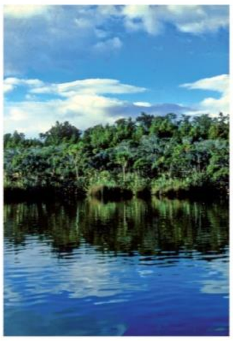

Modelling the economic impact of New Zealand's post-2020 climate change contribution

Landcare Research
Manaaki Whenua

Modelling the economic impact of New Zealand's post-2020 climate change contribution

Adam Daigneault

Landcare Research

Prepared for:

Ministry for Primary Industries & Ministry for the Environment

Wellington 6143
New Zealand

May 2015

Landcare Research, 231 Morrin Road, St Johns, Private Bag 92170, Auckland 1142, New Zealand, Ph +64 9 574 4100, Fax +64 9 574 4101, www.landcareresearch.co.nz

Reviewed by:	*Approved for release by:*
Mario Fernandez Economist Landcare Research	Suzie Greenhalgh Portfolio Leader – Enhancing Policy Development Landcare Research
Landcare Research Contract Report:	LC2208

Disclaimer

This report has been written by Landcare Research for the Ministry for Primary Industries and the Ministry for the Environment. If used by other parties, no warranty or representation is given as to its accuracy and no liability is accepted for loss or damage arising directly or indirectly from reliance on the information in it.

Acknowledgements

The Ministry for Primary Industries and Ministry for the Environment provided data and reviewed an earlier version of this report.

Contents

Abbreviations

AR4	IPCC Fourth Assessment Report
Baseline	Economic projection given a 'business as usual' approach, i.e. no action taken on climate change in New Zealand or in the rest of the world
BAU	Business as usual. The projected economic and greenhouse gas emissions path that assumes no action taken on climate change (i.e. a carbon price of $0)
BRICS	A country grouping used in the CliMAT-DGE model that comprises Brazil, Russia, India, China and South Africa
Carbon budget	The quantity of allowable greenhouse gas New Zealand can emit over the commitment period (e.g. 2021–2030), to meet its emissions reduction target
Carbon price	The price of a carbon unit, which allows the emission of one tonne of carbon dioxide or other equivalent GHG
Carbon price path	The carbon price trajectory estimated over the commitment period. For the purposes of this report, it can be 'low', 'medium' or 'high'.
Carbon pricing	Whether emissions from a specific sector, or of a gas, are subject to a market price
Carbon unit	An internationally tradable unit which allows the holder to emit one tonne of carbon dioxide or other equivalent GHG
CEPII	Centre d'Etudes Prospectives et d'Informations Internationales
CH_4	Chemical formula for the greenhouse gas methane
CliMAT-DGE	Climate Mitigation and Trade in Dynamic General Equilibrium. The integrated assessment model used in this report
CO_2-e	Carbon dioxide equivalent, measured using AR4 global warming potentials
Commitment Period	Period of time over which parties agree to adhere to their intended nationally determined contribution, e.g. 2021–2030
Domestic Abatement	Reduction in greenhouse gas emissions within New Zealand that results from policy interventions
EDGAR	Emissions Database for Global Atmospheric Research
Emissions intensity	The ratio of greenhouse gas emissions relative to economic output

Emissions reduction target	Target that a country could set for decreasing GHG emissions within a set timeframe. Can be expressed relative to the business as usual baseline (in Mt CO_2-e) or relative to emissions in a base year (e.g. as a % relative to emissions in 1990)
Endogenous	A parameter calculated within the model
EPPA	Emission Prediction and Policy Analysis, the MIT model on which CliMAT-DGE framework is based
Exogenous	A parameter used by the model defined outside the model (e.g. $C is exogenous in this report)
F-gases	Fluorinated Gases, a subset of greenhouse gases that include a fluorine atom (e.g. Sulphur hexafluoride, chlorofluorocarbons and halofluorocarbons)
Forestry Removals	Sequestration of carbon dioxide by New Zealand forests
GHG	Greenhouse Gas
Gross emissions	All greenhouse gas emissions and removals, excluding forestry activities.
GTAP	Global Trade Analysis Project. The GTAP compile a trade database that underpins the CliMAT-DGE model
GTM	Global Timber Model
GWP	Global Warming Potential – factors that convert the global warming impact of greenhouse gases to a carbon dioxide equivalent
IAM	Integrated Assessment Model, a model that includes both physical and social science
INDC	Intended Nationally Determined Contribution. Nationally determined targets for stabilising or reducing greenhouse gas emissions.
International Purchasing	The purchasing of carbon units on the international market. For the purposes of this report, this is usually to offset a mitigation shortfall in emissions to meet the emissions reduction target
IPCC	Intergovernmental Panel on Climate Change
Kyoto Protocol	International agreement for reducing greenhouse gas emissions up to 2020
LULUCF	Land Use, Land Use Change and Forestry
MfE	Ministry for the Environment

Mitigation	Reduction in greenhouse gas emissions within New Zealand that results from policy interventions
Mt CO_2-e	Mega Tonnes of Carbon Dioxide equivalent, calculated using IPCC AR4 GWPs
N_2O	Chemical formula for the greenhouse gas nitrous oxide
NAM	North America, a grouping of countries used in the CliMAT-DGE model comprising Canada and the United States of America
Net emissions	Greenhouse gas emissions and removals, including forestry removals
NZIAMS	New Zealand Integrated Assessment Modelling System
OECD	Organisation for Economic Cooperation and Development
QELRC	Quantified Emission Limitation or Reduction Commitment
QELRO	Quantified Emission Limitation or Reduction Objective, also known as a QELRC
RGDP	Real Gross Domestic Product
RGNDI	Real Gross National Disposable Income. A measure of national economic performance, calculated from GDP and financial flows in and out of the country
ROW	Rest of the World, a grouping of countries used in the CliMAT-DGE model that comprises all countries not covered by the other specified regions
Sequestration	A process by which carbon dioxide is removed from the atmosphere and held in solid or liquid form. For the purposes of this report, sequestration predominantly refers to the removal of carbon from the atmosphere to be held in New Zealand forests
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

Negotiations towards a new international climate change agreement under the United Nations Framework Convention on Climate change (UNFCCC) are scheduled to be concluded in Paris in December 2015 and to come into effect from 2020. This paper presents the results of economic modelling carried out to explore possible intended nationally determined contributions (INDCs) that New Zealand might put forward under the agreement.[1]

Under the post-2020 Climate Change agreement, parties have flexibility to define their INDC; however, the contributions are likely to include aspects similar to those in the previous commitment periods where parties take ‘responsibility’ for emissions covered under a specified target and an associated carbon budget. The agreement and rules allowed under the agreement have yet to be finalised, but for the purposes of this modelling, it is assumed that New Zealand will draw on the following to deliver its emission reduction target:

- Domestic abatement – reductions in domestic greenhouse gas (GHG) emissions within New Zealand that result from national policy interventions
- Forestry removals – reductions in domestic GHG emissions as a result of carbon sequestration in New Zealand forests[2]
- The purchase of carbon units on the international market

The purpose of this report is to investigate the economic impact of different emissions reduction targets that New Zealand could include within its INDC. This report does not explore what domestic policies might be used to achieve that (e.g. NZ ETS settings).

Methodology

The analysis applied an integrated assessment modelling (IAM) methodology using the New Zealand Integrated Assessment Modelling System (NZIAMS). A bulk of the assessment is conducted with Landcare Research’s computable general equilibrium (CGE) model *Climate Mitigation and Trade in Dynamic General Equilibrium* (CliMAT-DGE).

It is important to note that no model can forecast the exact state of the New Zealand economy over the medium term. This modelling exercise has been undertaken to estimate the effect that policies might have over the period 2021 to 2030 (i.e. a possible post-2020 ‘commitment period’). IAM and CGE approaches are useful for determining the magnitude and direction of policy impacts, but values presented should not be taken as an estimate of the exact policy outcomes. Some of the model parameters and assumptions in this analysis are uncertain. The results presented here are indicative of the range of possible outcomes, given this specified set of assumptions.

---

[1] This scope extends only to New Zealand’s emission reduction target/s, and does not extend to adaptation, climate finance or other contributions that may be included within New Zealand’s INDC.

[2] The accounting rules for forestry removals are still under discussion and hence this option is not explored in this analysis.

Development of a baseline and comparative scenarios

A 'baseline' economic and GHG emissions profile for the New Zealand economy was initially developed against which different INDCs could be tested. This baseline included projections for anticipated domestic GHG emissions and of the New Zealand economy through indicators such as real gross domestic product (RGDP) and real gross national disposable income (RGNDI) [3] over the commitment period, based on a 'business as usual' scenario in which New Zealand and the rest of the world did not undertake any climate change policy[4]. Key baseline estimates are listed in Table E1. For context, the baseline average gross GHG emissions[5] over the 2021–2030 commitment period are estimated to be 85.4 $MtCO_2$-e/yr, which is about 35% above the 1990 level of 63.3 $MtCO_2$-e.

Table E1: Key baseline estimates for New Zealand over 2021–2030 commitment period

Indicator	2021	2030	2021–2030 Total
Economic Output (Billion 2012 NZD)			
Total RGDP	$285.5	$343.6	$3,144
*Consumption**	$222.9	$271.9	$2,471
Investment	$60.1	$68.4	$641
Exports	$75.3	$90.8	$830
Imports	-$72.7	-$87.4	-$798
Net Exports	$2.6	$3.4	$32
Total RGNDI	$288.7	$348.1	$3,182
New Zealand Emissions / Units (Mt CO_2-e)			
Total Gross Emissions	81.7	88.9	853.6
Carbon Dioxide (CO_2)	41.2	42.9	421.4
Methane (CH4)	29.7	33.8	317.5
Nitrous Oxide (N2O)	9.3	10.6	99.3
Fluorinated Gases (FGAS)	1.5	1.6	15.3

*includes both household and government

Policy Scenarios

This analysis modelled a range of policy scenarios that were compared against the baseline scenario to assess how the costs to New Zealand varied with different domestic GHG emissions reduction targets in the period 2021–2030. Carbon price paths derived from international projections were used to simulate global action on climate change. The

[3] RGNDI is considered a useful indicator of the impact of climate change mitigation policy on national welfare. It consists of GDP minus production in New Zealand by foreign-owned interests plus production overseas by New Zealand owned interests, as well as the direct cost of purchasing international emissions reductions.

[4] CliMAT-DGE was calibrated to New Zealand Government projections for RGDP and GHG emissions.

[5] N.B. All emissions in this report are calculated using Global Warming Potentials (GWPs) from the IPCC Fourth Assessment Report (AR4).

exogenously specified carbon prices were based on an assessment of projections from the Climate Change Authority, Reuters and the IPCC.[6]

Under the modelled policy scenarios, New Zealand commits to reducing the GHG emissions produced across all sectors and gases to a specified level by a given year. However, one of the assumptions is that the agricultural emissions and forestry carbon sequestration are not being used to reach the target, and hence excluded from carbon pricing. The target is be set relative to a base year (e.g. 10% below 1990 emissions), with a "carbon budget" of allowable emissions over the commitment period calculated based on emissions reaching this target by a specified year (e.g. 2030). Any shortfall in domestic emissions reductions relative to the carbon budget would be made up by purchasing international carbon units, unless specified otherwise.

A total of six policy scenarios were conducted for this analysis. The 'core' policy scenario (scenario B1L) evaluated a reduction target of 10% decrease below 1990 emission levels by 2030, and assumed a global carbon price that is \$8/tCO_2-e in 2015 and gradually increases to \$50/tCO_2-e by 2030. Achieving this target requires a 260 Mt CO_2-e reduction in emissions relative to the baseline over the 10-year commitment period (Table E2).

Three other scenarios assumed the same carbon price path as scenario B1L, but varied the reduction target to between a 5% decrease to a 40% decrease below 1990 emission levels by 2030 (scenarios Q1L–Q3L). Scenario P1L evaluated the impact of a 10% decrease below 1990 emission levels by 2030 target, but assumed a higher global carbon price than the core scenario that reaches \$135/tCO_2-e by 2030.

