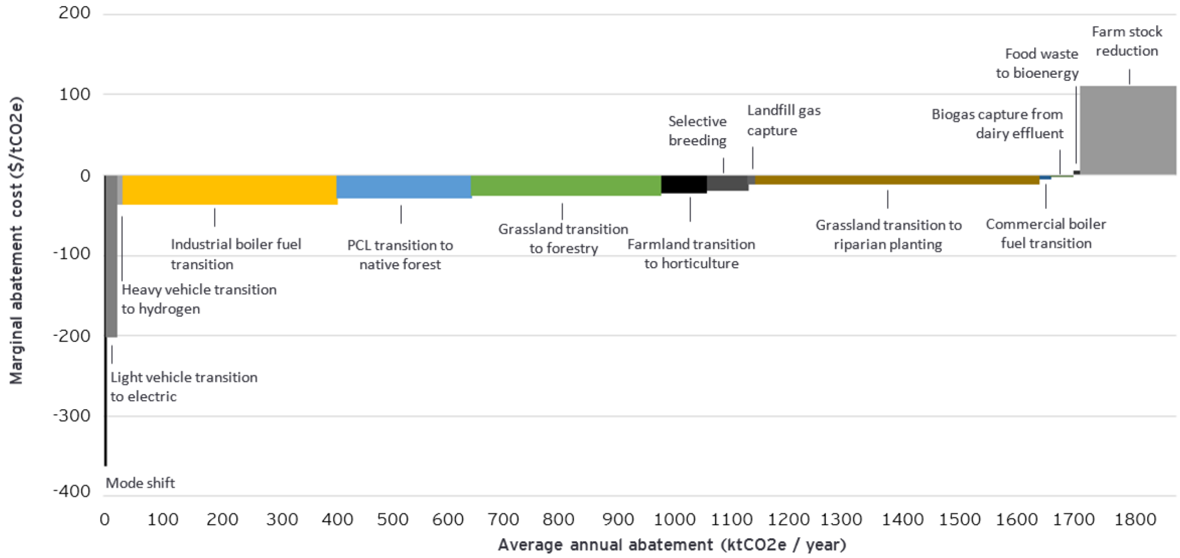

Figure 1: Marginal abatement cost curve of the modelled mitigation options.

Key findings from the **overall analysis**:

1. Southland is not on track to meet net zero emissions under the current trajectory which is in line with the Climate Change Commission's findings for New Zealand in the Climate Change Commission's 2021 Draft Advice for Consultation (Climate Change Commission, 2021) (hereon known as the '*CCC Draft Advice*').
2. An economically viable transition pathway to a net zero emissions economy exists for the Southland region using identified mitigation pathways which are complementary to the *CCC Draft Advice*.

Key findings from the **physical and economic risk analysis**:

1. Projected changes in the climate are diverse, reflecting geographic variability within the region. Changes include (but are not limited to) river and surface flooding in parts of the region, increased rainfall, rising surface temperatures, and increased hot days and greater risk of drought.
2. Economic impacts from changes in the climate are most strongly felt in the agriculture and tourism sectors. Impacts include fluctuations in crop yields and livestock productivity, pasture damage, increased expenditure to minimise flood impacts, infrastructure damage (e.g. airports) and loss of natural assets (e.g. walking and hiking trails).
3. All sectors benefit from acting early to implement emissions reduction strategies and limiting climate change impacts.

Key findings from the **emissions reduction modelling analysis**:

1. The Southland region can transition to a net zero emissions economy through a diverse portfolio of options.
2. Southland can achieve net zero emissions by 2050 from mitigation pathways with a positive net financial outcome using carbon pricing recommended by the CCC Draft Advice.
3. To give effect to emissions reductions across the region requires that action is embraced across all sectors.
4. Investment requirements are focussed on the sectors in which emissions reduction is strongest.
5. 80% of the abatement potential identified comes from mitigation options which provide a positive net financial outcome.
6. Mitigation options with positive net financial outcomes and low implementation costs include mode shift. Mitigation options with long-term economic benefits despite high implementation costs include fuel switching light vehicles to electric, fuel switching industrial boilers, conversion of livestock to crops and horticulture and biofuel capture from effluent.
7. Positive net present value mitigation pathways not only provide a financial return but contribute to reducing the physical impacts from climate change and deliver co-benefits.

Outcomes from the emissions reduction modelling analysis suggest Southland can achieve net zero emissions by 2050 with positive financial outcomes. To achieve this, a connected approach encompassing the social, environmental, and cultural values associated with achieving a net zero emissions future for Southland must be undertaken.

To give effect to the options modelled in this report it is recommended an effective implementation plan for Southland is developed.

2. Introduction

In Aotearoa, the Government has committed to reaching net zero emissions of long lived gases by 2050, and to reducing biogenic methane emissions by between 24-47% by 2050 (Climate Change Commission, 2021).

In addition to the economic benefits from reducing emissions and achieving net zero by 2050, transitioning to a low emissions economy will assist in mitigating the physical impacts of climate change. Whilst not quantitatively modelled, it is expected that physical risks from climate change would significantly affect Southland's economy, from infrastructure damage and the loss of tourism attractions, to productivity losses and increased volatility for the agriculture sector. As tourism and agriculture are Southland's largest contributors to GDP, it is critical to minimise its exposure to climate risks.

Southland is leading the way in identifying a future pathway to achieving a net zero emissions future where our environment will thrive, and our people will prosper. To that end, Great South (Southland's regional development agency) have partnered with The Tindall Foundation and the Ministry for the Environment to deliver the Carbon Neutral Advantage project – a three-year initiative bringing together regional industry leaders and community members to work together towards identifying pathways to achieving a low emissions future for Southland, and by extension New Zealand. One of the project's deliverables is the establishment of an econometric analysis for the Southland region.

Ernst & Young have been engaged by Great South to develop an econometric climate change analysis for the Southland region. This analysis comprises reviewing the current physical changes in the climate and the resulting economic risks to the region and comparing these to modelled emissions mitigation options for achieving net zero emissions (long lived and methane) for the Southland region.

Development of the mitigation options was focused on key sectors across Southland (transport, industry and land use and agriculture). The modelled net present value and marginal abatement costs have guided where the greatest opportunities to reduce emissions are, while retaining a stable Southland economy.

The *Net Zero Southland Report* is intended to provide options to aid decision making on the journey to achieving a low emissions future for Southland.

3. Motivation for Analysis

The Paris Agreement is a global agreement on climate change entered into force November 2016. The Paris Agreement commits all countries to act on climate change. New Zealand submitted a National Determined Contribution (NDC) under the Paris Agreement, committing to reducing greenhouse gas emissions by 30% below 2005 levels by 2030, which will apply from 2021.

In 2018, the United Nations Intergovernmental Panel on Climate Change (IPCC) released its special report *Global Warming of 1.5ºC*. In this report, the IPCC alerted that limiting global warming to 1.5ºC to avoid the worst effects of climate change implies reaching net zero emissions by 2050.

In 2019, the New Zealand government released the Climate Change Response (Zero Carbon) Amendment Act 2019 which provides a framework by which New Zealand can develop and implement clear and stable climate change policies to achieve New Zealand's commitment under the Paris Agreement, and to allow New Zealand to prepare for, and adapt to, the effects of climate change.

In December 2020, New Zealand declared a state of climate emergency and announced the Carbon Neutral Government Programme requiring all government organisations to be carbon neutral by 2025.

The Carbon Neutral Advantage project, led by Great South, was established in 2018 with specific project deliverables linked to the partnership funding with Ministry for the Environment and The Tindall Foundation. One of these deliverables is the development of an econometric climate change analysis for the Southland region.

This analysis builds on findings from:

- The *Southland Climate Change Report* (NIWA, 2018) prepared by the National Institute of Water and Atmosphere (NIWA) for Environment Southland, Invercargill City Council, Southland District Council and Gore District Council.

- The Southland Regional Greenhouse Gas Emissions Inventory (AECOM, 2018) developed by AECOM for Great South.

- *Wood Energy South* (www.woodenergysouth.co.nz) – a project which Venture Southland[1] in conjunction with EECA coordinated as an authoritative source of current information and best practice aimed at promoting the use, and development of supply chains for clean wood energy in Southland.

- The Southland *Dairy Biogas Project* (Dairy Green Ltd, n.d.) – a methane recovery project facilitated by Dairy Green Ltd on a 950 cow farm in Southland.

- The *Strategy for Sustainable Business in Southland* (Venture Southland, Sinclair Knight Merz Ltd, 2008).

[1] Venture Southland became Great South in March 2019.

4. Approach and Engagement in Development of this Report

Great South have facilitated a collaborative approach and engaging process in the development of the *Net Zero Southland Report*.

Ernst & Young has a demonstrated history of providing expert climate change and economic modelling services to clients. To that end, Ernst & Young were engaged by Great South to identify, develop, model, and analyse economically viable mitigation scenarios to assist Southland with striving towards a net zero emissions future.

Specifically, Ernst & Young were engaged to conduct a review of the physical risks and potential economic impacts that climate change poses for Southland (Section 8), and to model for emissions reduction under a business as usual setting (Section 9.1), and under a mitigation scenario setting (Section 9.2).

A panel of youth (aged 18-25 years' old) representing the diverse economy, community and institutions in Southland was established with the purpose of engaging young minds to brainstorm their idea of what a net zero emissions future looks like for Southland, and the associated co-benefits. These outputs were used by Ernst & Young in their emissions reduction modelling.

Great South Strategic Projects workshopped mitigation options for Southland, with a focus towards identifying probable mitigation pathways, where the implementation probability scale correlates with being able to deliver on some of these options within the next ten years. Like the *CCC Draft Advice* released 31 January 2021, these mitigation options are focused on key sectors across the Southland region, identifying where the greatest opportunities to reduce emissions are.

The Carbon Neutral Advantage Project Steering and Advisory Groups were engaged to provide governance, technical expertise, and leadership in the development of this foundational report.

5. Development of the Mitigation Options and Themes

Ernst & Young and Great South collaboratively developed mitigation options that were used in the emissions reduction modelling. These options were largely determined from the emissions baseline and business as usual projection. Ernst & Young also engaged with the youth panel in a workshop setting to brainstorm and formulate mitigation options. The outputs from this workshop enabled Ernst & Young to identify a scaffold from which to present these options and the creation of two themes emerged: Technology and Innovation, and Land Use and Agriculture.

In a second iteration undertaken during the development of this report, Great South further refined these mitigation options to reflect a probability scale, whereby the probability of implementing the mitigation option within the next 1-10 years was determined. Great South also linked these probable mitigation options to the highest emitting sectors for the Southland region: land use and agriculture, industry, and transport. The results of this are detailed in Table 1.

Table 1: Mitigation options developed for the emissions reduction modelling.

Theme	Sector	Mitigation Option	Description
Technology and Innovation	Industry	Residential space heating improvements	Floor and ceiling insulation, and double-glazed windows in 80% of existing residential homes by 2050.
		Landfill methane gas capture	Capture of methane gas produced in landfills for combustion use primarily, and to supply electrical as secondary.
		Commercial boiler fuel transition	Converting all boilers from fossil fuels to biomass, pellets and electricity at planned replacement year or asset end of life.
		Industrial boiler fuel transition	Converting all boilers from fossil fuels to biomass and pellets at planned replacement year or asset end of life.
		Biogas capture from food waste	Capture of methane gas generated from food waste, and generation of biogas in an anaerobic digestion facility to substitute electricity consumption.
	Transport	Mode shift	Commuters living less than 5km from work shifting mode of transport from car to cycling, walking, public transport or shared transport.
		Heavy vehicle transition to hydrogen	Transition heavy vehicles from fossil fuels to hydrogen, achieving a 60% share by 2050.
		Light vehicle transition to electric	Increasing the electric vehicle uptake rate for light vehicles to achieve a 92% electric vehicle share for this class by 2050.
	Land Use and Agriculture	Biogas capture from dairy effluent	Capture of methane from dairy cattle effluent at 430 Southland dairy farms with the energy generated to be used on-farm.
		Public Conservation Land (PCL) transition to native forest	Converting 1,500ha high producing grassland, 18,500ha low producing and 4,500ha with woody biomass from Public Conservation Land ("PCL") to natural forest by 2050.
		Selective breeding	Selective breeding of dairy cattle, beef cattle and sheep that exhibit low residual

			methane production. 30% adoption for cattle and 80% adoption for sheep.
Land Use and Agriculture		Grassland[2] transition to riparian planting	56,500 ha high producing land, 6,500 ha low producing land and 2,000 ha grassland with woody biomass converted to 50% natural forest and 50% grassland with woody biomass. This was modelled as a piecewise uptake, with 50% of conversion occurring between 2045-2050.
		Grassland transition to forestry	A net conversion of 7% from low producing farmland to forestry (half exotic and half native forest).
		Farmland[3] transition to horticulture	A net conversion of 4.1% from farmland used for livestock raising, to crops and horticulture between 2020 and 2050.
		Farm stock reduction	A 10% stock reduction in dairy cattle, beef cattle and sheep applied linearly from 2035 to 2050.

[2] 'Grassland' is categorised by high producing, low producing and woody biomass as defined by the *Land Use and Carbon Analysis System – Satellite imagery interpretation guide for land-use classes* report prepared by Ministry for the Environment.
[3] 'Farmland' is defined as being used for livestock raising (Parliamentary Commissioner for the Environment, 2019).

6. Alignment with the CCC's Draft Advice

It is important to note that the assumptions underpinning the mitigation options are in alignment with the *CCC Draft Advice* released in January 2021. Like the *CCC Draft Advice*, this report notes that current policies do not put New Zealand on track to meet the emissions budget under the Zero Carbon Act. This conclusion is reflected in our business-as-usual modelling.

Ernst & Young's emissions reduction modelling adopted the Transition Pathway One (TP1) carbon price, the most conservative price projection. This projection influenced the land use change observed under business-as-usual. The Climate Change Commission also separated carbon pricing into biogenic methane (ETS2) and all other gases (ETS1), with the biogenic methane price curve differing from all other gases by reducing in price from 2035 on, while the ETS1 continues to climb, resulting in the ETS1 price being six times higher than biogenic methane in 2050. Ernst & Young's emissions reduction modelling adopted a similar approach, applying the ETS2 carbon price to options with biogenic methane and the ETS1 carbon price to all other options.

Under the modelled business-as-usual, agricultural forecasts align with the *CCC Draft Advice* with a 15% reduction in livestock numbers modelled by 2035.

Like the *CCC Draft Advice*, this analysis includes a similar rate of uptake for light vehicle transition to electric vehicle by 2050.

In this analysis a transition to hydrogen fuel for heavy transport was modelled. The reason for this was that Southland acknowledges the real opportunity for this as a mitigation option in the region. This differs from the modelled heavy transport option in the *CCC Draft Advice*.

The conclusions from this report align with key findings from the *CCC Draft Advice*, which lays out the course for reducing emissions in New Zealand. However, the modelling scope and approach differs, so results may not be directly comparable.

7. Regional Physical Risks Analysis

Flooding and heatwaves are the two most prevalent physical risks Southland is predicted to experience. Fiordland is forecast to be most significantly impacted by the increase in rainfall, and the upper centre of Southland to be most affected by drought and an increase in hot days[4]. NIWA, 2018 predicts Southland's climate out to 2100 using climate markers such as temperature, precipitation, and rain frequency. This analysis used four Representation Concentration Pathway (RCP) scenarios, which indicate the increase in radiative force compared to pre-industrial values. All scenarios are possible, depending on how little action is taken to mitigate GHG emissions. The most significant impacts under the RCP8.5 scenario are considered in the analysis below, aligning to 3-4°C of warming by 2100, significantly over the goals set under the Paris Agreement and the Zero Carbon Act.