The final policy scenario evaluated the effect if New Zealand faced a unilateral climate policy and could not purchase international offsets (U1L). This scenario did not model an explicit emissions reduction target, but rather assessed the level of domestic emissions reductions that could be achieved if New Zealand faced a carbon price of \$300/tCO_2-e over the entire commitment period while the rest of the world continued to face the global carbon price that reached \$50/tCO_2-e by 2030.

[6] Ministry for the Environment 2014. Carbon price path scenarios: 2015–2030.

Table E2: Scenario policy analysis assumptions

Scenario	Reduction Target (Mitigation needed over 2021-2030 commitment period)	GHG emissions priced[7]		GHG Price Path ($/t$CO_2$-e)	
		Non-agriculture and forestry	*Agriculture and forestry*	*New Zealand*	*Rest of the World*
Baseline	0 MtCO2-e	Not priced	Not priced	None	None
B1L[8]	10% below 1990 levels by 2030 (260 MtCO2-e)	Priced	Not priced	$25 in 2020, increasing to $50 in 2030	$25 in 2020, increasing to $50 in 2030
Q1L	5% below 1990 levels by 2030 (242 MtCO2-e)	Priced	Not priced	$25 in 2020, increasing to $50 in 2030	$25 in 2020, increasing to $50 in 2030
Q2L	20% below 1990 levels by 2030 (305 MtCO2-e)	Priced	Not priced	$25 in 2020, increasing to $50 in 2030	$25 in 2020, increasing to $50 in 2030
Q3L	40% below 1990 levels by 2030 (389 MtCO2-e)	Priced	Not priced	$25 in 2020, increasing to $50 in 2030	$25 in 2020, increasing to $50 in 2030
P1L	10% below 1990 levels by 2030 (260 MtCO2-e)	Priced	Not priced	$85 in 2020, increasing to $135 in 2030	$85 in 2020, increasing to $135 in 2030
U1L	Not defined	Priced	Not priced	$300 over entire commitment period	$25 in 2020, increasing to $50 in 2030

Summary of Policy Analysis

Estimates for the 'core' B1L policy scenario with a 10% below 1990 GHG emission reduction target and a carbon price that reaches up to $50/t$CO_2$-e by 2030 indicate that domestic GHG emissions are reduced by about 10.6% relative to the baseline over the commitment period. This results in approximately 90 Mt CO_2-e of domestic abatement. As a result, New Zealand would still need to purchase 170 million international carbon units, costing a total of $6.7 billion (Table E3).

A target of a 10% reduction of emissions relative to 1990 levels by 2030 would be associated with a decrease in RGNDI over the commitment period of about 0.6%. To put this in perspective, a decrease in RGNDI of this magnitude would see the same level of RGNDI per capita reached about 6 months later than in the baseline scenario.

[7] 'Priced' means that a carbon price is assigned to the economic sector from which these emissions are produced under the NZ ETS or other carbon pricing mechanisms.

[8] The scenarios are identical to those described in Infometrics (2015). The L is used to differentiate the results between Infometrics and Landcare.

RGDP is estimated to decrease by 0.23% relative to the baseline. The impact to RGDP is less than RGNDI because it does not directly account for the cost of purchasing international units. The investment component is expected to have the largest decline (-1.6%). Total consumption (private and government combined) is not estimated to decline much (-0.1%) because the reductions in household consumption associated with higher prices of goods and services are nearly offset from the increase in government consumption as a result of the additional revenue earned from placing a price on GHG emissions[9]. Both imports and exports are expected to decline as a result of the carbon price policy being applied at the global level, but imports decline by a greater amount, thereby improving New Zealand's balance of trade by almost 13% relative to the baseline.

The largest source of domestic GHG emission reductions in scenario B1L is from the conversion of fossil-based electricity to renewables (61% of total domestic reductions), followed by manufacturing (29%). Transport provides limited abatement over the commitment period (6%) due to the lack of viable cost-effective substitutes, as do primary energy refining and processing (4%) due to its small contribution to New Zealand's baseline emissions profile. There is minimal change in agricultural and forestry sector GHGs relative to their baseline trajectories because they are not priced under these scenarios.

Output for most sectors is estimated to decline by less than 1% relative to the baseline. The key exception is coal and natural gas extraction, which decline by about 35% as a result of New Zealand's electricity sector becoming 95% renewable generation by 2030, compared to 83% in the baseline.

Table E3: Core policy scenario (B1L) estimated impacts to New Zealand (2021–2030)

Indicator	**B1L (10% below 1990 emissions)**	
	Total value (2021–2030)	*% change from baseline*
Economic Indicators (billion $)		
Total RGDP	$3,137	–0.23%
Consumption	$2,470	–0.05%
Investment	$631	–1.60%
Exports	$825	–0.61%
Imports	–$789	–1.14%
Net Exports	$36	12.83%
Total RGNDI	$3,163	–0.59%
International Permit Purchasing Cost	$6.7	n/a
GHG Emissions ($MtCO_2$-e)		
Total Emissions	764	–10.6%
Total Domestic Reduction	90	n/a
International Purchases	170	n/a
Cumulative GHG Reduction	260	n/a

[9] The carbon pricing mechanism effectively acts as a tax on GHG emissions in the CGE model, thereby earning revenue for the government in the form of payments from emitters.

A number of alternatives to the core scenario were modelled to assess the range of impacts of different factors influencing the cost of New Zealand's post-2020 emission reduction target. This includes changing the level of the target (Q1L-Q3L), increasing the global carbon price (P1L), and whether emissions reduction targets can be met without purchasing international units (U1L). A summary of the key impacts are listed in Table E4.

Table E4: Estimated impacts to New Zealand (2021–2030), alternative scenarios

Indicator	Q1L (5% below 1990)	Q2L (20% below 1990)	Q3L (40% below 1990)	P1L (10% below 1990)	U1L (no explicit target)
Economic Indicators					
Total RGDP (% chg from base)	–0.23%	–0.23%	–0.24%	–0.64%	–2.13%
Consumption	–0.04%	–0.07%	–0.12%	–0.11%	–0.09%
Investment	–1.60%	–1.61%	–1.63%	-2.79%	–5.04%
Exports	–0.61%	–0.58%	–0.54%	–2.10%	–4.01%
Imports	–1.12%	–1.20%	-1.29%	-2.26%	-0.14%
Net Exports	12.08%	14.72%	18.23%	1.85%	-100.5%
Total RGNDI	–0.56%	–0.63%	–0.74%	–1.35%	–2.25%
Int'l Purchasing Cost (bil $)	$5.8	$8.2	$11.4	$12.2	$0.0
GHG Emissions ($MtCO_2$-e)					
Emissions (% chg from base)	–10.6%	–10.6%	–10.6%	–17.7%	-29.3%
Total Domestic Reduction	90	90	90	151	250
International Purchases	151	214	299	109	0
Cumulative GHG Reduction	242	305	389	260	250

Some important findings from the scenario analysis include:

- The estimated impacts to New Zealand's RGNDI over the commitment period vary depending on the emissions reduction target, assuming the same global carbon price of $50/tCO_2$e. A target of 5% below 1990 emissions is estimated to reduce RGNDI by –0.56% relative to the baseline while a 40% below 1990 emissions target has an impact of –0.74%. The impacts to RGDP for the same targets range from –0.23% to –0.24%. The effect on RGDP is less variable because (a) the indicator does not explicitly account for the cost of purchasing international offsets, and (b) the effect of the policy on consumption and investment are offset by a counter-effect on net exports.
- An increase in the global carbon price relative to the core scenario will incentivise more domestic abatement, but it will also have a greater impact on the New Zealand economy. A carbon price that is estimated to reach $135/tCO_2$-e by 2030 is estimated to reduce New Zealand's GHG emissions over the commitment period by 17.7% relative to the baseline (and 18% above 1990), but also to reduce RGNDI and RGDP by 1.35% and 0.64%, respectively.
- New Zealand is unlikely to achieve emission reduction targets below 1990 levels of emissions through domestic GHG emissions abatement alone without an unrealistically large carbon price (and/or not pricing agriculture and forestry emissions). This is due to the mix of New Zealand's economic and emissions profile. For example, the country already produces a high proportion of its electricity from renewable resources and hence has limited opportunities for further emissions abatement from the sector. A large proportion of its emissions are from agriculture (nearly 50%, on average), which is not

priced in these policy scenarios, and can be difficult to mitigate given the current set of available technologies.

- New Zealand's carbon price would have to be at least \$300/tCO_2-e in order for the country to be close to achieving a target of 10% below 1990 emissions reduction without having to purchase international offsets (and without pricing agriculture or forestry emissions). This unilateral approach would result in a -2.25% reduction in RGNDI and a 2.1% reduction in RGDP, while reducing gross GHG emissions by almost 30% relative to the baseline (i.e. about 7% below 1990 emissions). This approach has large consequences for New Zealand's balance of trade, as the relatively high domestic carbon price reduces the country's competitiveness and firms and consumers purchase more goods from overseas. The key sectors impacted by the high price are primary energy, energy-intensive manufacturing, and transport, while food and wood product manufacturing and services are relatively unaffected.
- The purchase of international carbon units will initially form an important mitigation response for New Zealand for the post-2020 Climate Change agreement until domestic GHG emissions can be reduced or the cost of domestic GHG emissions abatement becomes less than the price of international carbon units. However, there are economic risks associated with a dependency on international purchasing due to the potential fluctuation in the price of carbon units.

Box E1 – Comparing model estimates with Infometrics (2015)

A similar modelling exercise was conducted by Infometrics (2015) who used the static-CGE model ESSAM to analyse the same six scenarios presented in this report. Both models estimated that there would be negative economic impacts for all policies, but CliMAT-DGE typically estimated that New Zealand would reduce a greater level of GHG emissions at lower costs compared to ESSAM (Table E5).

Table E5: ESSAM and CliMAT-DGE estimated impacts to New Zealand (2021–2030)

Indicator	ESSAM B1	C-DGE B1L	ESSAM Q3	C-DGE Q3L	ESSAM P1	C-DGE P1L	ESSAM U1	C-DGE U1L
RGDP	–0.9%	–0.2%	–1.1%	–0.2%	–2.0%	–0.6%	–3.1%	–2.1%
RGNDI	–1.2%	–0.6%	–1.7%	–0.7%	–2.5%	–1.4%	–2.4%	–2.3%
Total GHG	–5.7%	–10.6%	–5.7%	–10.6%	–10.8%	–17.7%	–17.1%	–29.3%

There are many differences between the two models that can lead to varied impact estimates. Further investigation revealed that the two most significant reasons are: (a) the treatment of past and future substitution between fossil fuel generation and renewables generation in electricity, and (b) whether the rate of return on investment in New Zealand can be expected to decline (or not) vis à vis the rest of the world when the our economic competitiveness is affected by a carbon price and/or an emissions responsibility target. Another factor that is likely to influence the results is that CliMAT-DGE has the assumption of perfect foresight where agents can gradually make changes in savings and consumption behaviour in anticipation of an anticipated emissions reduction policy, thereby smoothing impacts over time.

As a result of these differences, we could expect ESSAM to show relatively higher costs of an emissions reduction policy. That being said, each model has its relative strengths and can provide useful insight on the impacts to various sectors of the New Zealand economy.

1 Introduction

Negotiations towards a new international climate change agreement under the United Nations Framework Convention on Climate change (UNFCCC) are scheduled to be concluded in Paris in December 2015 and to come into effect from 2020. This paper presents the results of economic modelling carried out to explore possible intended nationally determined contributions (INDCs) that New Zealand might put forward under the agreement.[10]

Under the post-2020 Climate Change agreement, parties have flexibility in defining their INDC; however, the contributions are likely to include aspects similar to those in the previous commitment period where parties take 'responsibility' for emissions covered under a specified target and an associated carbon budget. The exact rules allowed under the agreement have yet to be finalised, but for the purposes of this modelling, it is assumed New Zealand will draw on the following to deliver its emission reduction target:

- Domestic abatement – reductions in domestic greenhouse gas (GHG) emissions within New Zealand that result from national policy interventions
- Forestry removals – reductions in domestic GHG emissions as a result of carbon sequestration in New Zealand forests[11]
- The purchase of carbon units on the international market

The key objective of this report is to evaluate how setting different emissions reduction targets might impact on New Zealand's economy over the period 2021–2030 (i.e. a possible post-2020 "commitment period"). Policy settings that might be implemented domestically by New Zealand were not investigated.

For the policy scenarios conducted in this report, New Zealand is assumed to commit to reducing the GHG emissions produced by all sectors and gases to a specified level by a given year. However, we assume that agricultural emissions and forestry carbon sequestration are not being used to reach the target, and hence excluded from carbon pricing. A target would be set relative to a base year (e.g. 1990), with a "carbon budget" of allowable emissions over the entire commitment period calculated based on this target.[12] An example carbon budget for the commitment period is shown in Figure 1. Any shortfall in domestic emissions reductions relative to the carbon budget would be made up by purchasing international carbon units.

---

[10] This scope extends only to New Zealand's emission reduction target/s, and does not extend to adaptation, climate finance or other contributions that may be included within New Zealand's INDC.

[11] The accounting rules for forestry removals are still under discussion and hence this option is not explored in this analysis.

[12] Emissions and carbon budgets are calculated using global warming potentials (GWPs) from the IPCC Fourth Assessment Report (AR4).

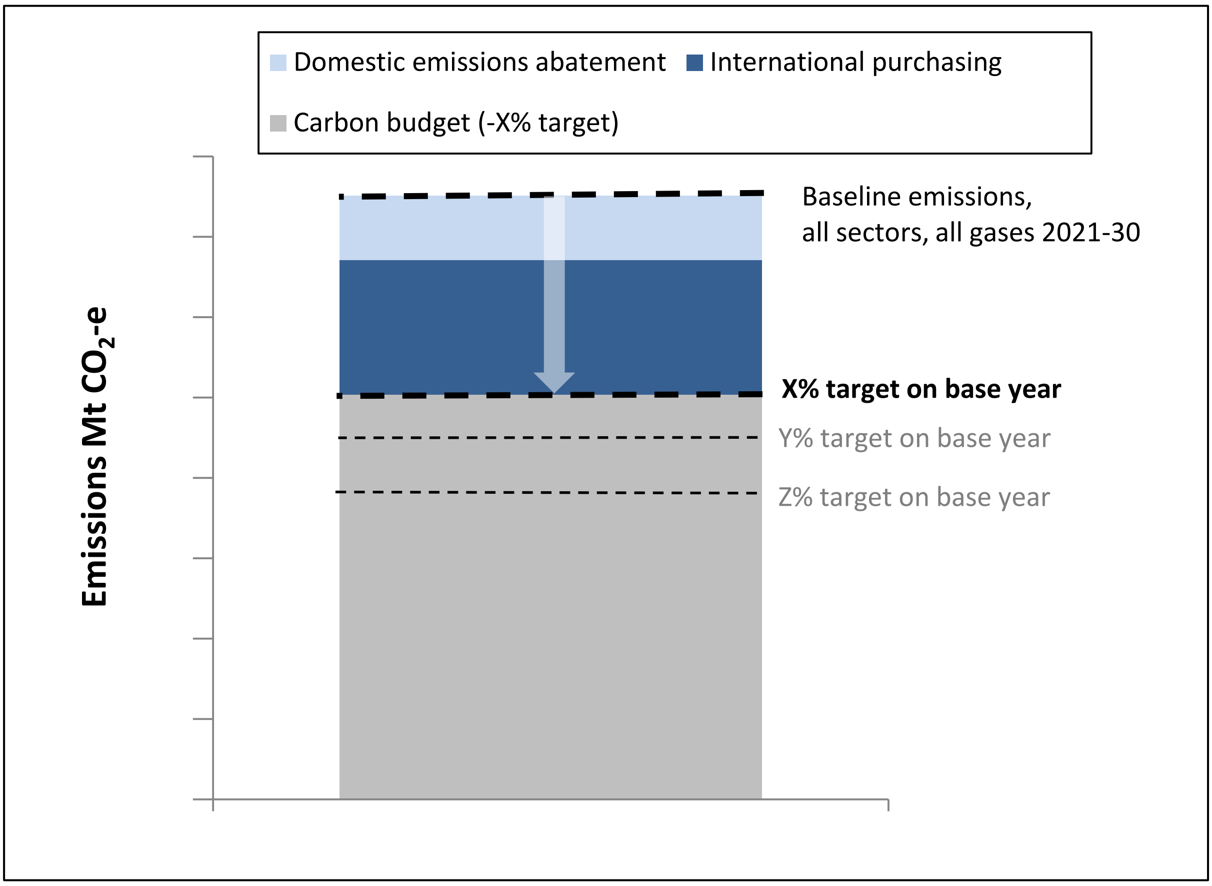

Figure 1: Example of how to estimate international offset purchasing to meet New Zealand's carbon budget for the contribution cycle if the target is at a level X.

Methodology

The analysis uses an integrated assessment modelling (IAM) approach, the New Zealand Integrated Assessment Modelling System (NZIAMS). A bulk of the assessment is conducted with CliMAT-DGE, a multi-regional and multi-sectoral dynamic computable general equilibrium (CGE) model that covers all regions of the globe (Fernandez & Daigneault 2015). Additional impacts to the forestry sector were modelled using the Global Timber Model (GTM) (Daigneault et al. 2012).

A 'baseline scenario' defined as "no international or domestic actions being taken regarding GHG mitigation" was initially developed. Six policy scenarios were then modelled to assess the impacts from New Zealand's emission reduction target for the 10-year period 2021–2030 (i.e. 'the commitment period').

In the scenarios implemented, there is no '1 for 2' concession,[13] no \$25/tCO_2-e cap, and no allocations to trade-exposed industries as currently featured within New Zealand's Emissions Trading Scheme (ETS). Unless noted otherwise, the rest of the world faces the same GHG emission price as New Zealand, and that price is applied to the same sectors and GHGs. This is done to help factor out some of the potential 'terms of trade' effects. For example, if New Zealand faces a higher carbon price relative to the rest of the world, it could see a significant decline in exports due to loss of competitiveness.

For all scenarios it is assumed that New Zealand takes a target ending in 2030, with the commitment period defined as the period 2021–2030.[14] Furthermore, it is also assumed that New Zealand does not "carry over" any excess carbon credits from the transitional period 2013–2020 towards the post-2020 commitment period. This means that all domestic emissions reductions or international purchases to meet the 2021 to 2030 target must occur during that time period.

Emissions and removals from forestry are excluded from this modelling report. Uncertainty about the exact detail of accounting settings after 2020 makes it difficult to quantify the future effect of forestry and land use on New Zealand's future emissions and removals after 2020. Depending on the accounting assumptions and rules applied after 2020, New Zealand's forestry and land use could either be a carbon sink or a source of emissions.

For this analysis, the CliMAT-DGE model was aggregated to six regions (i.e. New Zealand, Australia, North America (NAM), Rest of OECD, China, and all remaining countries in the rest of the world (ROW)), and 18 economic sectors (e.g. primary production, energy, manufacturing, transport, etc.). For most of this document, we further aggregated regions to New Zealand and Rest of the World (ROW) for ease of reporting (see Table 1).

The report is organised as follows: Section 2 describes the integrated economic model, modelling method, and scenarios; Section 3 shows the calibrated baseline estimates; Section 4 presents the policy scenario analysis.

[13] In the current ETS, some sectors only need to surrender one New Zealand Unit (NZU) for two units of emissions.
[14] Negotiation of the commitment period length is currently ongoing, and could see a commitment period length of 2021–2025 or some other variant.

2 Methodology

We used an integrated economic modelling system (NZIAMS) to estimate the potential economic impacts of GHG emissions reduction policy scenarios. A bulk of the modelling in this report was done with CliMAT-DGE, a multiregional and multi-sectoral dynamic computable general equilibrium (CGE) model that covers all regions of the globe. Additional impacts to the forestry[15] sector were modelled using the partial equilibrium Global Timber Model (GTM), as it can model the sector in more detail than the CGE model. The key components of the modelling system are diagrammed in Figure 2.

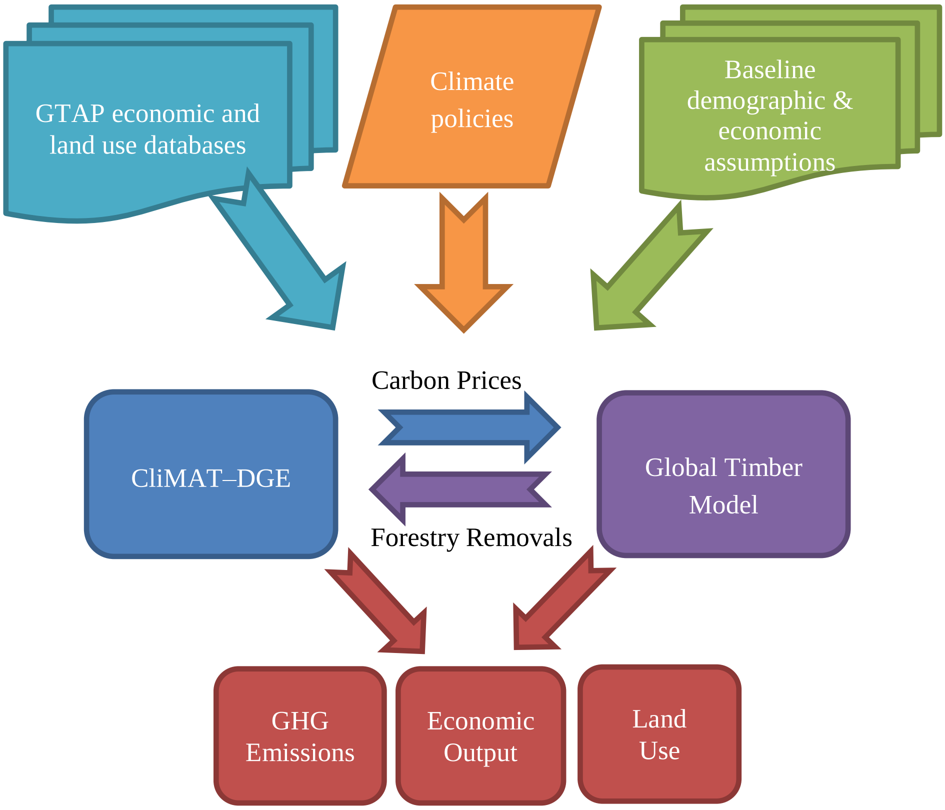

Figure 2: Economic modelling system linkages.

[15] Emissions/carbon sequestration from the forestry sector is referred to in this report as land use, land use change, and forestry (LULUCF) or forest carbon sequestration.

2.1 CliMAT-DGE

CliMAT–DGE is a multiregional, multi-sectoral, forward-looking dynamic computable general equilibrium (CGE) model with a relatively long time horizon of approximately 100 years (Fernandez & Daigneault 2015). CliMAT-DGE's framework is based on the Massachusetts Institute of Technology's (MIT's) Emission Prediction and Policy Analysis (EPPA) Model (Babiker et al. 2008), but with a strong focus on aggregate sectors and trade partners that are important to New Zealand's economy.

The key purpose of the model is to analyse the responses of the New Zealand economy when changes in domestic and foreign environmental policy and/or trade patterns occur. The model represents all transactions that take place within the economy, in a regional, national or worldwide context, for a particular year. Because the model has been calibrated for multiple years, it is suitable for dynamic analysis in order to incorporate long-term issues such as climate change and GHG emissions reduction policies.

CliMAT-DGE primarily uses the Global Trade Analysis Project (GTAP) version 8 dataset that accounts for 129 regions of the globe and 57 economic sectors.[16] CliMAT-DGE is calibrated to represent observed data from 2007, the most recent GTAP year. The model requires information and data on projected changes in regional population, GDP, technology, and consumption growth. For this purpose, the model incorporates realistic projections of key macroeconomic (e.g. labour productivity) and other (e.g. energy efficiency) variables and has been developed from a number of sources. The economic baseline is primarily constructed on a growth scenario developed by the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII); The World Economy in 2050: a Tentative Picture (Fouré et al. 2010). That scenario in turn is built on economic forecasts of the International Monetary Fund, labour force projections of the International Labour Organisation, and demographic projections of the United Nations. Energy supply and efficiency projections are based primarily on several 2009 through to 2012 editions of the World Energy Outlook (International Energy Agency 2013). The modelled baseline scenario assumes that no explicit climate policies are being implemented in any regions of the world.