Figure 2 provides a high-level overview of Southland's Climate Change Risks in a simple infographic. With sea level rise affecting the southern coast; increased rainfall in Fiordland and the headwaters of all Southland's major rivers (Waiau, Aparima, Ōreti and Matāura); and increased hot days and drought risk across both the northern, and southern Southland plains.

Figure 2: Infographic demonstrating Southland's Climate Change Risks (source: Great South).

The differing sub-regional climate risks and key economic industries require localised adaptation strategies to maximise regional resilience. High level sub-regional summaries are presented in

[4] (NIWA, 2018)

Appendix B and focus on the physical changes in the climate that will have the biggest local economic impact.

8. Quantitative Transition Modelling Results

Future GHG emissions projections are uncertain, encompassing unknowns in population and economic growth, technological developments, political, social and climate change. Acknowledging this level of uncertainty and using available data (refer to Appendix A for further detail), Ernst & Young developed credible mitigation pathways for achieving net zero emissions to assist Great South with evaluating and prioritising emissions mitigation options.

Carbon Dioxide Equivalent

Results from the emissions reduction modelling are expressed in carbon dioxide equivalent (CO_2e) using the 100-year Global Warming Potential values.

The Global Warming Potential (GWP) is a concept used in calculating the "carbon dioxide equivalent" (CO_2e) of a mix of greenhouse gases, i.e. carbon dioxide, methane, nitrous oxide. The GWP is used to represent the effect of a particular gas's effect on global warming: how strongly it absorbs infrared radiation and how long it stays in the atmosphere. The GWP describes the number of grams of carbon dioxide that would provide the same "warming" effect over a certain period of time as one gram of the gas of interest.

Table 2 shows the GWPs for the different greenhouse gases for a 100-year time horizon.

Table 2: 100 year Global Warming Potentials (IPCC, Fifth Assessment Report)

Carbon dioxide (CO_2)	Methane (CH_4)	Nitrous oxide (N_2O)
1	28	265

For example, methane has a 100 year global warming potential of 28, which suggests that for a given weight of methane released into the atmosphere now, would have 28 times as much effect on global warming over the next 100 years as would the same amount of carbon dioxide.

8.1 Business as Usual

Modelling a future where no additional mitigation options are implemented, "business as usual", is an important part of emissions reduction analysis as it provides a baseline against which to assess the impact of mitigation options. The business as usual scenario assumes that there will be no significant changes in technology, economics, or policies but current available mitigation options continue to be deployed. The business as usual scenario models what would happen if we did nothing beyond the status-quo. The key trends underpinning the Southland region's business as usual scenario are detailed in Table 3. The modelled assumptions used to support these trends are provided in Appendix A.

Table 3: Key trends under the business as usual scenario by sector.

Sector	Key trends
Agriculture	Declining livestock numbers; falling nitrogen fertiliser application.
LULUCF (Land Use, Land Use Change, & Forestry)	Converting low producing land to forestry (at a net conversion of 14% from 2020 to 2050).
Transport	Electric and hydrogen fuel cell vehicle uptake in the light and heavy vehicle classes and in off-road vehicles.
Residential	Relatively constant emissions, tied to population forecasts.

Commercial	Rising emissions, tied to economic growth forecasts.
Industrial	Gradually falling emissions, tied to economic growth forecasts but offset by expected efficiency improvements; the New Zealand Aluminium Smelter closure significantly reduces emissions from this sector.
Industrial Processes and Product Use (IPPU)	Trends follow national emissions projections which sees IPPU emissions rise in the near term and then gradually fall from around 2025; the New Zealand Aluminium Smelter closure significantly reduces emissions from this sector.
Waste	Rising emissions due to constant waste to landfill and rising degradable organic carbon stock.

The sectoral emissions profile of the business as usual scenario is depicted in Figure 3. By 2050, the Southland region's net emissions fall from 4.7 $MtCO_2e$ in 2018 to 1.3 $MtCO_2e$ in 2050, a reduction of 73%. Southland's gross emissions reduce by 33% from 2018 to 2050 and Southland's land use, land-use change, and forestry ("LULUCF") sector is able to sequester nearly 4 $MtCO_2e$ (76% of Southland's gross emissions) by 2050.

The highest emitting sectors in the Southland region are agriculture, industry, and transport (AECOM, 2018).

The industrial processes and product use ("IPPU") sector baseline data is drawn from many sources. Given limited data to accurately assess the baseline emissions from the IPPU sector, this sector has been excluded from the following mitigation analysis. The IPPU sector covers greenhouse gas emissions occurring from industrial processes, from the use of greenhouse gases in products, and from non-energy uses of fossil fuel carbon.

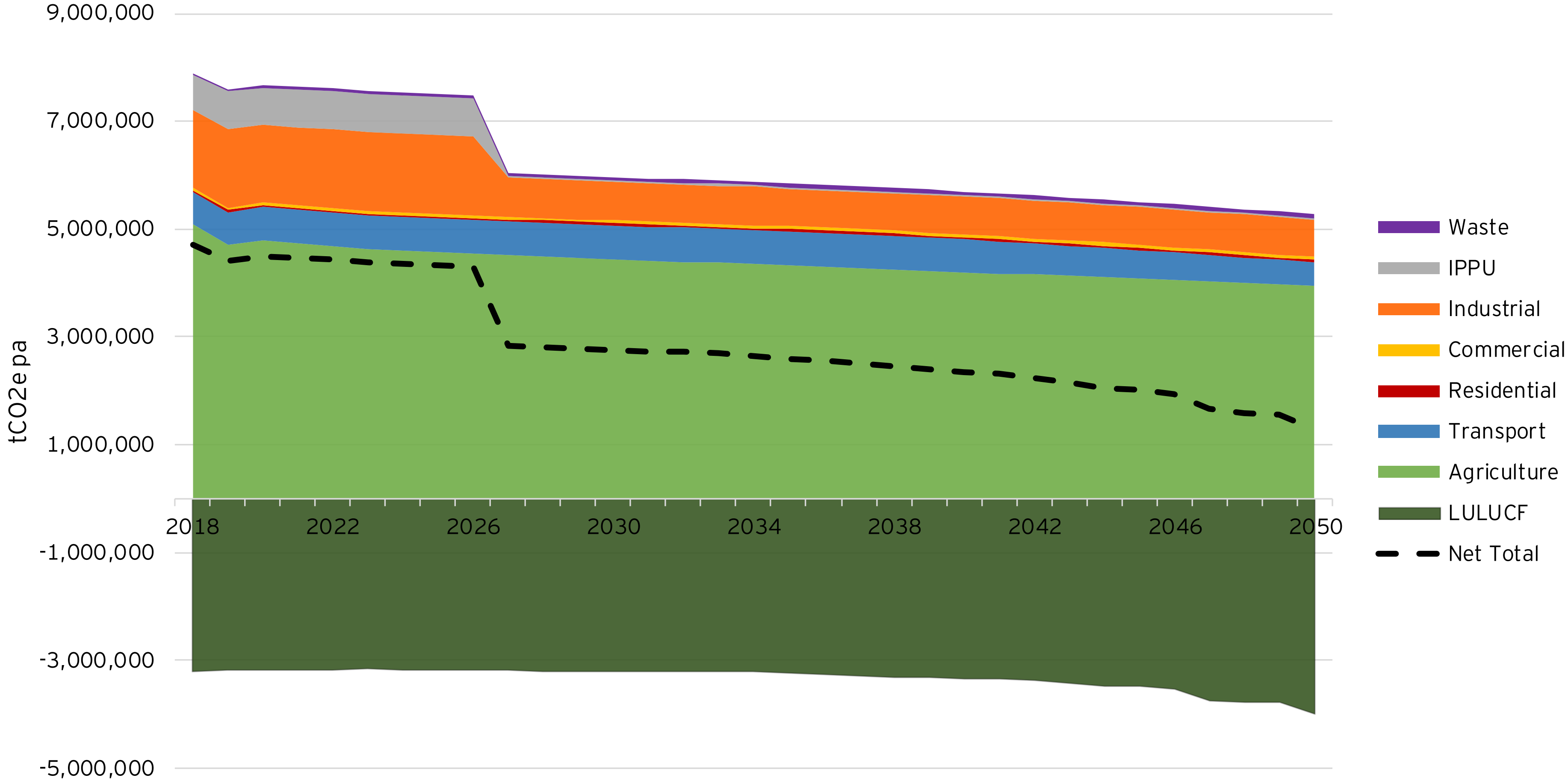

Figure 3: Business as usual modelled scenario.

8.2 Mitigation Pathways Analysis

Two emissions reduction themes were modelled: a Technology and Innovation theme and a Land Use and Agriculture theme. Both themes achieve net zero emissions by 2050, however, the sectoral and economic impacts are distinct. It should be noted that whilst mitigation options have been grouped in this way for the purposes of this analysis, nothing precludes Southland from pursuing its own portfolio of options.

"Key outcomes" (Table 4 and Table 6) are expressed as:

- Net Present Value (NPV) – is the value of all future cashflows (benefits less costs) discounted to a present value. Assumptions underpinning these costs are provided in Appendix A.
- Total Abatement – is the total reduction in carbon dioxide equivalent emissions to be realised by 2050.
- Average Annual Abatement – is the reduction in carbon dioxide equivalent emissions averaged for each year out to 2050.
- Average cost per tCO_2e abated – is the Net Present Value divided by the Total Abatement to give the average net present value (expressed in dollars) per tonne of carbon dioxide equivalent that is abated.

8.2.1 Technology and Innovation Theme

This theme relies on a diverse technology mix of options across sectors combined achieving net zero. It reflects a collaborative approach to emissions reduction, as each sector implements mitigation options.

This theme includes mitigation options from the land use and agriculture sectors; specifically, selective breeding, biofuel capture from dairy effluent and Public Conservation Land transformation. These mitigation options are included in this theme, as they reflect technological improvements and innovation within the agricultural sector, rather than requiring land-use changes.

The path to net zero emissions under this theme is gradual and the overarching economic outcome is positive. Only targeting the positive net present value options will be even more favourable.

The key outcomes from this theme are in Table 4 and the mitigation path of all mitigation options are presented in Figure 4.

Table 4: Key outcomes for the technology and innovation theme.

	Net present value	Average annual abatement	Total abatement	Average cost per tCO_2e abated[5]	Net zero emissions achieved by
All options	\$ 788 million	788 $ktCO_2e$ / yr	23.1 $MtCO_2e$	-\$34 / tCO_2e	2050
Only positive NPV options	\$ 817 million	777 $ktCO_2e$ / yr	22.8 $MtCO_2e$	-\$36 / tCO_2e	2050

[5] A negative result represents a financial benefit per tonne of abatement, as opposed to a cost

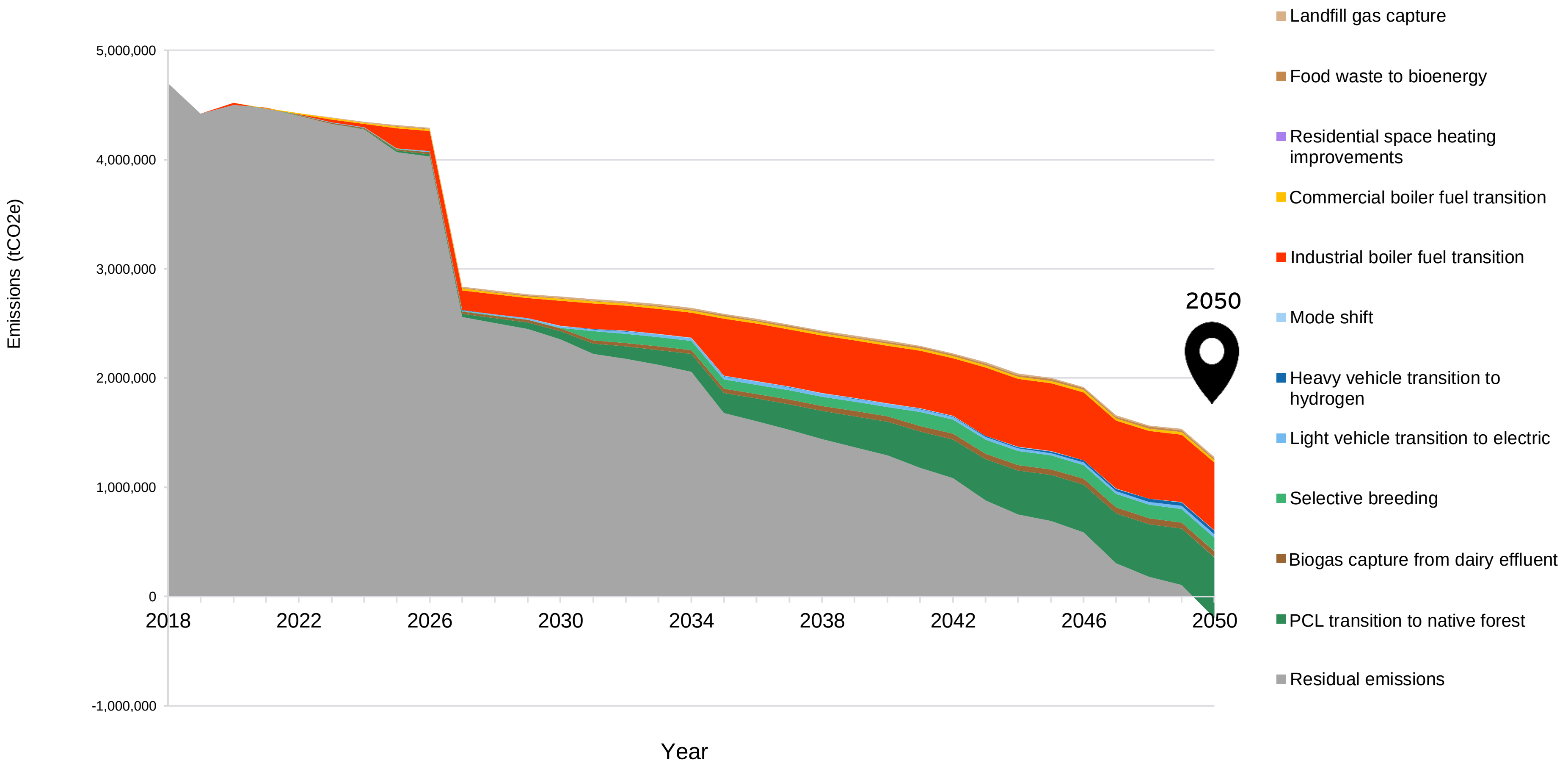

Figure 4: Modelled mitigation pathways of the technology and innovation theme (all options).

A description of each mitigation option underpinning this theme and their high level assumptions are listed in Table 5. Appendix A provides the detailed assumptions used in the emissions reduction modelling.

Table 5: Mitigation options under the technology and innovation theme.