For computational efficiency, CliMAT-DGE model is currently configured for 6 regions and 18 aggregated sectors (including energy and land sectors). The model is tailored to assess policy impacts on the New Zealand economy, which is included as a separate region. The primary production sectors are aggregated to focus on the land and food sectors as these are the most important for the New Zealand economy. The energy sectors include major GHG emitters as well as carbon free electricity which make up a significant part of New Zealand's energy share.

The model's regional and sectoral aggregations for this anlaysis are listed in Table 1. While all policy scenarios were conducted at the six region-level, the results in this report are aggregated into NZ and Rest of the World (ROW) for ease of comparison.

---

[16] For further details, see: https://www.gtap.agecon.purdue.edu/databases/v8/

Table 1: Regional, industry, energy and other sectors used in CliMAT-DGE

Name	Abbreviation	Notes
	Regions	
New Zealand	NZL	
Australia	AUS	
China	CHN	
North America	NAM	USA, Canada
Rest of OECD	OECD	Rest of OECD + Singapore, Chile, Turkey, and Korea
Rest of the World	ROW	All other GTAP regions
	Agriculture/Primary Production Sectors	
Grains including rice	GRA	
Other crops	CRO	
Oil seeds and sugar cane	OSC	
Plant based fibres	PFB	
Bovine cattle, sheep and goats, horses	CTL	
Raw milk	RMK	
Forests	FST	
	Energy and Electricity Sectors	
Coal	COA	
Oil	OIL	
Gas	GAS	
Petroleum, coal products	P_C	
Fossil electricity	EFS	
Carbon-free electricity	ECF	
Coal-fired electricity with carbon capture and sequestration	CEC	
	Manufacturing/Industrial/Value Added Sectors	
Food products	FOO	
Harvested wood products	HWP	
Energy-intensive manufacturing	EMT	
Non-energy-intensive manufacturing	NSV	
Transport	TPT	All transport-related services (e.g. air, water, road)

More details on CliMAT-DGE are provided in Appendix 3. The more technical aspects of the model are included in Fernandez and Daigneault (2015).

2.2 Policy Scenarios

The policies assessed in this report were implemented in in the model by imposing an exogenously specified price on sector-based GHG emissions. This price is applied to all GHGs and all sectors of the economy with the exception of agriculture and forestry, and across all regions of the globe. Agriculture emissions have not been priced as it is unlikely that New Zealand or other countries will implement agricultural pricing until there are feasible measures to reduce agricultural emissions.

When a price is placed on GHG emissions, firms will reduce their activities that produce GHGs up until the point that their marginal cost of reducing emissions are equal to their marginal benefits.

The core carbon price path (Table 2) was specified exogenously and based on plausible trajectories for post-2020 carbon prices globally published in international literature by the IPCC, Australian Climate Change Authority and Reuters (MfE 2014b). Carbon prices were assumed to be uniform across all regions of the globe, unless specified otherwise. In reality, however, carbon prices and the price faced by firms and consumers may differ between regions. In addition, carbon pricing may be one of many mechanisms utilized by countries to implement their climate change policy.[17]

Table 2: Exogenously specified GHG price path, climate change policy scenarios

Year	GHG Price ($/t$CO_2$-e)
2007–2015	$8.00
2016	$11.40
2017	$14.80
2018	$18.20
2019	$21.60
2020	$25.00
2021	$27.50
2022	$30.00
2023	$32.50
2024	$35.00
2025	$37.50
2026	$40.00
2027	$42.50
2028	$45.00
2029	$47.50
2030–end	$50.00

[17] For example, emissions will also be sensitive to a range of other policies, including the encouragement of public transport, fuel levies, and new building codes and standards.

In addition to specifying an exogenous GHG price path, we also set New Zealand's total emissions over the commitment period (2021–2030) at a specific cumulative GHG reduction target (e.g. 10% reduction from 1990[18]). This was set as a constraint in the model: if the target was not met through a domestic GHG abatement, then New Zealand had to purchase additional GHG units from the international market (i.e. 'trading' of 'purchasing offsets'). If trading was required, then it was assumed New Zealand did this evenly over the commitment period rather than buying all the GHG offsets to meet the cumulative target in a particular year. In addition, the international reductions were assumed to be purchased at the GHG price of that given year.[19] More details on how GHG reduction policies are modelled in CliMAT-DGE, including the purchasing on international GHG emissions reductions, are provided in Fernandez and Daigneault (2015).

Additional scenarios were conducted to test the impact of alternative GHG price trajectories and emissions reduction targets. The results of these alternative scenarios are presented in Section 4.

2.3 Model outputs

All GHG emissions are reported as carbon-dioxide equivalent (CO_2-e), where equivalent values were converted using IPCC AR4 global warming potentials (GWP). All monetary outputs are reported in 2012 New Zealand dollars, which were scaled from the standard CliMAT-DGE output of 2007 US dollars by using a combination of the New Zealand Treasury CPI and the World Bank GDP deflator.[20] Although the models were run for several decades, most outputs focus on the modelled commitment period (2021–2030).

2.4 Strengths and limitations of CGE Modelling

An advantage of CGE modelling is that it considers how policy shocks (i.e. policy changes) affect the allocation of resources between industries and sectors in an economy. This is essential if we are to get a good macroeconomic understanding of how policy changes might affect the structure of an economy. The application of CGE modelling to estimate the impacts of climate change mitigation policy scenarios is now widespread, as CGE models are well suited to examining the inter-sectoral and inter-country effects of pricing carbon dioxide and other greenhouse gases. However, climate change policy modellers still face a number of common challenges, including:

- Estimating abatement costs – the costs to individual sectors (and hence the macroeconomic costs and benefits) of mitigating climate change vary depending

[18] N.B. An X% target on 1990 implies this level of annual emissions is reached in the last year of the commitment period. This means that average reductions over the commitment period are less than X%. See http://unfccc.int/resource/docs/2010/tp/03r01.pdf.

[19] N.B. The policy also did not include the option to bank emissions, which could have incentivised firms to purchase emissions at a lower GHG price in early periods and then surrender them during later periods when the GHG price was higher.

[20] This approach results in a factor of 1.62 2012 NZD per 2007 USD.

on the ability of firms to reduce emissions in an economically efficient way. The ability of firms to adjust is largely dependent on the possibility of substituting less emissions-intensive production processes or materials and the development of cost-reducing technological advances. These effects are uncertain and require the use of assumptions.

- Most CGE models, including CliMAT-DGE, do not model endogenous technological improvements. Instead, it is common to run scenarios in which technological change is induced by a carbon price that can be examined.
- Accurately accounting for land use changes – although CGE models to assess climate change policies are becoming more sophisticated, they are not yet able to fully capture the opportunity costs of alternative land uses and land-based mitigation strategies. This is largely due to a lack of high quality, economy-wide data, specifically, consistent global land resource and non-CO_2 GHG emissions databases linked to underlying economic activity and GHG emissions and sequestration drivers. As a result, CliMAT-DGE has been designed to link with more detailed land use models such as the New Zealand Forest and Agriculture Regional Model (Daigneault et al. 2014).
- The dynamic modelling of forestry land use, particularly in static CGE models, is especially problematic, due to long investment timeframes and difficulties capturing the inter-temporal aspects of forest carbon management. As a result we link CliMAT-DGE to the Global Timber Model (GTM) to evaluate the forest sector impacts in more detail.

Another source of potential bias of CGE models is the omission of full marginal income tax schedules. As a result the models will underestimate the welfare gains from lower taxation to households.

Finally, CGE models do not generally capture non-economic costs and benefits. For example, CGE models do not generally capture changes to social and health outcomes that may arise from climate change mitigation policies, even though these outcomes may have real economic costs and benefits[21].

More details on the strengths and limitations of CGE modelling can be found in Infometrics (2015).

[21] N.B. NZIAMS can model the impacts of climate change on agricultural yields, but this option was excluded from this analysis.

3 Baseline Calibration

CliMAT-DGE was initially calibrated to a 'baseline' or reference case which all policy scenario analysis is referenced against. In CGE modelling it is imperative to have a baseline which the scenarios can be measured against. The baseline scenario estimates what will happen if the economy continued to evolve along a business-as-usual (BAU) pathway (i.e. without any shocks to the model like a carbon price). Existing governmental policies are implicit in the baseline calibration. Any changes to these policies or the occurrence of exogenous shocks (e.g. unanticipated recessions) would change the baseline trajectory. Careful modelling should account for the interactions and confounding effects of implementing multivariate scenarios.

3.1 GHG emissions

CliMAT-DGE was calibrated so that New Zealand's emissions closely aligned with the projections in the 6th National Communications (MfE 2014a), which were updated to use the A4 GWPs (Figure 3). CliMAT-DGE estimates gross emissions to increase from about 80 $MtCO_2$-e in 2007 to 89 $MtCO_2$-e in 2030, with emissions averaging 85.4 $MtCO_2$-e/yr over the commitment period (35% above 1990 levels). The figure shows that gross emissions are closely aligned with MfE projections over the entire time period, particularly for energy/industrial and total gross emissions. The model estimates greater emissions for the transport sector, suggesting that it could be a larger source of abatement than the MfE projection. CliMAT-DGE estimates less baseline emissions from the agriculture sector than MfE, although this is of little consequence because the sector is not priced in any of the scenarios considered for this report.

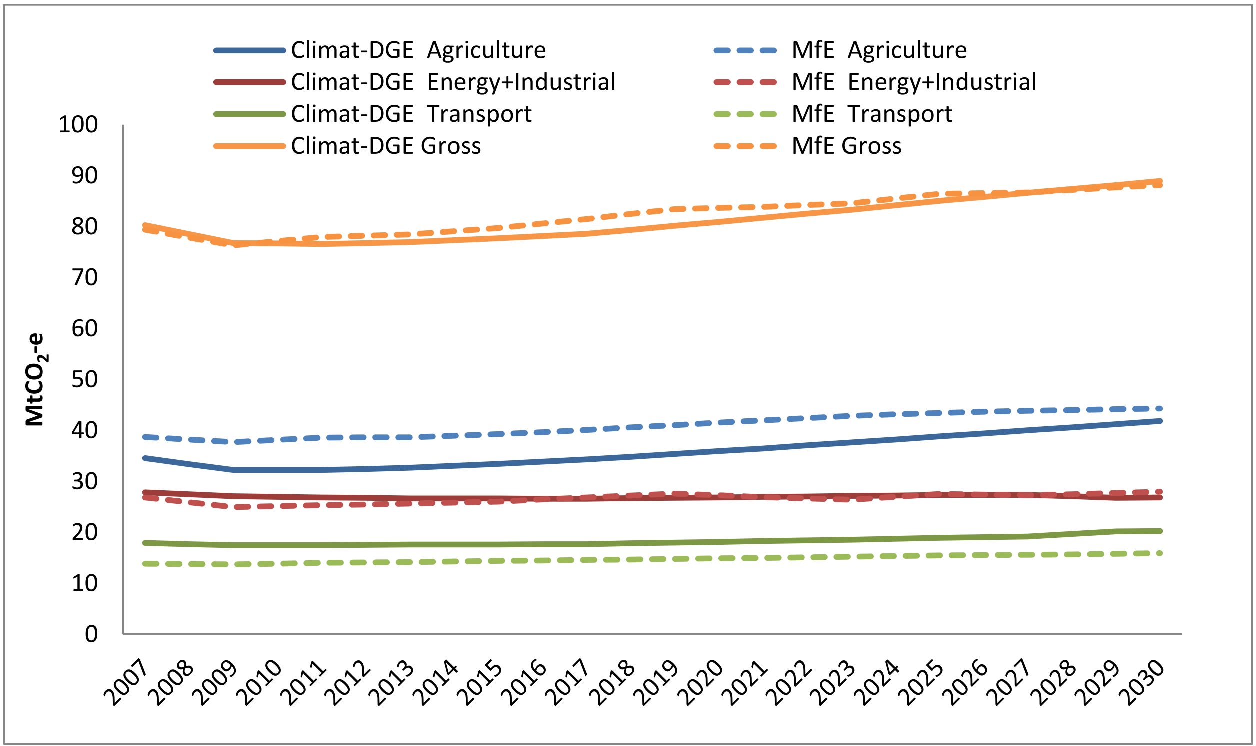

Figure 3: New Zealand gross GHG baseline emissions by sector ($MtCO_2$-e).

Figure 4 shows the projected baseline GHG emissions by individual gas. Carbon dioxide (CO_2) is estimated to be relatively constant over time, while all three non-CO_2 gases are estimated to increase over time at a rate of about 1%/yr. Most of the aggregate increases in non-CO_2 emissions are estimated to occur in the agricultural sector, which is also consistent with MfE projections.

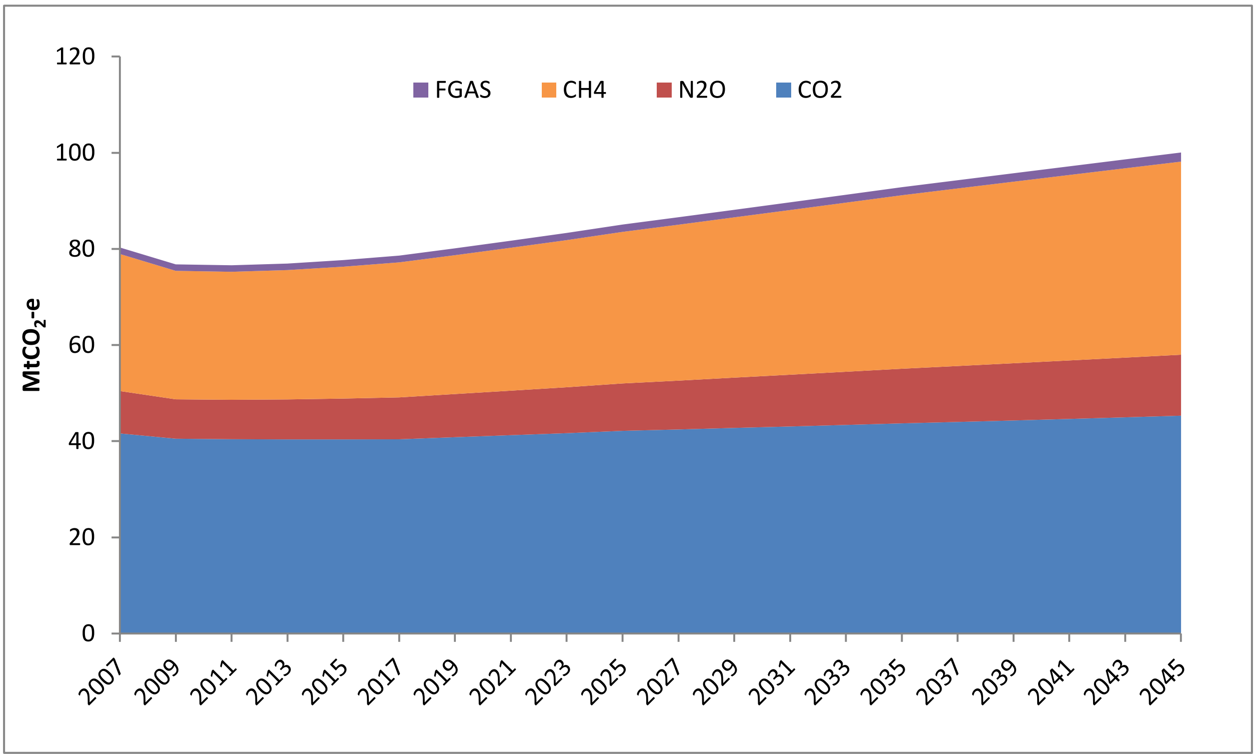

Figure 4: New Zealand baseline GHG emissions by gas ($MtCO_2$-e).

3.2 Economic Indicators

Real gross domestic product (RGDP) measures the value of all the finished goods and services produced within a nation's borders, of which its key components are private and government consumption, investment, exports, and imports. The CliMAT-DGE baseline RGDP projection by each component is shown in Figure 5. The model estimates that total RGDP is estimated to increase from $201 billion in 2007 to $344 in 2030. For context, the trajectory of RGDP over the modelled period is relatively similar to the long-term projections published by the NZ Treasury.

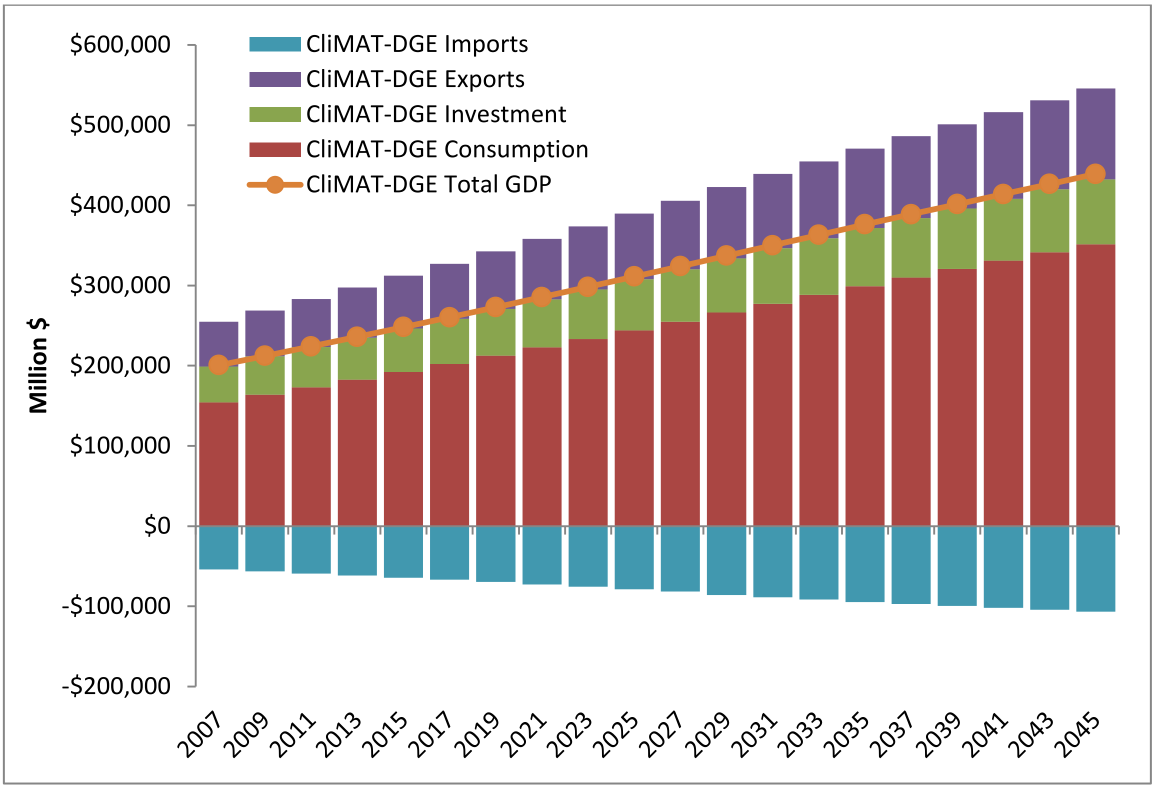

Figure 5: Baseline New Zealand RGDP Projection.

Real gross national disposable income (RGNDI) measures the real purchasing power of national disposable income. It includes RGDP, but also takes into account changes in the terms of trade, and real gains from net investment and transfer income with the rest of the world. In other words, it is a measure of the volume of goods and services over which New Zealand residents have command, and is sometimes used to represent national welfare. CliMAT-DGE estimates that RGNDI will increase almost linearly from about $200 billion in 2007 to $348 billion in 2030.

3.3 Baseline Summary

A summary of some aggregate key estimates from the baseline for the commitment period are listed in Table 3. Sector-based baseline estimates are listed in Table 4. These are the values that the following scenarios will be compared to for the policy impact assessment.

Table 3: Key New Zealand baseline estimates, 2021–2030 commitment period

Indicator	2021	2030	2021–2030 Total
Economic Output (Billion 2012 NZD)			
Total RGDP	$285.5	$343.6	$3,144
*Consumption**	$222.9	$271.9	$2,471
Investment	$60.1	$68.4	$641
Exports	$75.3	$90.8	$830
Imports	–$72.7	–$87.4	–$798
Net Exports	$2.6	$3.4	$32
Total RGNDI	$288.7	$348.1	$3,182
New Zealand Emissions / Units (Mt CO_2-e)			
Total Gross Emissions	81.7	88.9	853.6
Carbon Dioxide (CO_2)	41.2	42.9	421.4
Methane (CH4)	29.7	33.8	317.5
Nitrous Oxide (N2O)	9.3	10.6	99.3
Fluorinated Gases (FGAS)	1.5	1.6	15.3

*includes both household and government

Table 4: Key New Zealand sector-based baseline estimates, 2021–2030 commitment period average

CliMAT-DGE Sector	Abbrev.	GHGs ($MtCO_2$-e)	Output (billion $)	Exports (billion $)	Imports (billion $)
Plant-based fibres	PFB	0.03	0.04	0.00	0.01
Bovine cattle, sheep and goats, horses	CTL	22.83	7.80	0.49	0.19
Dairy (raw milk)	RMK	14.91	15.99	0.00	0.00
Coal Mining	COA	0.38	0.65	0.40	0.03
Oil	OIL	0.04	0.49	0.11	2.80
Gas	GAS	0.52	1.48	0.00	0.00
Petroleum, coal products	P_C	0.00	0.00	0.00	0.16
Grains, including rice	GRA	0.11	0.56	0.03	0.16
Oils and sugar cane	OSC	1.13	4.37	0.52	4.23
Other crops	CRO	1.14	6.33	1.74	1.51
Food products	FOO	1.31	59.10	29.27	6.10
Timber, pulp, & paper products	HWP	0.49	29.36	5.56	3.76
Energy-intensive manufacturing	EMT	5.10	37.80	9.30	12.83
Non-energy-intensive manufacturing	NSV	10.11	449.24	25.20	41.98
Transport	TPT	19.11	30.50	9.49	5.99
Fossil electricity	EFS	8.16	1.75	0.00	0.00
Carbon-free electricity	ECF	0.00	8.54	0.00	0.00
Forestry	FST	n/a	5.62	0.88	0.05
New Zealand Total	Total	85.4	659.6	83.0	79.8

4 GHG Emission Reduction Policy Scenarios

This section presents the modelled estimates of the six GHG emissions reduction policy scenarios. The results focus on the economic impacts and sources of abatement for New Zealand to meet an emission reduction target for all GHG emissions produced across all sectors of the economy over the 2021–2030 'commitment period'

Most of the modelled scenarios follow a policy approach that is similar to the commitments taken by New Zealand for commitment period 1 of the Kyoto Protocol (2008–2012) and the transitional period (2013–2020). That is, New Zealand commits to reducing the GHG emissions produced across most sectors of the economy (with exception of forestry and agriculture) and all gases to a specified level by a given year. A target would be set relative to a base year (e.g. 1990), with a "carbon budget" of allowable emissions over the entire commitment period calculated based on this target. Any shortfall in domestic emissions reductions relative to the carbon budget would be made up by purchasing international carbon units.