Option	High level assumption
Landfill methane gas capture	Capture of methane gas produced in landfills for combustion use primarily, and to supply electrical as secondary.
Biogas capture from food waste	Diverting 10,000 tonnes of food waste per annum from landfill to use as generation of biogas in an anaerobic digestion facility to substitute process heat and electricity consumption.
Residential space heating improvements	Floor and ceiling insulation, and double-glazed windows in 80% of existing residential homes by 2050.
Commercial boiler fuel transition	Converting all boilers from fossil fuels to biomass, pellets or electricity at planned replacement year or asset end of life.
Industrial boiler fuel transition	Converting all boilers from fossil fuels to biomass, pellets or electricity at planned replacement year or asset end of life.
Mode shift	30% of commuters living less than 5km from work shifting mode of transport from car to cycling, walking, public transport or shared transport.
Heavy vehicle transition to hydrogen	Transition heavy vehicles from fossil fuels to green hydrogen, achieving a 60% share by 2050.
Light vehicle transition to electric	Increasing the electric vehicle uptake rate for light vehicles to achieve a 92% electric vehicle share for this class by 2050.
Selective breeding	Selective breeding of dairy cattle, beef cattle and sheep that exhibit low residual methane production. 80% adoption assumed for sheep and 30% for dairy and beef cattle.
Biogas capture from dairy effluent	Capture of methane from dairy cattle effluent at 430 Southland dairy farms with the energy generated to be used on-farm.
Public Conservation Land (PCL) transition to native forest	Converting a net 1,500ha high producing grassland, 18,500ha low producing and 4,500ha with woody biomass from Public Conservation Land to natural forest by 2050.

8.2.1.1 Challenges, Opportunities and Co-Benefits

Challenges

The main barrier for implementing innovative and technology-based options is the large upfront costs. This is a common barrier to implementing emissions reduction activities, such as switching to passenger electric vehicles. A review of barriers to electric vehicle uptake by the New Zealand Government highlighted that the upfront purchase price is the most significant and requires marketing or financial product innovation to overcome short-sightedness and human nature to preference smaller-sooner over larger-later rewards[6]. Capital and behavioural constraints will need to be overcome, as it is important to allocate capital today to avoid cost blowouts in the future. Interventions to overcome these barriers will lead to better long-term financial and environmental outcomes, potentially avoiding future write-offs and stranded assets.

[6] (Hearnshaw & Girvan, 2018)

Several options within this theme entail significant fuel switching. For this theme to be feasible, a long-term secure supply of biomass is needed. Venture Southland in conjunction with Energy Efficiency & Conservation Authority (EECA) conducted the Wood Energy South project[7] which found that Southland's corporate forest estate is significant, stable, and provides a reliable woodflow supply. Furthermore, woodflows are planned to increase significantly in the future. This steady increase in harvest volume provides a secure supply for biomass users, which should be sustained into the future.

A consideration for selective breeding is the relationship between animals which exhibit low residual methane production and other favourable characteristics. It is expected that these won't be correlated, at least not as a general rule. It's therefore critical to determine whether there are sufficient incentives in place for farmers to choose to breed on the basis of low residual methane production as opposed to other characteristics, such as high milk production.

Current legislative challenges that reside within the "PCL transition to native forestry" mitigation option, includes the prevention of planting on Crown owned land administered by the Department of Conservation and/or local and regional councils.

Opportunities

There is an immediate opportunity to transition existing coal boilers to wood pellets or dried wood chip now rather than wait to end-of-asset-life. Conversion to wood pellets or dried wood chip would require changes to the fuel handling, storage infrastructure, and controls, and consideration would need to be given to the condition of the existing boilers, when they were commissioned, and their maintenance regime. Notwithstanding the immediate effect to carbon abatement that would be achieved with transitioning away from coal, the reduction in particulate emissions to atmosphere will improve air quality and thereby social and human health improvements.

Biogas capture and utilisation represents a significant opportunity for Southland. Methane capture from organic matter at landfills, wastewater treatment facilities and agricultural production can be captured and used primarily as process heat, but also to supply as electricity to the local grid.

The "biogas capture from food waste" mitigation option offers additional benefits to that of diverting food waste from landfill to a dedicated aerobic digestion facility. There is potential to establish biogas capture facilities on existing processing sites where generated food grade waste can be diverted from wastewater treatment plants to the onsite biogas facility where the product gas can be directly utilised.

With 58% of Southland's land either a national park or covered by the Conservation Estate of the Department of Conservation, there are significant opportunities for the public sector to either create initiatives or partnerships with private organisations and community groups to increase tree planting on these estates. Specifically planting to "right tree, right place" within riparian strips, ex-lease Public Conservation Land, and low marginal lands, with the co-benefits of any income generated from the regional carbon sink able to be invested back into the local community, plus displacing the potential for pest weeds to establish.

[7] (Wood energy south, n.d.)

Co-Benefits

Alongside the modelled emissions reductions benefits, and corresponding financial benefits, a number of the mitigation options contribute additional benefits to society and the natural world.

- Most will be linked with air quality improvements, as reducing emissions for climate change reasons will directly impact this factor as well.
- Commuter mode shift will likely increase social connectivity, reduce congestion, free up people's time, and lead to mental and physical health improvements.
- Electrification of the light vehicle fleet will provide added storage capacity and modularity in the power network, providing real resilience benefits to energy and electricity supply.
- Capturing gas from dairy, industrial and metropolitan effluent, and food waste streams will allow for the potential of either electricity generation or production of biofuel. Situating these aerobic digestion plants alongside existing industry can provide significant process efficiencies, energy sharing and waste reduction through circular use of products.
- Native tree planting will provide additional biodiversity benefits.
- Focussing on innovation and emerging low-emissions technologies will provide potential job creation and the possibility of new export markets.

8.2.2 Land Use and Agriculture Theme

This theme focuses primarily on transforming Southland's agricultural sector, which accounts for 69% of the region's emissions. The mitigation pathways not only reflect the greatest opportunity for emissions reduction, but also takes into consideration the wellbeing of the land, with the co-benefits of improved air and water quality.

The mitigation potential of the modelled pathways starts slowly before accelerating to net zero due to increasing and maturing forest estate. The combined financial metrics for this theme are less favourable compared to the Technology and Innovation theme, with a lower NPV of $220 million. However, this theme is expected to reach net zero earlier at 2045, before going beyond net zero.

Table 6: Key outcomes for the land use and agriculture transformation theme.

	Net present value	Average annual abatement	Total abatement	Average cost per tCO_2e abated	Net zero emissions achieved by
All options	$ 220 million	1,074 $ktCO_2e$ / yr	30.7 $MtCO_2e$	-$7 / tCO_2e	2045
Only positive NPV options	$ 514 million	907 $ktCO_2e$ / yr	28.0 $MtCO_2e$	-$18 / tCO_2e	2046

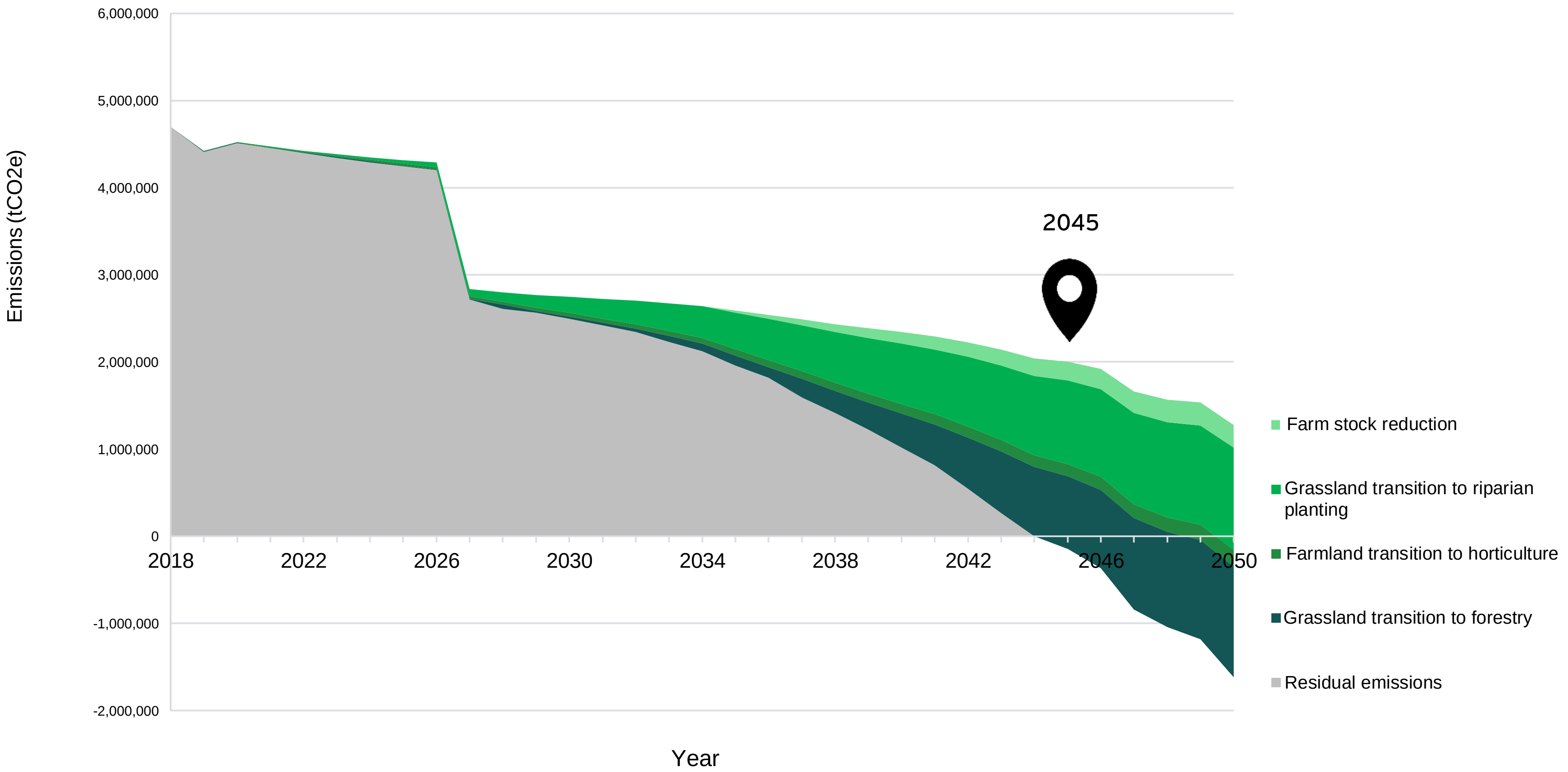

Figure 5: Modelled mitigation pathways of the land use and agriculture theme (all options).

A description of each mitigation option underpinning this theme and their high-level assumptions are listed in Table 7. Appendix A provides the detailed assumptions used in the emissions reduction modelling.

Table 7: Mitigation options under the land use and agriculture theme.

Option	High level assumption
Grassland transition to forestry	A net conversion of 7% from low producing farmland to forestry between 2020 and 2050 (using the Motu model[8] for land change under the high carbon price scenario).
Farm stock reduction	A 10% stock reduction in dairy cattle, beef cattle and sheep applied linearly from 2035 to 2050. This acts to increase land used by each animal.
Farmland transition to horticulture	A net conversion of 4.1% from farmland used for livestock raising to crops and horticulture between 2020 and 2050 (using the Motu model).
Grassland transition to riparian planting	56,500 ha of high producing land, 6,500 ha low producing land and 2,000 ha grassland with woody biomass converted to 50% natural forest and 50% grassland with woody biomass. This was modelled as a piecewise uptake, with 50% of conversion occurring between 2045-2050.

8.2.2.1 Challenges, Opportunities and Co-Benefits

Challenges

Under the "Grassland transition to forestry" mitigation option, low producing farmland is converted equally into pine forest (harvested at 25 years) and native forest (not harvested thus acting as a carbon bank) and includes the cost of land conversion, planting, pruning and insurance. The inclusion of agriculture and forestry in the New Zealand Emissions Trading Scheme (NZ ETS) is a large driver behind this option's financial benefit. However, it is not a silver bullet. The Forestry Reference Group highlighted in their recent report that the potential of the NZ ETS to encourage afforestation is confounded by the reluctance of farmers to change land use, uncertainty around carbon prices, high land prices, and controls on forest establishment and harvesting. Unless these factors are addressed in ways that fairly spread the sectoral costs, it is unlikely; anything like the area of trees suggested in zero-carbon models will be planted[9].

Whilst farm stock reduction has little economic appeal, there is a growing appetite for sustainably raised meats. One benefit of reducing farm intensity, in conjunction with other regenerative measures, may be access to the market for low carbon and sustainable agricultural products. These

[8] Motu (a research institute) modelled the interaction between carbon price and land use change for a report commissioned by the parliamentary commissioner for the environment. This model incorporates the Land Use in Rural New Zealand (LURNZ) model to simulate how major land use sectors (forestry, horticulture, dairy, sheep and beef farming) change in response to changes in the carbon price. This is driven by two sub-models that are econometrically estimated. The first incorporates national level drivers of change (including commodity prices), while the second is a spatial model determining the spatial location of land use relating to geophysical characteristics of the land (e.g. slope, land use capability) to find proxies for cost of market access and feasibility of conversion. With the spatial projection, the LURNZ model determines land production, associated emissions and in turn profitability of each parcel of land. Changing the carbon price effects the optimal distribution of land. Southland's land transformation theme used the land change associated with a higher carbon price, capturing the hectares of land that are spatially able to be converted.

[9] (Forestry Reference Group, 2018)

products generally earn a price premium to their unsustainable counterparts. This premium has not been modelled as part of this analysis.

Feasibility studies at the farm-level are needed to realise these opportunities. Considering livestock to crops and horticulture, these studies will ensure that; crops are selected that suit the land's soil and climate, costs are known, retail ties are created, and skilled labour is available to assist with the conversion. Careful consideration of additional inputs required in the conversion to horticultural, such as fertiliser and water, is required to ensure the conversion will reduce emissions and not jeopardise other natural resources. Local governments or Government-owned entities, such as Pāmu, may choose to adopt a leadership position and convert low producing council land into forest estate or trial new farming low-emissions practices.

Opportunities

A key consideration for "Farmland transition to horticulture" mitigation option is the suitability of different plants to Southland's climate and terrain. Crops that have been considered as being commercially viable in Southland include oats, hemp, blueberries and amaranth grain[10]. It should be noted that average earnings before interest and taxes per ha data was used to derive the financials. As the analysis was high-level and not at the implementation level, we did not look at the feasibility of individual crops and the potential opportunity that exists for each crop. New Zealand's social awareness of climate change is increasing with 1 in 3 New Zealanders consciously limiting their meat consumption[11]. The conversion of farmland to the production of vegetarian protein alternatives may allow farmers to position themselves in line with this emerging trend. Furthermore, reduced supply of meat proteins production may assist in stabilising the profitability of meat farms that choose to continue operating.

Co-Benefits

The mitigation options identified in the land use and agriculture theme all share some significant key co-benefits. Water quality, air purification, habitat creation and connectivity, and biodiversity values are all set to increase. Many of the pathways that include planting trees will contribute to local climate and microclimate moderation and modification by storing more water in the system and thereby mitigating against more extreme weather events. Vegetation around riparian zones has the added benefit of slowing water flows and improving infiltration which helps to prevent and mitigate against flood events and associated impacts.

Most mitigation options will increase and improve soil quality and soil carbon – notably the land use change to horticulture will improve the quality of pastoral land. Moreover, forestry products provide a source of renewable biofuel, an opportunity to achieve long-term sequestration and provide carbon storage through wood products and construction.

[10] (Great South, 2019)
[11] (Brunton, 2019)

8.3 Economic Assessment

Results of the emissions reduction modelling clearly show Southland can reach net zero emissions by 2050. This can be achieved with a positive net present value across both themes, when a carbon price is included in the modelling. An in-depth discussion of the economic findings associated with the modelled transition pathways is provided here.