Table 5: Scenario policy analysis assumptions

Scenario	Reduction Target (Mitigation needed over 2021–2030 commitment period)	GHG emissions priced[22]		GHG Price Path ($/tCO$_2$-e)	
		Non-agriculture and forestry	*Agriculture and forestry*	*New Zealand*	*Rest of the World*
Baseline	0 MtCO2-e	Not priced	Not priced	None	None
B1L	10% below 1990 levels by 2030 (260 MtCO2-e)	Priced	Not priced	$25 in 2020, increasing to $50 in 2030	$25 in 2020, increasing to $50 in 2030
Q1L	5% below 1990 levels by 2030 (242 MtCO2-e)	Priced	Not priced	$25 in 2020, increasing to $50 in 2030	$25 in 2020, increasing to $50 in 2030
Q2L	20% below 1990 levels by 2030 (305 MtCO2-e)	Priced	Not priced	$25 in 2020, increasing to $50 in 2030	$25 in 2020, increasing to $50 in 2030
Q3L	40% below 1990 levels by 2030 (389 MtCO2-e)	Priced	Not priced	$25 in 2020, increasing to $50 in 2030	$25 in 2020, increasing to $50 in 2030
P1L	10% below 1990 levels by 2030 (260 MtCO2-e)	Priced	Not priced	$85 in 2020, increasing to $135 in 2030	$85 in 2020, increasing to $135 in 2030
U1L	Not defined	Priced	Not priced	$300 over entire commitment period	$25 in 2020, increasing to $50 in 2030

[22] 'Priced' means that a carbon price is assigned to the economic sector from which these emissions are produced under the NZ ETS or other carbon pricing mechanisms.

4.1 Scenario B1L – 10% below 1990 levels

The 'core' B1L scenario considered an emissions target of 10% decrease below 1990 emission levels by 2030. Achieving these targets requires a 260 Mt CO_2-e reduction in New Zealand's cumulative emissions relative to baseline over the 2021–2030 commitment period, amounting to annual reductions 26.0 MtCO_2-e/yr. Mitigation to attain the targets included pricing emissions from the energy, electricity, industrial manufacturing, and service sectors, and the purchase of international units. Agriculture and forestry emissions were not priced and hence the sector's emissions follow a similar pathway as BAU with slight deviations due to price and trade effects caused by the carbon pricing on other sectors.

Key results for the B1L scenarios are listed in Table 6. The results indicate that the carbon price would reduce New Zealand's gross emissions would be reduced by –10.6% relative to the baseline. This amounts to approximately 90 Mt CO_2-e over the commitment period at carbon prices of up to \$50/tCO_2-e by 2030. Thus, New Zealand would need to purchase 170 million international carbon units to reach the GHG emission reduction target, costing a total of \$6.7 billion (average of \$670 million per annum).

A target of a 10% reduction of emissions relative to 1990 levels by 2030 would be associated with a decrease in real gross national disposable income (RGNDI)[23] over the commitment period of about 0.6%. To put this in perspective, a decrease in RGNDI of this magnitude would see the same level of RGNDI per capita reached about 6 months later than in the baseline scenario.

The real gross domestic product (RGDP) impacts are expected to 0.23% relative to the baseline. The impact to RGDP is less than RGNDI because it does not directly account for the cost of purchasing international emissions reduction targets. The investment component is expected to have the largest decline (–1.6%). Total consumption (private and government combined) is not estimated to decline much (–0.1%) because the reductions in household consumption associated with higher prices of goods and services are nearly offset from the increase in government consumption as a result of the additional revenue earned from placing a price (i.e. tax) on GHG emissions.[24] Both imports and exports are expected to decline as a result of the policy, but imports decline by a greater amount, thereby improving New Zealand's balance of trade by 12.8% relative to the baseline.

The largest source of domestic emission reductions in scenario B1L is from the conversion of fossil-based electricity to renewables (61% of total domestic reductions), followed by manufacturing (29%). Transport provides limited abatement over the commitment period (6%) due to the lack of viable substitutes, as do primary energy refining and processing (4%) due to its small contribution to New Zealand's baseline emissions profile (see Table A1.1). The agricultural and forestry sectors have minimal change in GHGs relative to their baseline

[23] RGNDI is considered a useful indicator of the impact of climate change mitigation policy on national welfare. It consists of RGDP minus production in New Zealand by foreign-owned interests plus production overseas by New Zealand owned interests, as well as the direct cost of purchasing international emissions reductions.

[24] N.B. There could also be an implicit impact on household savings that are captured in the investment component of RGDP

trajectories as they are not priced under these scenarios. An overview of the sources of abatement for the B1L scenarios is shown in Figure 6.

Table 6: Core policy scenario (B1L) estimated impacts to New Zealand (2021–2030)

Indicator	B1L (10% below 1990 emissions)	
	Total value (2021–2030)	*% change from baseline*
Economic Indicators (billion $)		
Total RGDP	\$3,137	–0.23%
Consumption	\$2,470	–0.05%
Investment	\$631	–1.60%
Exports	\$825	–0.61%
Imports	–\$789	–1.14%
Net Exports	\$36	12.83%
Total RGNDI	\$3,163	–0.59%
International Permit Purchasing Cost	\$6.7	n/a
GHG Emissions ($MtCO_2$-e)		
Total Emissions	764	-10.6%
Total Domestic Reduction	90	n/a
International Purchases	170	n/a
Cumulative GHG Reduction	260	n/a

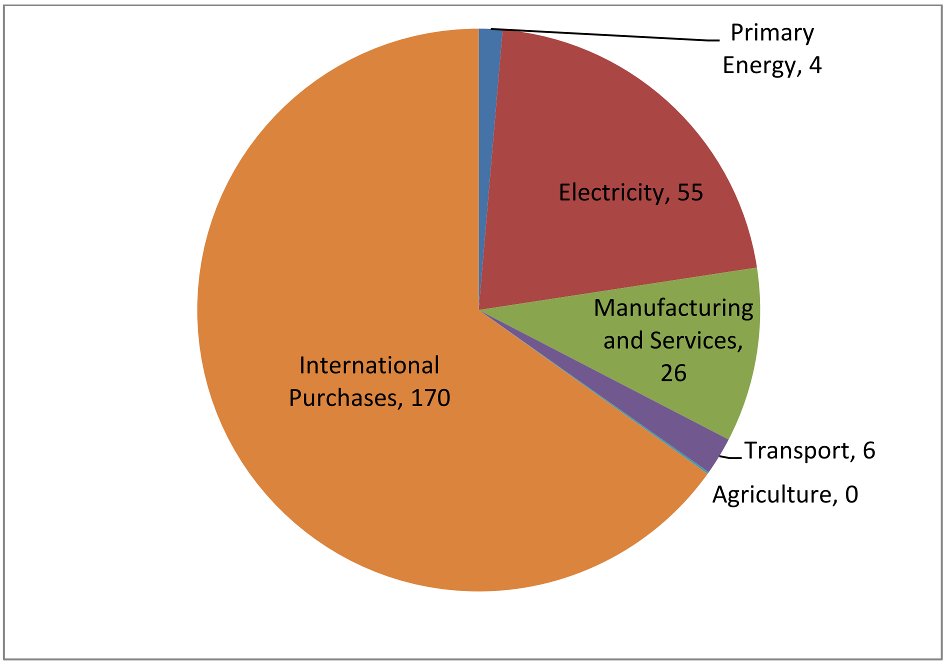

Figure 6: New Zealand GHG mitigation ($MtCO_2$-e) by source (reduction from baseline), B1L Scenario. Total mitigation sums to 260 Mt CO_2e over the 2021–2030 period.

Gross output for most sectors is estimated to decline by less than 1% relative to the baseline. The key exception is coal and natural gas extraction, which is estimated to be reduced by about 35% as a result of New Zealand's electricity sector becoming 95% renewable generation by 2030, compared with 83% in the baseline. More details on the sector-specific impacts for emissions, output, and trade are listed in Appendix 1.

The government raised revenue of 364 Mt CO_2e worth of carbon units by pricing all emissions in the economy except agriculture. This model assumed that 170 Mt worth of these were used for international purchases, and the remainder was recycled to reduce household tax.

4.2 Alternative policy scenarios emission reduction target levels

A number of sensitivities to the core scenario were modelled to assess the range of impacts of different factors influencing the cost of New Zealand's post-2020 emission reduction target. The sensitivities investigated in this analysis were:

- Varying the emissions reduction target (Q1L-Q3L)
- Access to international carbon markets (U1L)
- Increases in the global carbon price.

Varying emissions reduction target

The first set of alternative scenario analysis sensitivity analysis looks at the impact to the New Zealand economy of following the same policy approach and carbon price path as the core scenario, but adjusting the target level, i.e. a 5%, 20%, and 40% reduction on 1990 levels (Q1L-Q3L). A summary of the estimated impacts for these scenarios are listed in Table 7.

Table 7: Estimated impacts to New Zealand (2021–2030), alternative reduction targets. All scenarios assume a carbon price of $50/tCO2-e by 2030

Indicator	B1L (10% below 1990 by 2030)	Q1L (5% below 1990 by 2030)	Q2L (20% below 1990 by 2030)	Q3L (40% below 1990 by 2030)
Economic Indicators (% change from baseline)				
Total RGDP	–0.23%	–0.23%	–0.23%	–0.24%
Consumption	–0.05%	–0.04%	–0.07%	–0.12%
Investment	–1.60%	–1.60%	–1.61%	–1.63%
Exports	–0.61%	–0.61%	–0.58%	–0.54%
Imports	–1.14%	–1.12%	–1.20%	–1.29%
Net Exports	12.83%	12.08%	14.72%	18.23%
Total RGNDI	–0.59%	–0.56%	–0.63%	–0.74%
International Permit Purchasing Cost	$6.7 billion	$5.8 billion	$8.2 billion	$11.4 billion
GHG Emissions ($MtCO_2$-e)				
Total Emissions	764	764	764	764
Percent Reduction from Baseline	–10.6%	–10.6%	–10.6%	–10.6%
Total Domestic Reduction	90	90	90	90
International Purchases	170	151	214	299
Cumulative GHG Reduction	260	242	305	389

Impacts on New Zealand's RGNDI over the commitment period vary depending on the emissions reduction target. A target in line with a 5% reduction in emissions below 1990 levels by 2030 reduces New Zealand's RGNDI by about 0.56% below that of the baseline. At a target of 40% below 1990 levels by 2030, however, this reduction increases to 0.74% below the baseline as New Zealand has to purchase almost 300 $MtCO_2$-e of international offsets over the commitment period at a cost of more than $11 billion.

The RGDP estimates are relatively stable across the different reduction targets. This is because RGDP does not explicitly account for the cost of purchasing international permits, but rather just for the adjustment in government and private consumption, investment, and the balance of trade associated with the given emissions reduction target. In most cases, we found that with a carbon price although total imports and exports declined from the baseline levels, the amount of imports declined greater than exports. Furthermore, we also estimated that balance of trade improved as the abatement target increased because New Zealand had to produce relatively more exports in order to fund the purchasing of international GHG reductions.

Domestic GHG mitigation did not vary across the different emissions targets (Figure 7). In addition, the sector-specific impacts are also relatively constant over the different emission reduction targets (see Appendix 1). This indicates that at the same carbon price, the key difference is the level of international purchasing required to reach a specified emissions reduction target.

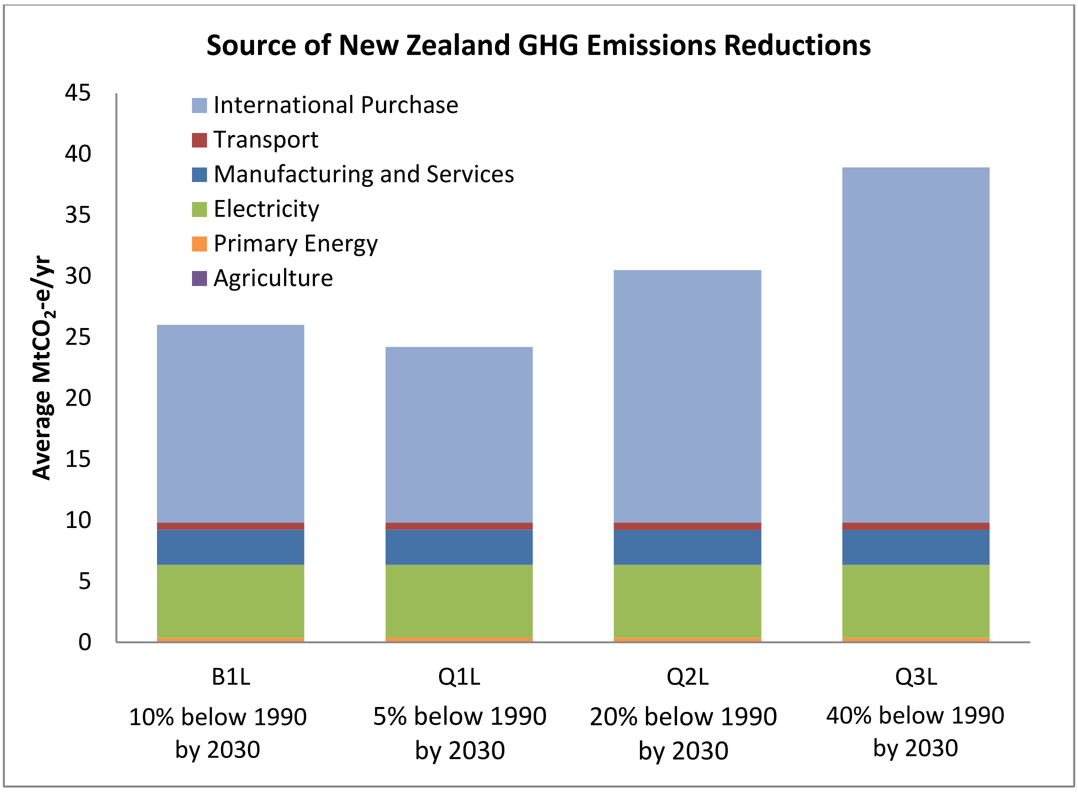

Figure 7: Source of NZ GHG emissions reduction, alternative reduction target scenarios.

Varying carbon price and unilateral action

A second set of alternative scenarios looks at the impact to the New Zealand economy of following the B1L emission reduction target, a 10% reduction on 1990 levels (or 260 MT below BAU emissions), but increasing the global carbon price or having New Zealand take unilateral action (i.e. no reliance on international offsets to meet domestic reduction targets). The high global carbon price scenario (P1L) assumes that all regions of the world face a carbon price that reaches \$135/tCO_2-e by 2030. The unilateral action scenario (U1L) assumes that New Zealand faces a domestic carbon price of \$300/tCO_2-e from the start of the commitment period onwards, while the rest of the world continues to face the same global carbon price as the core scenario (i.e. increases to \$50/tCO_2-e by 2030).[25] The carbon price trajectories for the various scenarios are shown in Figure 8.

[25] N.B. A \$300/tCO_2-e price over the entire commitment period was selected for this scenario not only because it was nearly high enough to achieve the 10% below 1990 target, but also because it was consistent with the price used for comparative modelling conducted by Infometrics (2015)

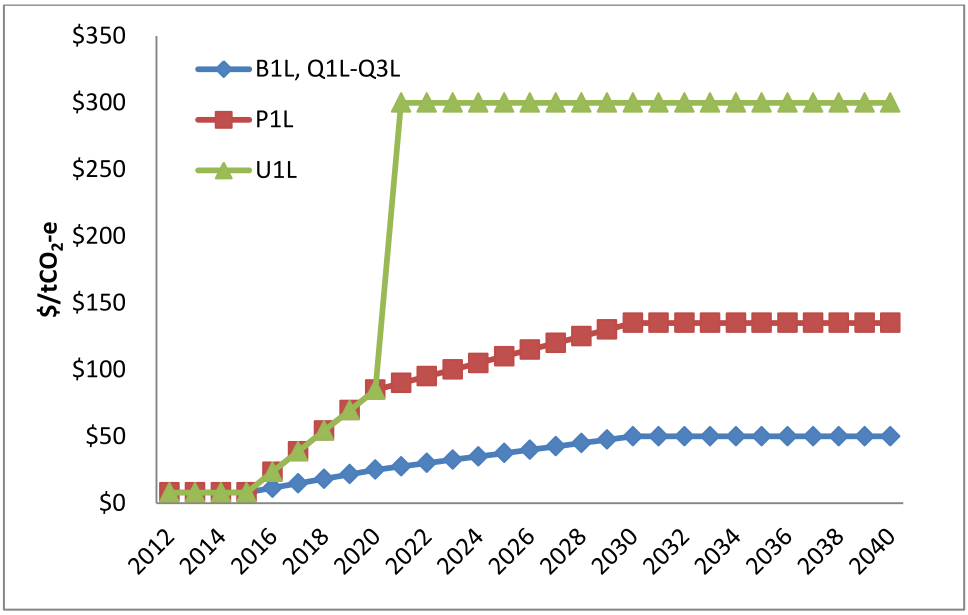

Figure 8: New Zealand carbon price paths for alternative policy scenarios.

Increasing the global carbon price relative to the core scenario will stimulate more domestic abatement, but it will also have a greater impact on the New Zealand economy (Table 8). Raising the carbon price reduces GHG emissions over the commitment period by 17.7% relative to the baseline (151MT or 18% above 1990), but it also reduces RGNDI and RGDP by 1.35% and 0.64%, respectively. Even with the higher carbon price and more domestic abatement, New Zealand still has to purchase 109 MtCO_2-e of international units, costing a total of more than $12 billion. While the total cost of purchasing the offsets is similar to the Q3L scenario, the higher carbon price leads to larger shocks to the wider economy and thus has a greater impact than the scenario with a lower carbon price but a higher emissions reduction target.

The largest sources of domestic GHG mitigation are still estimated to be electricity (46% of total reductions) and manufacturing and services (37%), with the manufacturing sector increasing its share of reductions relative to the B1L scenario (Figure 9). The share of mitigation from transport (12%) increases as sector output declines by about 6% relative to the baseline. Primary energy is still only a small source of reduction (3%) due to its relatively minimal contribution to New Zealand's total emissions footprint. Although agricultural non-CO_2 emissions are not priced, the high carbon price does have some flow-on effects that reduce sector output by about –0.3%, resulting in a slight reduction in the sector's GHGs.

Table 8: Estimated impacts to New Zealand (2021–2030), alternative carbon price and unilateral action

Indicator	B1L	P1L	U1L
Economic Indicators (% change from baseline)			
Total RGDP	–0.23%	–0.64%	–2.13%
Consumption	–0.05%	–0.11%	–0.09%
Investment	–1.60%	–2.79%	–5.04%
Exports	–0.61%	–2.10%	–4.01%
Imports	–1.14%	-2.26%	–0.14%
Net Exports	12.83%	1.85%	–100.5%
Total RGNDI	–0.59%	–1.35%	–2.25%
International Permit Purchasing Cost	\$6.7 billion	\$12.2 billion	\$0 billion
GHG Emissions ($MtCO_2$-e)			
Total Emissions	764	703	604
Percent Reduction from Baseline	–10.6%	–17.7%	–29.3%
Total Domestic Reduction	90	151	250
International Purchases	170	109	0
Cumulative GHG Reduction	260	260	250

A unilateral policy approach for reducing New Zealand's GHG emissions would likely require a very large carbon price.[26] A domestic carbon price of \$300/tCO_2-e results in 250 $MtCO_2$-e of GHG emissions reductions, equivalent to a target of 7% below 1990 emissions by 2030, which is slightly less than the 260 $MtCO_2$-e target. This would result in a –2.25% reduction in RGNDI and a 2.13% reduction in GDP. Because we assumed that the rest of the world faces a lower carbon price that only reaches \$50/tCO_2-e, the difference between domestic and global carbon prices has a strong effect on New Zealand's relative competitiveness. It is estimated that the very high domestic carbon price reduces New Zealand's total exports by about 4% relative to the baseline while only reducing its import value by 0.1%. This is because firms and consumers prefer the relatively lower price of goods purchased from overseas. The key sectors impacted by the high price are primary energy, energy-intensive manufacturing, and transport, while food and wood product manufacturing and services are relatively unaffected (see Table A1.6).

As with the other policy scenarios, one of the largest sources of domestic GHG mitigation is electricity, which is estimated to be completely renewable by 2030. Manufacturing and services contributes to about 35% of total reductions as firms invest in less GHG-intensive inputs for production. The share of mitigation from transport (27%) increases significantly relative to the B1L scenario, but output also declines by about 26% relative to the baseline as the high carbon price places a significant burden on the sector due to the lack of low-emissions substitutes in the model. Primary energy is still only a small source of reduction (4%), and flow-on effects of a high carbon price also result in the non-priced agricultural

[26] N.B. As \$300/tCO_2-e is at the high range of what the CliMAT-DGE is designed to model over the 2021–2030 time period, estimates – particularly the sector-level findings – should be treated with caution.

sector contributing to 2% of New Zealand's total emissions reductions. More details on impacts to sector-specific output are listed in Appendix 1.

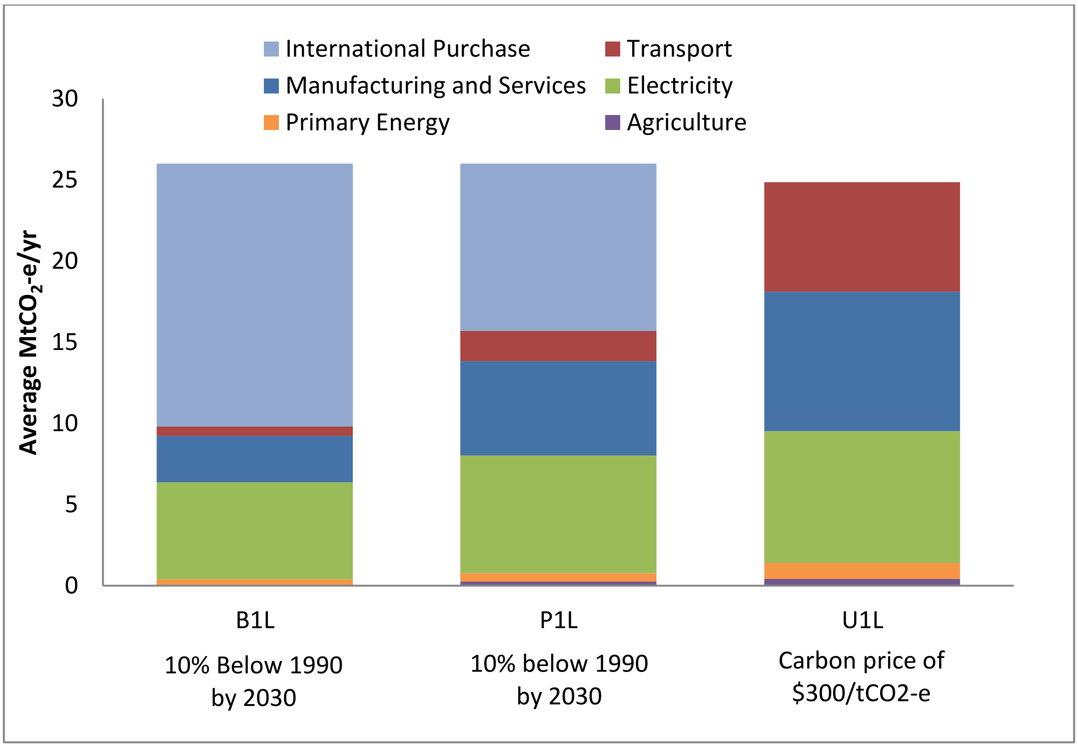

Figure 9: Source of NZ GHG emissions reduction, varying carbon price and unilateral action.

4.3 Comparison with Infometrics (2015)

A similar modelling exercise was conducted by Infometrics (2015), who used the static-CGE model ESSAM to analyse the same six scenarios presented in this report. Both models estimated that there would be negative economic impacts from all policies. CliMAT-DGE, however, estimated that New Zealand would reduce a greater level of GHG emissions and at lower costs compared with ESSAM. Table 9 lists the key model estimates for four of the scenarios. A more detailed comparison for all scenarios is in Appendix 2.