This discussion includes the net present value pathways and a marginal abatement cost analysis of all options. The net present value pathways reflect the cost-benefit relationship for the mitigation options modelled over time. The marginal abatement cost analysis provides a convenient metric with which to analyse the most cost effective and influential emissions abatement options. This will be particularly valuable when identifying the portfolio of emissions reduction projects the region will adopt and implement.

Table 8 provides an overarching breakdown of the economic outcomes, and emissions abatement for all the mitigation options identified in this analysis.

Table 8: Modelling results for all mitigation options

Option	Average annual abatement (tCO_2e pa)	NPV ($m)	Marginal Abatement Cost[12] ($ / tCO_2e)
Land Use and Agriculture			
Farmland transition to horticulture	78,590	-22	57
Farm stock reduction	166,740	110	-294
Biogas capture from dairy effluent	39,220	-3	3
Selective breeding	70,740	-19	41
Grassland transition to forestry	332,050	-26	277
Grassland transition to riparian planting	496,720	-12	181
Public Conservation Land transition to native forest	234,870	-29	188
Transport			
Light vehicle transition to electric	18,220	-203	118
Heavy vehicle transition to hydrogen	7,720	-38	8
Mode shift	2,730	-363	31
Industry			
Industrial boiler fuel transition	376,450	-37	423
Commercial boiler fuel transition	18,050	-6	3
Residential space heating improvements	150	6482	-28
Landfill methane gas capture	12,580	-12	4
Biogas capture from food waste	10,640	6	-2

8.3.1 Net Present Value

Net Present Value (NPV) – is the value of all future cashflows (benefits less costs) discounted to a present value. Our NPV analysis includes the financial impacts of a future carbon price using the Climate Change Commission's recommendations (refer to Appendix A for the carbon price assumptions underpinning this analysis). Of the two themes modelled, the Technology and Innovation theme returns a higher positive economic outcome for the region, as it is estimated to have a higher positive NPV. This theme reaches a breakeven point in 2033 and has a net present value of $788

[12] A negative MAC result represents a financial benefit per tonne of abatement, as opposed to a cost

million. The benefit-cost ratio (BCR) of this theme is 1.44, where the BCR is the ratio of discounted benefits relative to discounted costs.

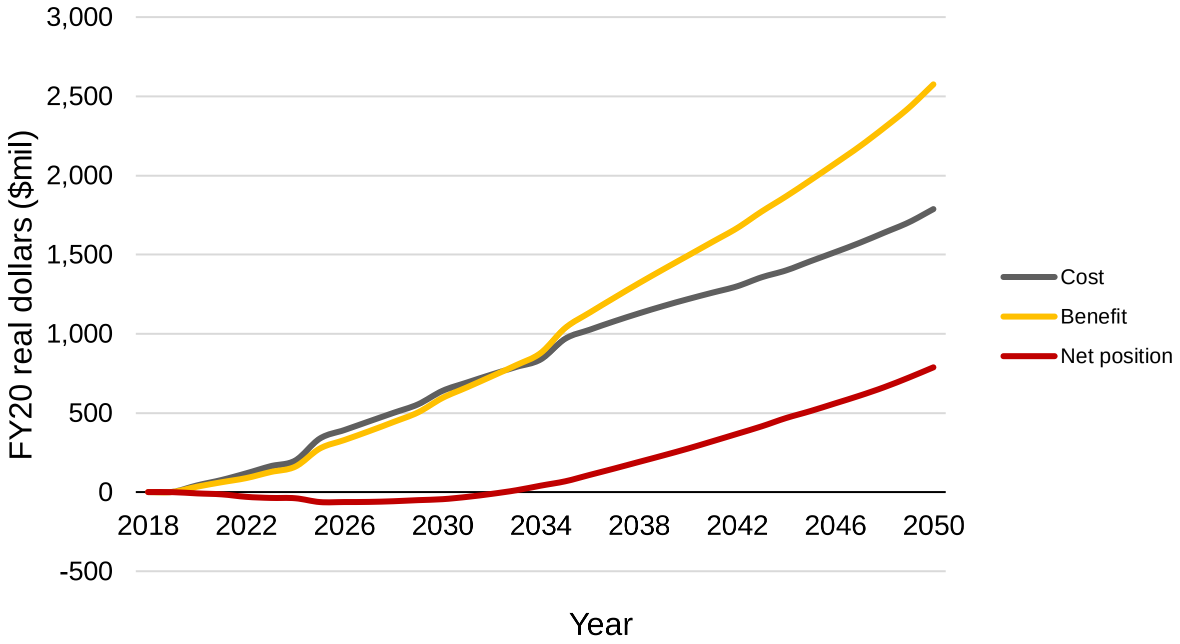

Figure 6: Cumulative cost benefit of the technology and innovation theme.

The mitigation options driving this positive financial outcome are industrial boiler fuel transition, light vehicle fuel transition and selective breeding, as well as mode shift to a lesser but still significant degree. Selective breeding and mode shift have minimal costs associated with them and derive significant benefits from avoided carbon price payments. Both industrial boiler and light vehicle fuel transition benefit from efficiency improvements and lower energy prices in addition to avoided carbon price payments.

The land use and agriculture theme provide a smaller NPV in the modelled period to 2050 at $220 million and a benefit-cost ratio of 1.05. This option's financial feasibility is largely driven by the carbon price, making land converted to forestry more profitable due to the large sequestration potential.

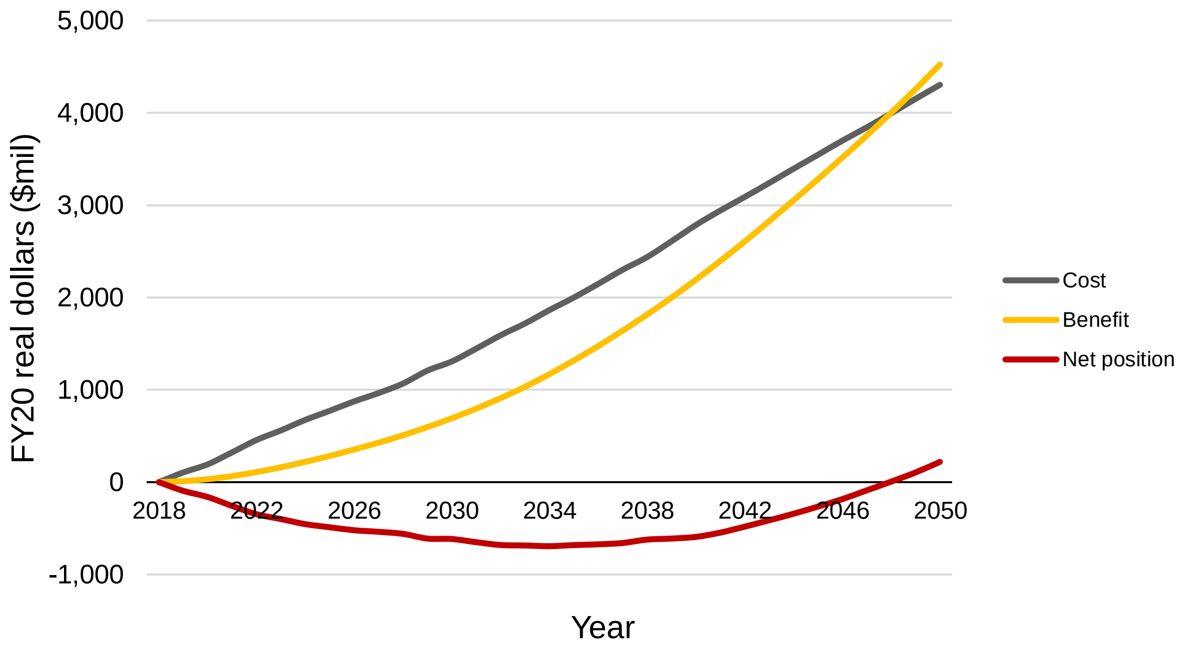

Figure 7: Cumulative cost benefit of the land use and agriculture theme.

Although the NPV of this theme is positive, it contains one NPV negative option, farm stock reduction, reflecting that the biogenic methane carbon price does not offset the profitability loss from reducing livestock numbers, if there is no offsetting increase in productivity from the smaller herd.

Overall, this theme breaks even by 2043. The main driver for the financial benefit is the carbon price, indicating the power of instituting a carbon price in driving a change in market profitability.

Figure 8 shows the cumulative cost benefit of the portfolio of all positive NPV options.

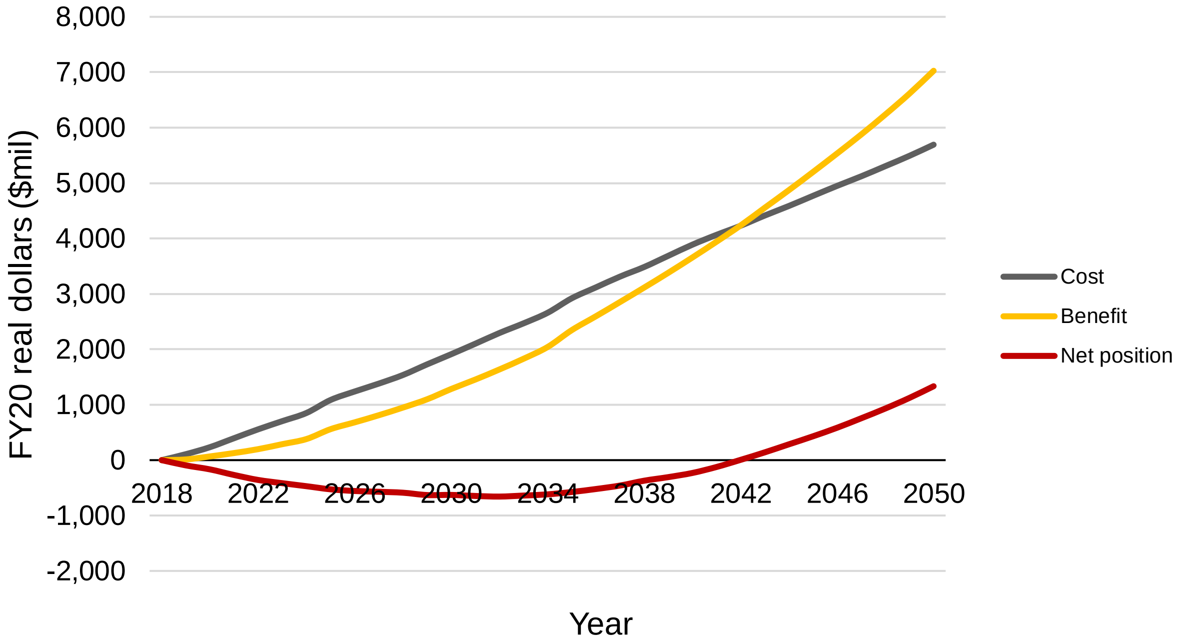

Figure 8: Cumulative cost benefit of the portfolio of all positive NPV options.

8.3.2 Marginal Abatement Cost Analysis

Marginal abatement cost ("MAC") analysis evaluates the financial costs and benefits of implementing mitigation options and compares this to their emissions abatement potential. A marginal abatement cost curve is used to visually summarise the estimated quantity of emissions reductions and the net cost of achieving those emissions reductions for a portfolio of mitigation options. It can be used to inform the prioritisation of mitigation options.

This analysis includes a price on carbon which in part acts to monetise the benefit to the environment of reducing emissions.

The results of the marginal abatement cost analysis are presented on Figure 9[13].

[13] Residential space heating improvements is excluded as it is high cost and low abatement and would skew the chart

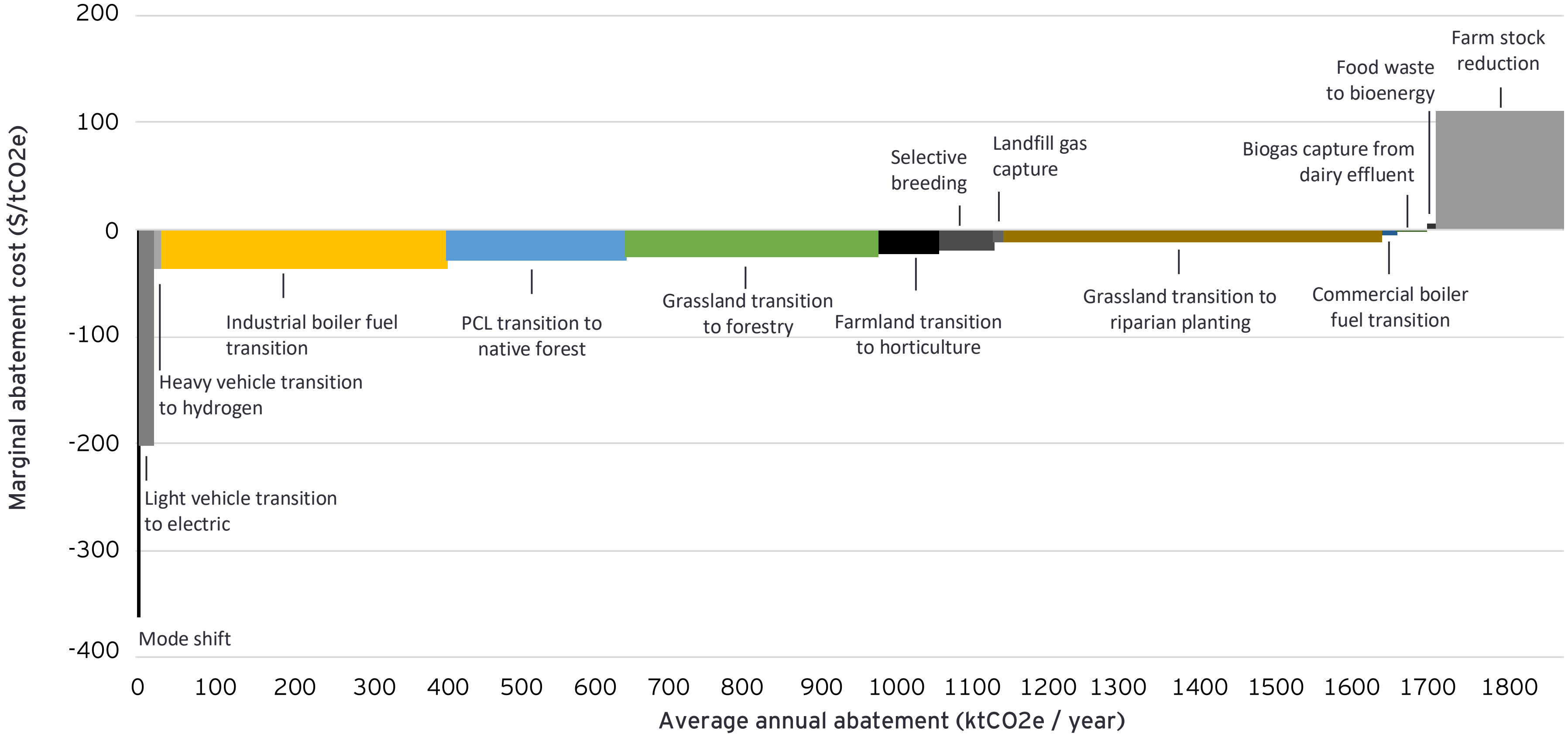

Figure 9: Marginal abatement cost curve of the modelled mitigation options.

Marginal abatement cost is the price of abating one tonne of carbon dioxide equivalent. A MACC's vertical axis plots the cost of abatement ($/t$CO_2$e) against the horizontal axis of potential volume of abatement (tCO_2e). Each column on the graph represents a different abatement measure, with the width representing the potential average annual abatement and the height representing the cost.

All abatement measures below the horizontal axis indicate a net financial benefit.

80% of the potential abatement options in this analysis are NPV positive and suggest a positive economic outcome for the Southland region.

Table 9: Key metrics for the individual mitigation options.

Mitigation option	**Net present value ($m)**	**Average annual abatement (ktCO_2e / year)**	**Total abatement (ktCO_2e)**	**Average cost per tCO_2e abated ($ / tCO_2e)**
Mode shift	31	3	85	-363
Light vehicle transition to electric	118	18	580	-203
Heavy vehicle transition to hydrogen	8	8	200	-38
Industrial boiler fuel transition	423	376	11,280	-37
Public Conservation Land transition to native forest	188	235	6,580	-29
Grassland transition to forestry	277	332	10,630	-26
Farmland transition to horticulture	57	79	2,520	-22
Selective breeding	41	71	2,120	-19
Landfill methane gas capture	4	13	350	-12
Grassland transition to riparian planting	181	497	14,900	-12
Commercial boiler fuel transition	3	18	560	-6
Biogas capture from dairy effluent	3	39	1,180	-3
Biogas capture from food waste	-2	11	290	6
Farm stock reduction	-294	167	2,670	110
Residential space heating improvements	-28	0.1	4	6,482

The options which are NPV positive have either low implementation costs or provide financial benefits which over time exceed their costs, assisted by either avoiding payments or receiving revenue from a carbon price.

NPV positive options with low implementation costs include biking or walking to work instead of commuting by car and selective breeding with marginal abatement costs of -$363 per t$CO_2$e and -$19 per tCO_2e respectively.

The positive NPV options where financial benefits outweigh costs over time include light vehicle fuel switching (at -$203 per t$CO_2$e), industrial boiler fuel transition (at -$37 per t$CO_2$e) and converting farmland to horticulture (at -$22 per t$CO_2$e).

Both the Public Conservation Land transition to native forest, and grassland transition to forestry options have positive NPV, with the Public Conservation Land having a slightly higher abatement cost (at -\$29 per tCO_2e) compared to (at -\$26 per tCO_2e) due to Public Conservation Land not foregoing livestock profit.

Investment is not spread evenly across the economy, but is focused on the sectors in which emissions reduction is strongest

Table 10 shows the cost of all mitigation options irrespective of theme by sector, where cost encapsulates capital expenditure, operation, and maintenance costs as well as changes in earnings. All discounted values are expressed in 2020 dollars.

Table 10: Cost by sector.

Sector	Cumulative mitigation potential 2020-2050 ($ktCO_2e$)	Discounted cost (2020 $m)	Discounted benefit (2020 $m)	NPV (2020 $m)
LULUCF	34,618	4,112	4,807	694
Industrial	11,282	709	1,132	423
Agriculture	5,966	404	154	-250
Transport	869	734	890	157
Waste	640	30	33	3
Commercial	559	79	82	3
Residential	4	30	3	-28

The land use and agriculture sectors have the greatest potential for emissions reduction and sequestration. However, to reduce emissions in these sectors will require extensive system change and come at a significant cost. The discounted cost to achieve the modelled emissions reduction within land use and agriculture is $4.52 billion over the modelled period to 2050. This is due to the high costs of land conversion and lower and deferred earnings from forestry, when compared with livestock production. The largest up-front capital investment is in land conversion from farmland to horticulture farming.

Another challenge for these sectors is the absence of incentives. It is expected that individual land - and farm-holders will bear the costs as they will need to make drastic changes including converting their land to forestry or horticulture and reducing their stocking rate. There has historically been little government support for agriculture with New Zealand farm subsidies ending in 1984[14]. Introducing pricing on agricultural emissions[15] will effect some change in these sectors, but this will also be a cost on farmers without additional incentives.

The transport and industrial sector mitigation options also require significant investment. However, avoided fuel costs and efficiency improvements reduce the overall impacts of these up-front costs. The discounted total cost for the transport sector is $734 million offset by the discounted total benefit of $890 million. In the industrial sector, the discounted benefit of $1.13 billion outweighs the up-front costs and the total discounted cost of $709 million. The initial capital outlay requirements nonetheless pose a challenge for these sectors. To partly account for this, we have modelled for end of life asset replacements in these sectors.

[14] (Nightingale, 2008)
[15] (Ministry for the Environment, 2020)

The commercial, residential and waste sectors require comparatively less investment. This correlates with their lower emissions reduction potential. A combined discounted cost of $140 million contributes 3.5% of the abatement in the technology and innovation theme in 2050.

This uneven distribution of investment across the economy and between economic sectors warrants careful consideration when developing policy to ensure a fair and orderly transition.

9. Discussion

9.1 Transport

Lowering emissions from internal combustion engines (ICEs) in the light and heavy vehicle industry both represent financially attractive options. With the light vehicle transition to battery electric vehicles (BEVs) giving an NPV of $118 million and the heavy vehicle transition to hydrogen fuel cell electric vehicles (FCEVs) giving an NPV of $7.6 million. The fuel switching technology is determined by the end use requirements of the different vehicle classes.

BEVs are currently 2.9x more efficient than FCEVs (per unit of kWh input to output)[16]. Although FCEVs are likely to undergo significant efficiency improvement in the near future, it is unlikely they will overtake BEV efficiency across shorter ranges. This is because BEVs have superior fuel production efficiency with a direct conversion from grid electricity to internal storage only resulting in a 5% energy loss. On the contrary, FCEVs has energy loss in electrolysis, transport, storage and distribution, resulting in a 48% energy loss from electricity source to vehicle fuel[17]. The lower energy loss correlates to lower operational expenditure, and the past ten years have seen a large decrease in BEV passenger capital price. Passenger BEVs are currently a financially attractive option, with comparable CapEx to ICE and significantly lower operational costs, alongside lower emissions. The financial favourability of BEVs is only expected to grow as fossil fuels are subjected to the carbon price.

BEVs attractiveness begins to break down in the heavy vehicle sector as the trucks battery's weight soon offsets the energy efficiency savings and restricts carrying capacity[18]. Range and refuelling also provide additional constraints in BEV trucks with a max range of 800km and a charging time of 8 hours (overnight)[19]. Reduced carrying capacity, range and long refuelling time collectively place considerable constraints to switching to BEV in the heavy transport industry. FCEVs offer a more practical transition option, with a similar range, towing capacity and refuelling time as ICEs. However, hydrogen technology is still in its infancy, creating uncertainty around cost and efficiency improvements, with significant improvement in both areas required to be a viable commercial alternative. Various studies have forecast total cost of ownership (TCO) by kilometre, with a global study conducted by Deloitte forecasting breakeven of FCEVs and ICEs by 2028[20] and a national study forecasting breakeven point in 2030[24].

Overall, the current feasibility analysis indicates that FCEVs are the most viable option for lowering emissions in the heavy road vehicle industry and BEVs for the passenger vehicle industry. With passenger BEVs profitable and viable now, and investment required to make heavy FCEVs cost competitive and commercially viable in the future. Notwithstanding such investment in advancing this technology, a current best practise option would be to mandate that only Euro6 standard heavy transport vehicles are allowed as new imports into New Zealand. This would have to be mandated at a national policy level.

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16 (Transport & Environment, 2020)
17 (Transport & Environment, 2020)
18 (Ara Ake, 2020)
19 (Transport & Environment, 2020)
20 (Deloitte, 2020)

9.2 Industry

To effect immediate benefit across carbon abatement and cost effectiveness, an approach that focuses on efficiency improvements should be adopted as a priority. This can be applied through measures such as: using efficient appliances, reducing power losses associated with harmonics the power factor, improving the efficiency of electricity distribution, ensuring efficient transport and distribution of resources, and maximising thermal efficiency of biogas capture from methane as an energy source.

The use of biogas (methane capture from dairy effluent, metropolitan and industrial effluent) as a direct replacement for liquid petroleum gas (LPG) in commercial cooking applications may offer an achievable and affordable fuel replacement option.

There is an immediate opportunity to transition existing coal boilers to wood pellets or dried wood chip now rather than wait to end of asset life. As boilers are replaced or converted, the carbon abatement will be quantified and recorded as part of the regional emissions profile tracking.

As part of their submission to the *CCC's Draft Advice*, Great South have advocated for policy change to favour wood, or other carbon neutral materials, in construction. The benefit in this is the long-term storage potential these materials offer, with the co-benefit of increased land use change to forest associated with the increased demand for wood products.

9.3 Land Use and Agriculture

This theme focuses heavily on biosequestration to achieve net zero emissions. The technology and innovation theme achieve net zero emissions by focusing on reducing gross emissions, whereas the land use and agriculture theme primarily targets increasing sequestration. Both themes reach net zero emissions, however, sequestration is less sustainable in the long term; as it is constrained by land availability and the maturation of forests (as forests mature, they sequester less carbon). Therefore, in the longer term, when Southland has maximised its biosequestration potential, the offsetting of emissions from forests will reduce significantly. This will delay the burden of addressing high gross emissions to future generations. So, whilst it is a short to medium term measure to assist with the transition to a net zero emissions economy, in the longer term, gross emissions need to fall. Thus, land transformation offers a *buffer* of time to allow other industries to implement low emission practices and technology to achieve a sustainable net zero emissions economy for Southland's future.

Although not quantitatively modelled in this report, there are substantial on-farm emission reductions to be made through agricultural practice changes such as rotational cropping, direct drilling, low tillage and a move away from high fertility, short rotational grasses. These are sometimes referred to as regenerative agricultural practices.

Agriculture is the largest contributor to both emissions, and GDP in the Southland region. Farmers make a significant contribution to the Southland economy and society, but reducing their emissions footprint is imperative for the region to meet the ambition of the Zero Carbon Act. Emission reductions made today will ensure a fair future for generations to come.

The identified mitigation options and modelled pathways presented here are intended to provide quantifiable options to effect real change with respect to achieving a net zero emissions pathway for the Southland region while retaining a resilient economy. Successful emission reduction action must come from all sectors. It is acknowledged that across New Zealand there are many groups focused on tackling climate change. It is recommended that an effective implementation plan for Southland is developed, leveraging the work of these groups.

10. Conclusion

In Aotearoa, the Government has committed to reaching net zero emissions of long lived gases by 2050, and to reducing biogenic methane emissions by between 24-47% by 2050 (Climate Change Commission, 2021)

Southland has recognised the need to be proactive in its approach to identifying mitigation pathways to achieving net zero emissions by 2050.

This document outlines, quantifies and summarises the economically viable mitigation pathways available to the Southland region to achieve a net zero emissions economy for the long-term.

Fifteen mitigation options were identified as probable pathways for Southland grouped by two main themes: Technology and Innovation, and Land Use and Agriculture. The key findings from the mitigation reduction analysis were:

- Southland can transition to a net zero emissions economy by 2050 through a diverse portfolio of mitigation options.
- Southland can achieve net zero emissions by 2050 with a positive net financial outcome.
- To give effect to emissions reductions across the region, it requires that action is embraced across all sectors.
- The identified mitigation options are not all-inclusive but rather identify probable pathways for the greatest emission reduction.
- The Technology and Innovation theme offers a potential net present value of $817 million to the economy if pursued.

Recommendations for consideration include:

- A collective and connected approach is considered when striving towards our net emissions future, considering culture, people, and environment.
- Developing an effective implementation plan to guide Southland's path to a net zero emissions economy.
- The creation of a circular economy within the mitigation framework, where possible.
- Focussing on pursuing a portfolio of the positive NPV options that achieve net zero emissions, such as those outlined in Table 11.
- Developing regular internal and external reporting channels, reflecting carbon reduction achievements.

Table 11: Positive NPV options.

Option	Average annual abatement (tCO_2e pa)	NPV ($m)	MAC ($ / tCO_2e)
Grassland transition to riparian planting	497,000	181	-12
Industrial boiler fuel transition	376,000	423	-37
Grassland transition to forestry	332, 000	277	-26
Public Conservation Land transition to native forest	235,000	188	-29
Farmland transition to horticulture	78,000	57	-22
Selective breeding	71, 000	41	-19
Biogas capture from dairy effluent	40, 000	3	-3
Light vehicle transition to electric	18,000	118	-203
Commercial boiler fuel transition	18,000	3	-6
Landfill methane gas capture	12,000	4	-12
Heavy vehicle transition to hydrogen	7,700	7	-38
Mode shift	2,700	30	-363

Limitations

This analysis required EY to perform long term forward-looking analysis. This type of analysis includes high levels of uncertainty surrounding:

- The variables underpinning business as usual emissions projections, for example livestock numbers and industrial activity;
- Capital, operation and maintenance costs of the mitigation options;
- Macro parameters, including the price on carbon; and
- The feasibility and effectiveness of mitigation measures at the forecast implementation level

Caution should be used when relying on or interpreting the results, due to its long-term nature and inherent uncertainties.

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Appendix A Technical Method

The following pages list the key assumptions applied in this analysis.

For further detail, and to view the data and calculations, please refer to the emissions modelling tool supplied to Great South.

MACRO ASSUMPTIONS	
Discount rate	Discount rate of 6% applied to nominal cash flows.
Carbon price	Adopted the TP1 carbon price projections for biogenic methane, ETS2, and all other gases, ETS1, from the Climate Change Commission's *Draft Advice for Consultation* report.
Energy prices	Nominal prices held constant at current levels to 2050.
Electricity grid emissions intensity	Held constant at 0.0977 $kgCO_2e$ / kWh.
Population	Subnational population projections to 2043 are sourced from Stats NZ. Population is extrapolated based on the historical trend to 2050.
Regional GDP	National Westpac forecasts of GDP to 2028 (as at 2 October 2020) are used, followed by growth of 1.66% each year to 2050.
BUSINESS AS USUAL ASSUMPTIONS	
Agriculture	
Livestock	Historical livestock numbers to 2019 sourced from Stats NZ. A logarithmic relationship was fitted to historical data and extrapolated to project livestock numbers to 2050. This relationship was followed for other cattle, sheep, horses and deer. Swine and goat numbers were held constant. Dairy cattle numbers are projected to steadily decrease reflecting expected trends. Emission factors for enteric fermentation and manure management were sourced from the Ministry for Primary Industries (MPI) 2020 agriculture inventory methodology report and 2006 IPCC Guidelines for National Greenhouse Gas Inventories worksheets 3A1 and 3A2. Reference: Stats NZ. Livestock Numbers by Regional Council. Retrieved from http://nzdotstat.stats.govt.nz/wbos/Index.aspx?DataSetCode=TABLECODE7423# Ministry for Primary Industries. (June 2020). *Methodology for calculation of New Zealand's agricultural greenhouse gas emission.* Retrieved from https//mpi.govt.nz/dmsdocument/13906/direct 2006 IPCC Guidelines for National Greenhouse Gas Inventories Vol 4 Agriculture, Forestry and Other Land Use, Annex 1 Worksheets – 3A1 and 3A2. Retrieved from https://ipcc-nggip.iges.or.jp/public/2006gl/vol4.html
Fertiliser	Lime and dolomite values obtained from Stats NZ's fertiliser and lime applied by territorial authority and type for the year to 30 June 2012. Nitrogen fertiliser values obtained from Stats NZ's 2017 Nitrogen and phosphorus in fertilisers. National level data was used to apportion Southland's nitrogen fertiliser into urea, diammonium phosphate and ammonium sulphate.

	Projected fertiliser application was based on historical trends and expected trends (e.g. water policy reforms) as well as consultation with the Fertiliser Association of New Zealand. Emission factors are sourced from the Ministry for the Environment. Reference: Stats NZ. (May, 2018). Agricultural production statistics: June 2017 (final). Retrieved from https://www.stats.govt.nz/information-releases/agricultural-production-statistics-june-2017-final Confidential input from the Fertiliser Association of New Zealand. Ministry for the Environment. (December 2020). *Measuring Emissions: A Guide for Organisations*. Retrieved from https://www.mfe.govt.nz
Transport	
Road and off-road vehicles	Baseline fuel demand from road and off-road vehicles for 2018 was obtained from the Southland Regional Greenhouse Gas Emissions Inventory developed by AECOM. For on-road light vehicles, historical trends of increasing light vehicle ownership per 1,000 people and decreasing kilometres travelled per light vehicle were extrapolated to 2050. Electric vehicle (EV) uptake projections provided by PowerNet, achieving a 60% share by 2050. For on-road heavy vehicles, the historical trend of increasing kilometres travelled per heavy vehicle has been extrapolated to 2050. The PowerNet projections for light vehicles were lagged by 5 years and applied to heavy vehicles, reflecting expected timing of cost parity between Internal Combustion Engines (ICE) and electric heavy vehicles, achieving 39% share by 2050. Fuel demand from off-road vehicles has been held constant with fuel switching to electric assumed to follow the same trajectory as on-road heavy vehicles. Fuel demand from buses is held constant to 2050. In 2018, buses accounted for 2.31% of road diesel usage and 0.03% of road petrol usage. Emission factors are sourced from the Ministry for the Environment. Reference: AECOM New Zealand Limited. (October 2019). *Southland Regional Carbon Footprint 2018*. Report prepared for Great South. Confidential input from PowerNet. Ministry for the Environment. (December 2020). *Measuring Emissions: A Guide for Organisations*. Retrieved from https://www.mfe.govt.nz
Rail	Fuel consumption data for FY19 and FY20 obtained from KiwiRail. FY20 consumption held constant to 2050. Emission factors are sourced from the Ministry for the Environment. Reference: Confidential input from KiwiRail. Ministry for the Environment. (December 2020). *Measuring Emissions: A Guide for Organisations*. Retrieved from https://www.mfe.govt.nz
Aviation	Flight data was obtained from the Invercargill Airport annual report and Stewart Island Flights website. Small passenger plane flights were excluded from this analysis. To estimate emissions from these flights, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories methodology and associated emission factors were used to

	calculate landing and take-off emissions (refer to equations 3.6.3 and 3.6.4 in IPCC report). In-flight emissions are excluded from this analysis. Energy demand is projected to increase by 0.7% each year. Reference: Invercargill Airport. Annual Report 2019. Retrieved from https://invercargillairport.co.nz/wp-content/uploads/2019/09/IAL-2019-Annual-Report.pdf Steward Island Flights. Retrieved from https://www.stewartislandflights.co.nz/ IPCC. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2. Retrieved from https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
Shipping	Two weeks' worth of marine traffic data at Bluff Harbour was obtained from www.marinetraffic.com. The number of ships by type was extrapolated to one year. To estimate emissions, data was segmented into vessel type; passenger, cargo, tanker etc. European Commission guidelines on the quantification of emissions from ships was used to calculate how long the vessel would take to manoeuvre into and out of port. The fuel consumption and emission factors were obtained using Table 3.5.6 in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Only in-port emissions were considered in this analysis. Energy demand is projected to increase by 0.7% each year. Reference: MarineTraffic. Port of Bluff, New Zealand. Retrieved from https://www.marinetraffic.com/en/ais/details/ports/2689/New_Zealand_port:BLUFF European Commission. Market Survey of Marine Distillates. Retrieved from https://ec.europa.eu/environment/archives/air/pdf/chapter3_end_ship_emissions.pdf IPCC. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2. Retrieved from https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
Residential	
Energy demand	Coal and wood demand were obtained from the Southland Regional Greenhouse Gas Emissions Inventory developed by AECOM. Grid electricity demand was obtained from PowerNet's Information Disclosures for the Commerce Commission. LPG usage was obtained from the LPG Association of New Zealand. Projections are in line with population projections for the region. An annual efficiency factor of 0.4% (i.e. an increasing energy/output ratio) is applied to projections. From 2019 to 2050, households are assumed to fuel switch from LPG to electricity at a rate of 1.4% each year. Emission factors are sourced from the Ministry for the Environment. Reference: AECOM New Zealand Limited. (October 2019). *Southland Regional Carbon Footprint 2018*. Report prepared for Great South. PowerNet. Information Disclosure Accounts for The Power Company Limited. Retrieved from https://powernet.co.nz/line-owners/the-power-company-limited/information-disclosure/ Confidential input from the LPG Association of New Zealand.

	Ministry for the Environment. (December 2020). *Measuring Emissions: A Guide for Organisations*. Retrieved from https://www.mfe.govt.nz
Solar generation	Baseline solar generation in Southland was found using Electricity Market Information data for the region. This data was forecast to 2050 using the trend published by MBIE in the projections of solar photovoltaic uptake report (2015). Reference: Electricity Authority. Electricity Market Information. Installed distributed generation trends. Retrieved from Electricity Authority - EMI (market statistics and tools) (ea.govt.nz) Ministry of Business, Innovation and Employment. (2015). *Projections of Solar Photo-Voltaic Uptake*. Retrieved from https://www.mbie.govt.nz/dmsdocument/4258-projects-of-solar-photo-voltaic-uptake
Commercial	
Energy demand	Grid electricity demand was obtained from PowerNet's Information Disclosures for the Commerce Commission. All other demand was obtained from Great South's process heat database which contains a list of boilers in the Southland region. There is expected to be some double counting between the electricity use captured by the boiler database and the Information Disclosures for the Commerce Commission. Projections are in line with regional GDP growth. An annual efficiency factor of -1.3% (i.e. a decreasing energy/output ratio) is applied to projections. Emission factors are sourced from the Ministry for the Environment. Reference: PowerNet. Information Disclosure Accounts for The Power Company Limited. Retrieved from https://powernet.co.nz/line-owners/the-power-company-limited/information-disclosure/ Great South. *Southland Boiler Database Sept2020.xlsx* Ministry for the Environment. (December 2020). *Measuring Emissions: A Guide for Organisations*. Retrieved from https://www.mfe.govt.nz
Industrial	
New Zealand Aluminium Smelter (NZAS)	Energy demand was provided by the New Zealand Aluminium Smelter and held constant to 2026. After which demand is set to zero due to the smelter's planned closure. Emission factors are sourced from the Ministry for the Environment. Reference: Ministry for the Environment. (December 2020). *Measuring Emissions: A Guide for Organisations*. Retrieved from https://www.mfe.govt.nz
Energy demand (non-NZAS)	Grid electricity demand was obtained from PowerNet's Information Disclosures for the Commerce Commission. All other demand was obtained from Great South's process heat database which contains a list of boilers in the Southland region. There is expected to be some double counting between the electricity use captured by the boiler database and the Information Disclosures for the Commerce Commission. Projections are in line with regional GDP growth. An annual efficiency factor of -1.7% (i.e. a decreasing energy/output ratio) is applied to projections. Emission factors are sourced from the Ministry for the Environment. Reference:

	PowerNet. Information Disclosure Accounts for The Power Company Limited. Retrieved from https://powernet.co.nz/line-owners/the-power-company-limited/information-disclosure/ Great South. *Southland Boiler Database Sept2020.xlsx* Ministry for the Environment. (December 2020). *Measuring Emissions: A Guide for Organisations*. Retrieved from https://www.mfe.govt.nz
Coal mining	Coal production was obtained for the Takitimu, Wairakei and New Vale mines. An emissions intensity factor of production of 0.0378 tCO_2e / tonne was applied. Production and therefore emissions were held constant until each mine's planned closure. Reference: New Zealand Petroleum & Minerals. Coal - 2018 production figures. Retrieved from https://www.nzpam.govt.nz/nz-industry/nz-minerals/minerals-statistics/coal/operating-mines/2018-production-figures/
Industrial processes and product use (IPPU)	
New Zealand Aluminium Smelter (NZAS)	The smelter provided emissions relating to perfluorocarbons, baked anode consumption, pitch volatiles, packing coke and soda ash. Emissions were held constant until 2026, after which emissions are equal to zero due to the smelter's planned closure. Reference: Confidential input from the New Zealand Aluminium Smelter.
Product uses as substitutes for ODS	Refrigerant use was obtained from the Southland Regional Greenhouse Gas Emissions Inventory developed by AECOM. This included refrigeration and air conditioning, foam blowing agents, fire protection and aerosols. Global Warming Potential values were obtained from the IPCC Fifth Assessment Report. Reference: AECOM New Zealand Limited. (October 2019). *Southland Regional Carbon Footprint 2018*. Report prepared for Great South. IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva, Switzerland, 151pp
Waste	
Solid waste disposal	Historical information regarding solid waste to the Southland Regional Landfill was obtained for the period 2007 to 2019 from the Southland Region Waste Assessment report (July 2020). As the landfill opened in 2005, the waste delivered to the landfill for the years 2005 and 2006 was based on the average over that period. A logarithmic relationship was fitted to historical data and extrapolated to arrive at estimates of waste to landfill through to 2050. The composition of waste was sourced from the Southland Region Waste Assessment report for the period April 2017 to April 2018 and held constant over the modelling period. Landfill emissions were estimated using a first order decay model. The Global Warming Potential for methane was obtained from the IPCC Fifth Assessment Report. Landfill gas capture of 250 m^3 / hr is assumed for the site. Reference: Morrison Low. (July 2020). *Southland Region Waste Assessment*. Report prepared for the Invercargill City Council, Southland District Council and Gore District Council.

	IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva, Switzerland, 151pp
Wastewater treatment and discharge	The City Inventory Reporting and Information System (CIRIS) methodology was employed with data sourced from the Southland Regional Greenhouse Gas Emissions Inventory developed by AECOM. The IPCC Fifth Assessment Report was used to obtain Global Warming Potential values. <u>Reference</u>: AECOM New Zealand Limited. (October 2019). *Southland Regional Carbon Footprint 2018*. Report prepared for Great South. IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva, Switzerland, 151pp
Land use, land-use change and forestry (LULUCF)	
Land use	Land use for the Southland region was obtained from the Ministry for the Environment's LUCAS NZ Land Use Map 2016. For each land use class, the steady state soil organic carbon stock, soil carbon stock maturity cycle, reference carbon stock from biomass, annual carbon stock change from biomass and biomass carbon stock maturity cycle was obtained from the Ministry for the Environment. Use of this information follows the Tier 1 guidance in the IPCC guidelines for calculating emissions for organic soils (IPCC, 2006a). Motu (a research institute) modelled the interaction between carbon price and land use change for a report commissioned by the parliamentary commissioner for the environment. The land use output from a conservative carbon price (the Model 7 carbon price projection) was used to model business as usual land use changes out to 2050. This model incorporates the Land Use in Rural New Zealand (LURNZ) model to simulate how major land use sectors (forestry, horticulture, dairy, sheep, and beef farming) change in response to changes in the carbon price. This is driven by two sub-models that are econometrically estimated. The first incorporates national level drivers of change (including commodity prices), while the second is a spatial model determining the spatial location of land use relating to geophysical characteristics of the land (e.g. slope, land use capability) to find proxies for cost of market access and feasibility of conversion. With the spatial projection, the LURNZ model determines land production, associated emissions and in turn profitability of each parcel of land. Changing the carbon price affects the optimal distribution of land. <u>Reference</u>: Ministry for the Environment. (2016). *LUCAS NZ Land Use Map 2016 v008.* Retrieved from https://data.mfe.govt.nz/layer/52375-lucas-nz-land-use-map-1990-2008-2012-2016-v008/ Ministry for the Environment. (April 2020). New Zealand's Greenhouse Gas Inventory 1990-2018. Retrieved from https://www.mfe.govt.nz/publications/climate-change/new-zealands-greenhouse-gas-inventory-1990-2018 Carbon price and land use change tables provided directly by Levente Timar at Motu. Recent work completed by Motu using the LURNZ model and a complex integrated modelling exercise can be found at https://www.pce.parliament.nz/publications/farms-forests-and-fossil-fuels-the-next-great-landscape-transformation
MITIGATION ASSUMPTIONS	
Agriculture	
Stock reduction	Stock reduction is modelled as 10% of livestock to be reduced 2035 to 2050. This relied on stock unit conversion factors that were sourced from table 2.3 in Land-use intensity and GHG in the LURNZ Model report (2014).

	This stock reduction assumed a linear decrease. This model assumes a constant profit per head of livestock, with profitability extracted from DairyNZ and Beef + Lamb NZ reports. Emission factors remain the same as under business as usual. <u>Reference</u>: Motu Economic and Public Policy Research. (2014). *Land-use Intensity and Greenhouse Gas Emissions in the LURNZ Model*. AgFirst. (August, 2017). *Analysis of drivers and barriers to land use change*. A Report prepared for the Ministry for Primary Industries. Retrieved from https://www.mpi.govt.nz
Selective breeding	Assumptions are based on the 2015 Meat & Livestock Australia report titled A marginal abatement cost analysis of practice options related to the NLMP program. A key assumption is that the cost of implementing selective breeding is zero on the basis that many producers already use systems that incorporate emissions reductions and the cost of purchasing livestock based on low residual methane production is not materially different to selection based on other traits. <u>Reference</u>: Meat & Livestock Australia. (2015). *A marginal abatement cost analysis of practice options related to the NLMP program.* Retrieved from https://www.mla.com.au
Biofuel capture from effluent	Parameters are primarily based on an anerobic digestion feasibility assessment done in cooperation with Great South and information supplied by Dairy Green Ltd (John Scandrett), which is based upon the Glenarlea Farms (Isla Bank) Biogas from Effluent project in Southland. By 2050, biofuel capture from dairy cattle effluent is projected to occur at 165 farms with pasture only (and 8.25% of manure collected), 215 farms with a stand-off area (and 18.25% of manure collected) and 50 farms with wintering sheds (and 23.5% of manure collected). It is assumed that all energy generated is used on farm, avoiding both electricity and hot water costs.
Transport	
Light vehicle transition to electric	92% of the fleet is assumed to be electric by 2050. This analysis included consideration of the lifecycle of cars, projected fuel efficiency in both ICE vehicles and EVs, capital investment of vehicles and public charging infrastructure. Efficiency rates, capital costs and lifecycle were sourced from Ministry for the Environment's Marginal abatement cost curves analysis for New Zealand: Potential greenhouse gas mitigation options and their costs. The cost is the difference in cost between EVs and ICE vehicles, i.e. the cost to purchase EV and power it (using annual km travelled as per BAU forecast) alongside infrastructure cost, against the cost that would've gone to buying an ICE and fuelling it (using annual km travelled as per BAU forecast). Equations to cost light electric vehicles $\#\,\text{EV from baseline} \times \left(\text{Electricityprice}\left(\frac{\$}{\text{kWh}}\right) \times \left(\frac{\text{kWh}}{\text{km}}\right) \times \frac{\text{km travelled}}{\text{year}} + \text{CapEx}\right)$ $\#\,\text{ICE from baseline} \times \left(\text{Fuelprice}\left(\frac{\$}{\text{L}}\right) \times \left(\frac{\text{L}}{\text{km}}\right) \times \frac{\text{km travelled}}{\text{year}} + \text{CapEx}\right)$ $+\,\text{Difference in Lifecycle Costs} + \text{Infrastructure Costs}$ The change in emissions were found by looking at the difference in emissions caused from the fuel switch. Battery emissions were excluded from this analysis. Emission factors remain the same as under business as usual. <u>Reference</u>:

	Ministry for the Environment. (2020). *Marginal abatement cost curves analysis for New Zealand*. Retrieved from https://mfe.govt.nz
Heavy vehicle transition to hydrogen	60% of the fleet is assumed to be powered by hydrogen fuel cells by 2050. Given the large uncertainty in hydrogen fuel prices, a total cost ownership ($/km) using (Deloitte, 2020) (Ara Ake, 2020) values were used. The forecast kWh values were extracted from the Ministry for Environment's efficiency factor for heavy electric vehicles in the MACC analysis and multiplied these by a scalar to incorporate the additional energy inefficiencies from FCEV. Emissions were found by looking at the difference in emissions from fuel consumption, using the same emission factors as under business as usual. Battery emissions were excluded from the analysis. <u>Reference</u>: Ara Ake. (2020). *Economics of using green hydrogen to decarbonise long-distance heavy freight in New Zealand: Stage 1 review of existing studies*. Deloitte. (2020). *Fuelling the future of mobility hydrogen and fuel cell solutions for transportation*. Ministry for the Environment. (2020). *Marginal abatement cost curves analysis for New Zealand*. Retrieved from https://mfe.govt.nz
Mode shift (cycling and walking)	2018 census data on the main means of travel to work for the region was obtained from Stats NZ. It was assumed that 30% of commuters live less than 5km from work, lower than the national average of 47% (taken from 2006 Stats NZ national data). Combining these sources allowed us to estimate the proportion of commuters that live less than 5km from work and still commute by car. It is assumed that modal shift is occurring after EV switch. The avoided fuel consumption and fuel costs were then calculated to determine the abatement potential and cost savings. <u>Reference</u>: Stats NZ. 2018 Census – Main means of travel to work and work status by status in employment. Retrieved from http://nzdotstat.stats.govt.nz/wbos/Index.aspx?DataSetCode=TABLECODE8296
Residential	
Space heating improvements	20% of residential dwellings were assumed to already have insulation and double-glazed windows. The number of occupied dwellings was sourced from census data from Stats NZ. The cost of insulation was taken from an NZ energy insulation quote site (Awarua Synergy). The expected energy efficiency was taken from a University Otago report Monitoring Energy Efficiency Upgrades in State Houses in Southern New Zealand. The percent of electricity and coal used in spatial heating was taken from EECA, and from this the energy saved was calculated. The emission factors and fuel prices used in BAU projections were used to extrapolate cost and emission savings. <u>Reference</u>:

	Stats NZ. 2018 Census – Occupied dwellings, unoccupied dwellings, and dwellings under construction, for private and non-private dwellings. Retrieved from http://nzdotstat.stats.govt.nz/wbos/Index.aspx?DataSetCode=TABLECODE8296 Awarua Synergy. (October, 2019). Cost of insulation. Retrieved from https://awaruasynergy.co.nz/heating-subsidies-may-cover-the-majority-of-your-insulation-install-costs/ University of Otago. (2006). *Monitoring of Energy Efficiency Upgrades in State Houses in southern New Zealand*. A research project by the Energy Management Group Physics Department – University of Otago. Retrieved from https://www.physics.otago.ac.nz EECA. Energy end use database. Retrieved from https://tools.eeca.govt.nz/energy-end-use-database/
Commercial and Industrial	
Boiler fuel switch	The CapEx and efficiency ratings of new boilers by fuel type were taken from the Ministry for the Environment's MACC analysis and amended by Grant Smith. Fuel prices are sourced from MBIE. Great South's process heat database includes the age of the boiler, boiler capacity, energy use, sector and fuel type. It was assumed that boilers are converted at the asset end of life. A default boiler life of 25 years was assumed. Some boilers are switching earlier, as informed by Great South. Capital costs for all options are assumed to scale linearly with capacity and fixed, uniform prices for the different fuel types were assumed. For conversion, the following logic was applied: any boiler conversions pre-2025 are either to pellets or biomass, then post-2025 small commercial boilers (<250 kW) to electricity, small industrial boilers (<500 kW) to pellets and all other boilers to biomass. The cost is calculated as the difference in cost between replacing the existing boiler with the same boiler fuel type and paying for the fuel versus buying the new boiler and purchasing the new fuel. Emission factors are the same as BAU. <u>Reference</u>: Ministry for the Environment. (2020). *Marginal abatement cost curves analysis for New Zealand*. Retrieved from https://mfe.govt.nz Ministry of Business, Innovation & Employment. (December, 2020). *Energy Prices – Price data tables (excel).* Retrieved from https://www.mbie.govt.nz
Waste	
Landfill gas capture	A 400kW system (at 30% efficiency) is assumed to be installed at the landfill, increasing the capture rate from 250 m3 / hr under BAU to 500 m3 / hr. The Landfill Gas Energy Cost Model (version 3.4, October 2020) developed by the US EPA Landfill Methane Outreach Program was used to cost the project. A standard engine project type is assumed. Given the existing system already on site, it is assumed that 100% of the electricity generated is exported to the grid and not consumed on site. <u>Reference</u>: United States Environmental Protection Agency. (October, 2020). *Landfill Gas Energy Cost Model – Landfill Methane Outreach Program*. *Version 3.4*. Retrieved from https://epa.gov/lmop/download-lfgcost-web
Food waste to bioenergy	The assumptions are based on the first large-scale food waste-to-bioenergy plant in New Zealand, the EcoGas Reporoa biogas plant.

	The annual volume of feedstock received at the plant is assumed to be 10,000 tonnes. For modelling purposes, the energy generated is assumed to displace electricity consumption. Reference: Smith, G. (March, 2021). *Waste to Energy Notes*. Powerpoint Presentation prepared for Great South.
Land use, land-use change and forestry (LULUCF)	
Land conversion to forestry	Motu's model leveraging the LURNZ model (used to predict business as usual LULUCF emissions) was run at a higher carbon price (the Model 9 carbon price projection) for this mitigation option. The additional hectares of land converted from low producing land to forestry as a result of the higher carbon price were included in this option. This resulted in a 7% net conversion to forestry from 2020 to 2050; 50% was assumed native while 50% was assumed to be pine forest that was harvested after 25 years. The age of the plantation was accounted for and the sequestration rate by age found in the Ministry for the Environment MACC analysis, which is also in line with the New Zealand Emissions Trading Scheme (NZ ETS). To cost this option, the cost of converting land came from a report prepared for the Ministry of Primary Industries titled Carbon sequestration potential of non-ETS land on farms. The cash flow each year was taken from Forest Opportunities released by crown research institute scion. The cash flow includes planting, insurance and pruning costs. For pine forests a revenue stream from harvest was also included, whereas this was excluded from native plantations. The cost foregone was calculated as the hectares of land that had been converted multiplied by the EBIT of that land using data from Beef + Lamb NZ and DairyNZ. To account for changes in carbon, the carbon sequestered from the increase in planting used age-based sequestration tables, accounting for the age of the tree and how much carbon it would sequester in that year. Alongside the biomass sequestration, changes in soil sequestration were accounted for. The change in biomass and soil stock used the carbon tables and equations obtained from the Ministry for the Environment. The loss in emissions from lower livestock numbers were also included in this analysis by scaling the number of animals by the change in farmland available compared with business as usual. Reference: Ministry for the Environment. (2020). *Marginal abatement cost curves analysis for New Zealand*. Retrieved from https://mfe.govt.nz Burrows et al. (September, 2018). *Carbon sequestration potential of non-ETS land on farms.* Prepared for Ministry for Primary Industries. Retrieved from https://www.mpi.govt.nz Ministry for Primary Industries. *Farm monitoring*. Retrieved from https://www.mpi.govt.nz/resources-and-forms/economic-intelligence/farm-monitoring/ AgFirst. (August, 2017). *Analysis of drivers and barriers to land use change.* A Report prepared for the Ministry for Primary Industries. Retrieved from https://www.mpi.govt.nz

	Ministry for the Environment. (April, 2020). *New Zealand's Greenhouse Gas Inventory 1990-2018*. Retrieved from https://www.mfe.govt.nz/publications/climate-change/new-zealands-greenhouse-gas-inventory-1990-2018 Carbon price and land use change tables provided directly by Levente Timar at Motu. Recent work completed by Motu using the LURNZ model and a complex integrated modelling exercise can be found at https://www.pce.parliament.nz/publications/farms-forests-and-fossil-fuels-the-next-great-landscape-transformation
Livestock to crops and horticulture	The model used to predict business as usual LULUCF emissions was run at a higher carbon price for this mitigation option. The additional hectares of land converted from high producing land to cropland as a result of the higher carbon price were included in this option. This assumed a 4.1% net conversion to crops and horticulture from 2020 to 2050. To cost this option, the cost of converting land and expected annual EBIT came from the report titled Analysis of drivers and barriers to land use change, prepared by MPI, and agriculture and horticulture statistics from Stats NZ. To account for changes in carbon, the changes in biomass and soil from changing between high producing land to cropland were accounted for. The loss in emissions from lower livestock numbers were also included in this analysis by scaling the number of animals by the change in farmland available compared with business as usual. <u>Reference</u>: AgFirst. (August, 2017). *Analysis of drivers and barriers to land use change*. A Report prepared for the Ministry for Primary Industries. Retrieved from https://www.mpi.govt.nz Carbon price and land use change tables provided directly by Levente Timar at Motu. Recent work completed by Motu using the LURNZ model and a complex integrated modelling exercise can be found at https://www.pce.parliament.nz/publications/farms-forests-and-fossil-fuels-the-next-great-landscape-transformation
Riparian planting	To model for riparian planting 56,500ha of high producing land, 6,500 ha of low producing land and 2,000ha of woody biomass land was linearly converted from 2020 to 2050 to Natural forest and woody biomass (50% split). These figures were supplied by Great South. The change in carbon associated with the biomass and soil was accounted for using the steady state soil organic carbon stock, soil carbon stock maturity cycle, reference carbon stock from biomass, annual carbon stock change from biomass and biomass carbon stock maturity cycle obtained from the Ministry for the Environment. The cost of conversion took an average across DairyNZ estimates and a Landcare research report titled Cost and Benefits of Riparian Buffers in NZ. These costs exclude non-financial benefits such as cleaner rivers and lower erosion. This land conversion impacted livestock numbers and the associated change in agriculture revenue and emissions were included in this analysis. <u>Reference</u>: Ministry for the Environment. (April, 2020). New Zealand's Greenhouse Gas Inventory 1990-2018. Retrieved from https://www.mfe.govt.nz/publications/climate-change/new-zealands-greenhouse-gas-inventory-1990-2018 AgFirst. (August, 2017). *Analysis of drivers and barriers to land use change*. A Report prepared for the Ministry for Primary Industries. Retrieved from https://www.mpi.govt.nz Landcare Research. (September, 2016). *Cost and Benefits of Riparian Buffers in NZ*. Retrieved from https://www.landcareresearch.co.nz/uploads/public/Events/Link-series/Riparian_Restoration_Cost_Benefit_Analysis.pdf
PCL land transformation	1,500ha of high producing grassland, 18,500ha of low producing grassland and 4,500 ha of woody biomass was converted to natural forest.

	This conversion was not on farmland and in turn, did not reduce livestock numbers/agriculture emissions and costs associated with foregone agriculture profit (seen in land conversion to forestry option). To cost this option, the cost of converting grassland to forestry came from a report prepared for the Ministry of Primary Industries titled Carbon sequestration potential of non-ETS land on farms. The cash flow each year was taken from research released by crown research institute Scion. The cash flow includes planting, insurance and pruning costs. As natural forest on PCL is not expected to be harvested, no harvest revenue was included in this analysis. To account for changes in carbon, the carbon sequestered from the increase in planting used age-based sequestration tables, accounting for the age of the tree and how much carbon it would sequester in that year. Alongside the biomass sequestration, changes in soil sequestration were accounted for. The change in biomass and soil stock used the carbon tables and equations obtained from the Ministry for the Environment. Reference: Burrows et al. (September 2018). *Carbon sequestration potential of non-ETS land on farms.* Prepared for Ministry for Primary Industries. Retrieved from https://www.mpi.govt.nz Ministry for the Environment. (April, 2020). New Zealand's Greenhouse Gas Inventory 1990-2018. Retrieved from https://www.mfe.govt.nz/publications/climate-change/new-zealands-greenhouse-gas-inventory-1990-2018

Appendix B Physical Risks and Resulting Economic Impact Analysis

A high level sub-regional breakdown consolidating research from NIWA and Statistics New Zealand is provided in the following pages. The NIWA report predicts Southland's climate to 2100 using climate markers such as temperature, precipitation and rain frequency. This analysis used four Representation Concentration Pathway (RCP) scenarios, which indicate the increase in radiative force compared to pre-industrial values. All scenarios are possible, depending on how little action is taken to mitigate GHG emissions. The most significant impacts under the RCP8.5 scenario are considered in the analysis below, aligning to 3-4°C of warming by 2100, significantly over the goals set under the Paris Agreement and the Zero Carbon Act.

High level sub-regional summaries are presented on the following pages and focus on the physical changes in the climate that will have the biggest local economic impact.

Fiordland and Islands

Economic overview

Fiordland and Islands is dominated by the tourism sector, accounting for 85% of GDP annually.

With 907,786 visitors in 2019 to Milford Sounds Fiordland National Park[21], highlighting the importance of nature in attracting tourists.

Fiordland and Islands Projected climate change

- +3.0°C by 2100
- +10 hot days >25 °C
- Increase heavy rain days
- Increase dry days

Main physical risks

Increased flood risk.

Increased number of heavy rain days.

Largest increase in precipitation in winter (above 40%) by 2090.

Main economic impacts

Damage to infrastructure from flooding and landslides.

Flooding and flooding damage affecting tourism as people unable to access Fiordland or become stranded in Fiordland.

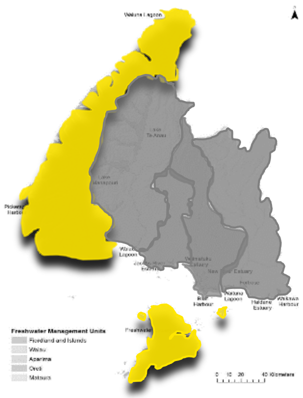


Figure 10: Fiordland and Islands FMU/sub-region highlighted.

Waiau

Economic overview

Southern Waiau is dominated by the agriculture and tourism industry. The region has seen a shift towards dairy farming in the past decade. Northern Waiau, around Te Anau, relies predominantly on Tourism.

Waiau Projected climate change

- +3.0°C by 2100 in Northern Waiau
- +30 hot days >25 °C
- Annual rainfall expected to increase
- Risk drought central Waiau

Main physical risks

Increased risk of drought in Northern Waiau with 10% decrease in precipitation forecast for summer months by 2090.

Main economic impacts

Heat stress to livestock reducing productivity. Drought increasing irrigation costs and fire risk for the forestry sector. Low rainfall also reduces growth rates, affecting forestry productivity and pasture fertility.

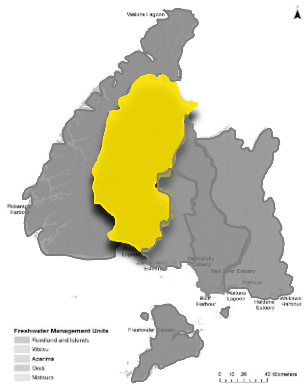


Figure 11: Waiau FMU/sub-region highlighted.

[21] (DOC, 2020)

Aparima

Economic overview

Aparima has strong reliance on the dairy industry, contributing 48% of GDP.

A recent survey of 151 Aparima farmers showed 80% have Farm Environment Plans[22], outlining the relevance of identify specific climate risk for the sub-region.

Aparima
Projected climate change

- +2.5°C by 2100 in Northern Aparima
- Increase hot days
- Increase risk of flood

Main physical risks

Increased flood risk across Northern Aparima.

Increased heatwave days and dry days across catchment.

Main economic impacts

Heat stress to livestock reducing productivity.

Increased chance of pasture damage from flooding, which in turn reduces the profitability of farms.

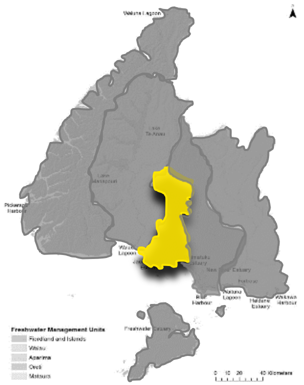


Figure 12: Aparima FMU/sub-region highlighted.

Ōreti

Economic overview

Ōreti's GDP is not dominated by one sector. The large population has created a strong services industry with finance, utilities and other services each contributing between 15-22% of sub-regional GDP.

Ōreti
Projected climate change

- +3.0°C by 2100 in Norther Ōreti
- +30 hot days/year >25 °C
- Increased wet days in the north
- Increased risk of drought

Main physical risks

Increase in temperature and increase in the risk of drought for Northern Ōreti.

Main economic impacts

Northern Ōreti faces the risk of drought affecting livestock and the cost of farming (particularly through increased irrigation requirements and feeding costs).

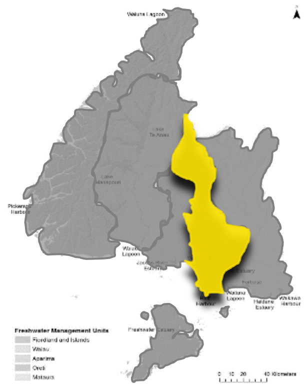


Figure 13: Ōreti FMU/sub-region highlighted.

[22] (DairyNZ, 2020)

Matāura

Economic overview

Matāura's primary source of GDP is from dairy and beef cattle farming, which together contributes around 29% of GDP.

Mataura
Projected climate change

- +3.0°C in northern Matāura
- +55 hot days northern Matāura/year >35 °C
- Increased flood risk
- Increased drought risk

Main physical risks

Increased flood risk.

Significant increases for water required for pasture growth in northern region.

Main economic impacts

Flood impacts to dairy industry by requiring mass relocation of livestock to higher ground and tankers unable to access farms to collect milk.

Significant cost in irrigation to ensure pasture growth not constrained by water shortage.

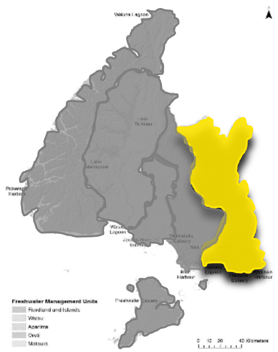


Figure 14: Matāura FMU/sub-region highlighted.

Appendix C Sectoral Analysis of Climate Change Risks and Opportunities

EY conducted an analysis of the key climate change risks and opportunities for the Southland economy's four largest sectors; agriculture, finance, tourism and utilities. This analysis shows that all sectors benefit from acting early to implement emissions reduction measures. Acting early will build resilience, provide economic benefit, create new markets and position the Southland region as a green economy which in turn may attract sustainable tourism and create a competitive advantage for local production.

Lowering emissions in Southland will also help to mitigate the physical risks outlined in the previous section of this report. Each sector's risks and opportunities have been categorised under a business as usual (BAU), which aligns to a 3-4°C warming scenario, and a 1.5-degree scenario (1.5DS). The results show that all sectors are at greater risk under business as usual than under a 1.5-degree scenario.

Business as usual

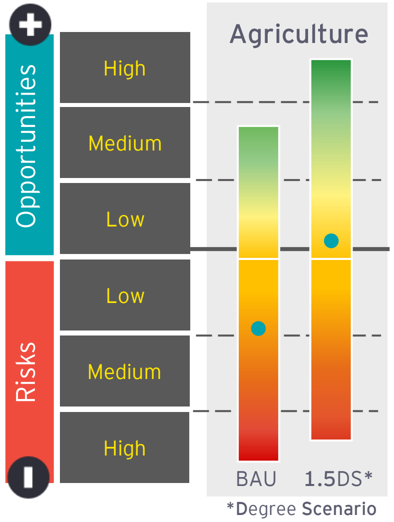
Assumes that all current and committed global climate and energy policy settings are implemented. Under this scenario, global greenhouse gas emissions continue to increase over time, and the physical impacts of climate change are more significant. This aligns with between three and four degree of warming from climate change by 2100.

1.5-degree scenario

Further policy setting is enabled globally and locally that maintains the increase in global temperatures to within 1.5°C of pre-industrial levels. Under this scenario, global greenhouse gas emissions will peak before significantly decreasing over coming decades, reaching net zero greenhouse gas emissions in the second half of the century. Whilst the physical impacts of climate change occur, they are less significant under this scenario. It also incorporates assumptions relating to uptake of new technologies and transition to clean energy sources.

The results of this analysis are presented on the following pages.

Climate change risks and opportunities in the agriculture sector



Fluctuations in crop yields

Resource Scarcity

More common pests and diseases outbreaks

Lack of clarity in direction policy

Increased insurance, operating and capital costs

Competition for land with other sectors

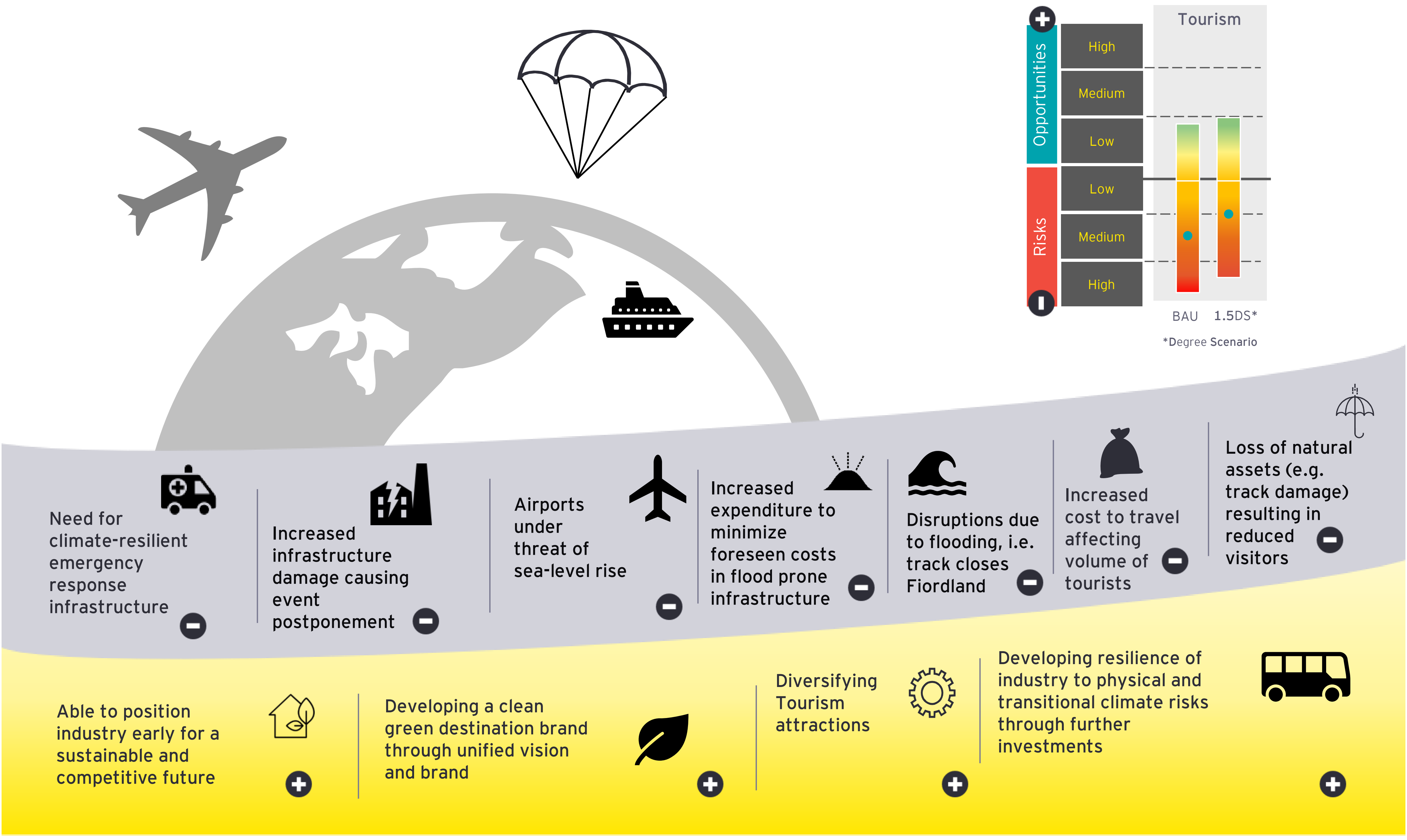
Rising demand for biofuel crops, sustainable and alternative food suppliers

Making biofuel from the capture of effluent from milking sheds

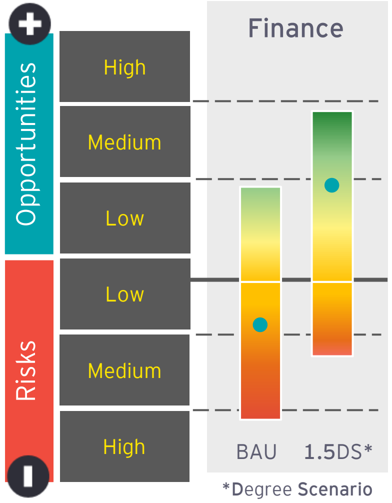
Converting animal farmland to horticulture and forestry- diversifying land use

Shift in consumer preferences favours alternative food suppliers

Climate change risks and opportunities in the tourism sector



Climate change risks and opportunities in the finance and insurance sector



Increased insurance premiums and financial stability risks from exposure to extreme weather events

Expectation of financial institutions and grant providers to include climate risk and support opportunities

Lending portfolio may be adversely impacted to climate change driven events – in particular if heavily invested in Tourism and Agriculture

Lack of clarity and direction in policy (e.g. carbon and energy) leading to potential write offs and stranded assets.

Diversification investment offerings e.g. green bonds and sustainable products

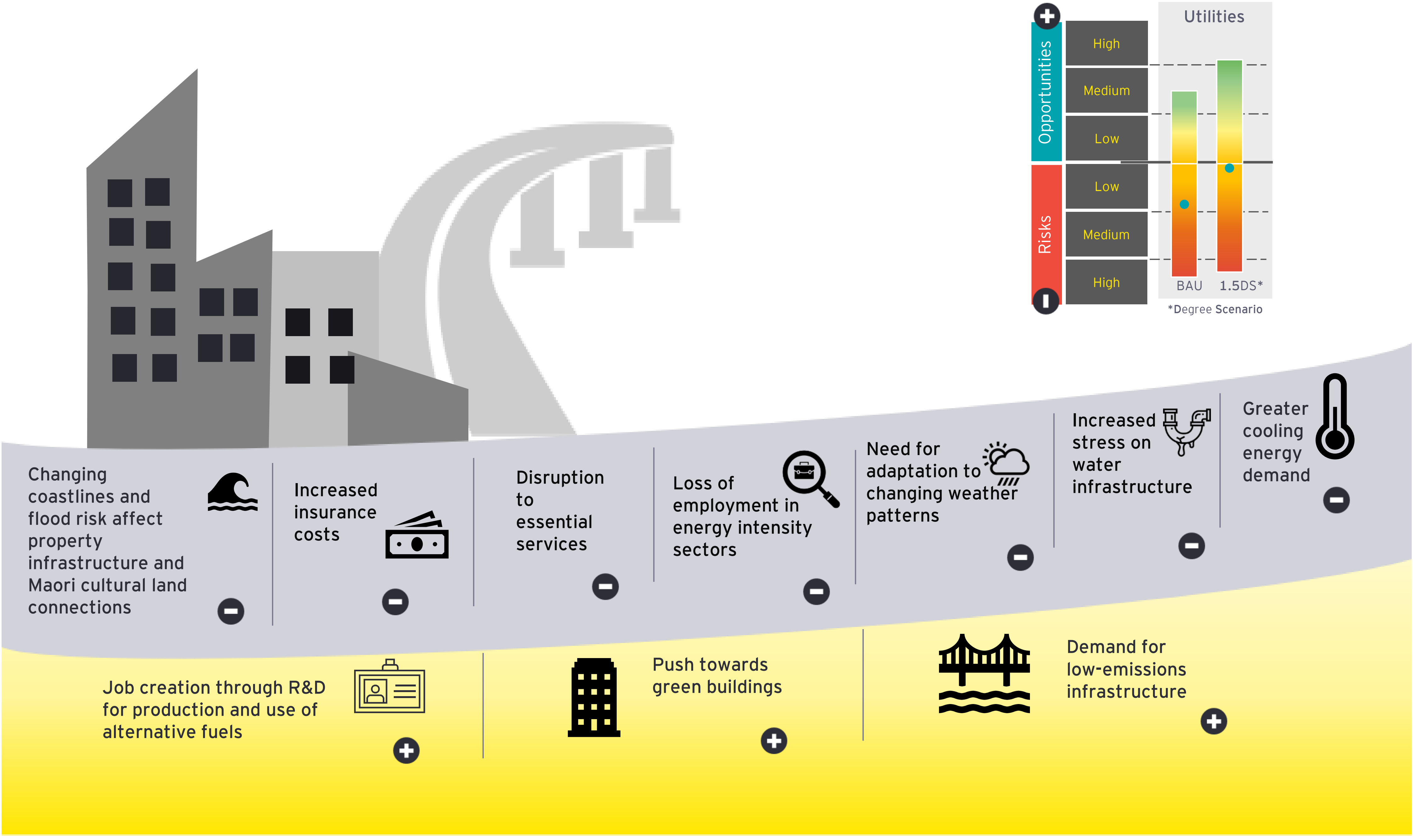
Facilitating sustainable and climate finance offerings and reinvest in NZ ETS to support low-emission uptake

Customers seeking sustainable investments leading to reputation benefits and market advantage

Investing in resilient and efficient infrastructure, e.g. energy efficient buildings (increasing asset value).

Proactive role driving transition to sustainable future through conscious investment and funding

Climate change risks and opportunities in the utilities sector



Appendix D Disclaimer

Ernst & Young ("Consultant") was engaged on the instructions of Southland Regional Development Agency ("Client") to model mitigation options for the Southland region ("Project"), in accordance with the consulting services agreement dated 3 August 2020 ("the Engagement Agreement").

The results of the Consultant's work, including the assumptions and qualifications made in preparing the report, are set out in the Consultant's report dated January 2021 ("Report"). You should read the Report in its entirety including the disclaimers and attachments. A reference to the Report includes any part of the Report. No further work has been undertaken by the Consultant since the date of the Report to update it.

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ED Mar 2021

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