Table 9: ESSAM and CliMAT-DGE estimated impacts to New Zealand (2021-2030)

Indicator	ESSAM B1	C-DGE B1L	ESSAM Q3	C-DGE Q3L	ESSAM P1	C-DGE P1L	ESSAM U1	C-DGE U1L
RGDP	−0.9%	−0.2%	−1.1%	−0.2%	−2.0%	−0.6%	−3.1%	−2.1%
RGNDI	−1.2%	−0.6%	−1.7%	−0.7%	−2.5%	−1.4%	−2.4%	−2.4%
Total GHG	−5.7%	−10.6%	−5.7%	−10.6%	−10.8%	−17.7%	−17.1%	−29.3%

The many differences between the two models lead to varied impact estimates. The two significant reasons for these differences are: (a) the treatment of past and future substitution between fossil fuel generation and renewables generation in electricity; and, (b) whether the rate of return on investment in New Zealand can be expected to decline, vis à vis the rest of the world, when the economic competitiveness is affected by a carbon price and/or an emissions responsibility target. We found that modifying some of the assumptions in ESSAM resulted in nearly identical estimates as CliMAT-DGE for the B1L scenario.

Another factor is that CliMAT-DGE models the assumption of perfect foresight. That is, agents can gradually change savings and consumption behaviour in anticipation of an emissions reduction policy, thereby smoothing the economic impacts over time. For example, Babiker et al. (2009) used the EPPA model to show that given the same data and model parameterisation, the recursive model requires a 30% higher carbon price than the forward-looking model to achieve the same emissions reduction target. As a result, we could expect a comparative static model such as ESSAM to show higher costs of an emissions reduction policy relative to a dynamic forward-looking model such as CliMAT-DGE.

Despite obvious differences in model structure and estimates, each model has its relative strengths. ESSAM is a NZ-centric static model with significant industry and household detail and can track the main financial flows such as taxes, benefits, interest and dividends for households, businesses, government and the rest of the world. In turn, CliMAT-DGE is a global dynamic model that includes multiple countries and industries, and tracks commodity trade flows to various parts of the globe as a result of region-specific policies. Thus, both models are useful tools to provide unique insight on the impacts of emissions reduction policies on a wide range of sectors of the New Zealand economy.

4.4 Summary

A core GHG emissions reduction scenario (10% below 1990 by 2030) and five alternatives were modelled to assess the range of impacts of different factors influencing the cost of New Zealand's post-2020 emission reduction target. Some key findings include:

- The estimated impacts to New Zealand's RGNDI over the commitment period vary depending on the emissions reduction target. Assuming a carbon price path that reaches \$50/tCO_2-e by 2030, a target of 5% below 1990 emissions is estimated to reduce RGNDI by –0.56% relative to the baseline while a 40% below 1990 emissions target has an impact of –0.74%. The impacts to RGDP for the same targets range from – 0.23% to –0.24%. The effect on RGDP is less variable because (a) the indicator does not explicitly account for the price of purchasing international offsets, and (b) the effect of the policy on consumption and investment are offset by a counter-effect on net exports.
- An increase in the global carbon price relative to the core scenario will stimulate more domestic abatement, but it will also have a greater impact on the New Zealand economy. A carbon price that is estimated to reach \$135/tCO_2-e by 2030 is estimated to reduce New Zealand's GHG emissions over the commitment period by 17.7% relative to the baseline, but also reduce RGNDI and RGDP by 1.35% and 0.64%, respectively.
- New Zealand is unlikely to achieve emission reduction targets below 1990 levels of emissions through domestic GHG emissions abatement alone without an unrealistically large carbon price (and/or not pricing agriculture and forestry emissions). This is due to the mix of New Zealand's economic and emissions profile. For example, the country already produces a high proportion of its electricity from renewable resources and

hence has limited opportunities for further emissions abatement from the sector. A large proportion of its emissions are from agriculture (nearly 50%, on average), which is not priced in these policy scenarios, and can be difficult to mitigate given the current set of available technologies.

- New Zealand's carbon price would have to be at least $300/t$CO_2$-e in order for the country to be close to achieving a 10% below 1990 emissions reduction target without having to purchase international offsets (and without pricing agriculture or forestry emissions). This unilateral approach would result in a 2.25% reduction in RGNDI and a 2.1% reduction in RGDP, while reducing gross GHG emissions by almost 30% relative to the baseline (i.e. 7% below 1990). This approach has large consequences for New Zealand's balance of trade, as the relatively high domestic carbon price reduces the country's competitiveness, and firms and consumers purchase more of goods from overseas.
- The purchase of international carbon units will initially form an important mitigation response for New Zealand for the post-2020 Climate Change agreement until domestic GHG emissions can be reduced or the cost of domestic GHG emissions abatement becomes less than the price of international carbon units. However, there are economic risks associated with a dependency on international purchasing due to the potential fluctuation in the price of carbon units.

5 References

Babiker MM, Gurgel AC, Paltsev S, Reilly JM 2008. A forward looking version of the MIT emissions prediction and policy analysis (eppa) model. Report 161. Cambridge MA, MIT Joint Program on the Science and Policy of Global Change.

Babiker MM, Gurgel AC, Paltsev S, Reilly JM 2009. Forward-looking versus recursive-dynamic modeling in climate policy analysis: a comparison. Economic Modelling 26: 1341–1354.

Climate Change Response Act 2002. Retrieved from http://www.legislation.govt.nz/act/public/2002/0040/latest/whole.html

Daigneault A, Greenhalgh S, Samarasinghe O 2014. Agro-environmental policy impacts on regional land use and ecosystem services in New Zealand. Paper presented at 2014 New Zealand Association of Economists Annual Meeting, 2–4 July 2014, Auckland.

Daigneault A, Fernandez M, Wright W 2015. Economic modelling of New Zealand's INDC for the post-2020 Climate Change Agreement: quality report. Landcare Research Contract Report LC2106 prepared for Ministry for the Environment. 59 p.

Daignault A, Sohngen B, Sedjo RA 2012. Economic approach to assess the forest carbon implications of biomass energy. Environmental Science & Technology 46: 5664–5671.

Fernandez M, Daigneault A 2015. The climate mitigation, adaptation and trade in dynamic general equilibrium (CliMAT-DGE) Model. Landcare Research Contract Report LC2156 prepared for Ministry for the Environment. Available online at: http://www.landcareresearch.co.nz/__data/assets/pdf_file/0017/87002/CliMAT_DGE_Technical_document.pdf.https://www.mfe.govt.nz/publications/climate/nz-sixth-national-communication/index.html 59p.

Fouré J, Bénassy-Quéré A, Fontagné L 2010. The world economy in 2050: a tentative picture. CEPII Working paper 2010-27. Paris, CEPII.

Infometrics 2015. A general equilibrium analysis of options for New Zealand's post-2020 climate change contribution. Infometrics report prepared for Ministry for the Environment. Available online at: http://www.mfe.govt.nz/publications/climate-change/general-equilibrium-analysis-options-new-zealand%E2%80%99s-post-2020-climate 24p.

International Energy Agency 2013. World energy outlook. Paris, IEA.

Ministry for the Environment (MfE) 2013. New Zealand's sixth national communication. MfE Report ME 1137. Available online at: http://mfe.govt.nz/publications/climate/nz-sixth-national-communication/index.html. 343 p.

MfE 2014a. New Zealand's greenhouse gas inventory 1990–2011. Available online at: http://www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-2014-snapshot/index.html

MfE 2014b. Carbon price path scenarios: 2015-2030.

NZIER & Infometrics 2009. Macroeconomic impacts of climate change policy impact of assigned amount units and international trading: Final Report to the Ministry for the Environment. Available online at: http://www.beehive.govt.nz/sites/all/files/NZIERInfometrics_Report.pdf

Appendix 1 – CliMAT-DGE New Zealand sector-specific estimates (2021-2030 commitment period average)

Table A1.1: Scenario B1L sector impacts (% change relative to baseline)

CliMAT-DGE Sector	Abbrev.	GHG	Output	Export	Import
Plant-based fibres	PFB	–14.7%	–1.3%	–2.1%	1.2%
Bovine cattle, sheep and goats, horses	CTL	0.1%	0.1%	–0.7%	–0.2%
Dairy (raw milk)	RMK	0.1%	0.2%	0.0%	0.0%
Coal Mining	COA	–44.2%	–44.2%	–44.5%	–61.8%
Oil	OIL	–7.8%	-3.0%	–6.2%	–1.0%
Gas	GAS	–36.2%	–33.0%	0.0%	0.0%
Petroleum, coal products	P_C	–1.1%	-1.2%	–1.9%	–3.7%
Grains, including rice	GRA	0.0%	0.4%	0.1%	–1.8%
Oils and sugar cane	OSC	0.0%	0.0%	0.0%	0.1%
Other crops	CRO	–4.0%	-0.2%	–0.8%	–0.8%
Food products	FOO	–32.2%	0.1%	0.1%	–1.7%
Harvested wood products	HWP	–28.0%	0.0%	–0.1%	–1.8%
Energy-intensive manufacturing	EMT	–10.3%	0.3%	0.2%	–2.2%
Non-energy-intensive manufacturing	NSV	–17.8%	–0.3%	–0.7%	–0.7%
Transport	TPT	–3.1%	-2.1%	–2.7%	1.0%
Fossil electricity	EFS	–73.5%	–69.4%	0.0%	0.0%
Carbon-free electricity	ECF	0.0%	11.8%	0.0%	0.0%
Forestry	FST	0.0%	–0.4%	–2.1%	1.1%

Table A1.2: Scenario Q1L sector impacts (% change relative to baseline)

CliMAT-DGE Sector	Abbrev.	GHG	Output	Export	Import
Plant-based fibres	PFB	–14.7%	–1.3%	–2.1%	1.3%
Bovine cattle, sheep and goats, horses	CTL	0.1%	0.1%	–0.7%	–0.2%
Dairy (raw milk)	RMK	0.1%	0.2%	0.0%	0.0%
Coal Mining	COA	–44.2%	–44.2%	–44.5%	–61.8%
Oil	OIL	–7.8%	–3.0%	–6.2%	–1.0%
Gas	GAS	–36.2%	–33.0%	0.0%	0.0%
Petroleum, coal products	P_C	–1.1%	–1.2%	–2.0%	–3.7%
Grains, including rice	GRA	0.0%	0.4%	0.1%	–1.8%
Oils and sugar cane	OSC	0.0%	0.0%	0.0%	0.1%
Other crops	CRO	–4.0%	–0.2%	–0.8%	–0.8%
Food products	FOO	–32.2%	0.1%	0.1%	–1.7%
Harvested wood products	HWP	–28.0%	0.0%	–0.1%	–1.8%
Energy-intensive manufacturing	EMT	–10.3%	0.3%	0.2%	–2.2%
Non-energy-intensive manufacturing	NSV	–17.8%	–0.3%	–0.7%	–0.7%
Transport	TPT	–3.1%	–2.1%	–2.7%	1.1%
Fossil electricity	EFS	–73.5%	–69.4%	0.0%	0.0%
Carbon-free electricity	ECF	0.0%	11.8%	0.0%	0.0%
Forestry	FST	0.0%	–0.4%	–2.1%	1.1%

Table A1.3: Scenario Q2L sector impacts (% change relative to baseline)

CliMAT-DGE Sector	Abbrev.	GHG	Output	Export	Import
Plant-based fibres	PFB	–14.7%	–1.3%	–2.1%	1.2%
Bovine cattle, sheep and goats, horses	CTL	0.1%	0.1%	–0.7%	–0.3%
Dairy (raw milk)	RMK	0.1%	0.2%	0.0%	0.0%
Coal Mining	COA	-44.2%	–44.2%	–44.4%	–61.8%
Oil	OIL	–7.8%	-3.0%	–6.2%	–1.0%
Gas	GAS	–36.2%	–33.0%	0.0%	0.0%
Petroleum, coal products	P_C	–1.1%	–1.2%	–1.9%	–3.7%
Grains, including rice	GRA	0.0%	0.4%	0.1%	-1.8%
Oils and sugar cane	OSC	0.0%	0.0%	0.0%	0.1%
Other crops	CRO	–4.0%	-0.2%	–0.8%	-0.8%
Food products	FOO	–32.2%	0.2%	0.2%	–1.8%
Harvested wood products	HWP	–28.0%	0.0%	–0.1%	–1.9%
Energy-intensive manufacturing	EMT	–10.2%	0.3%	0.2%	–2.3%
Non-energy-intensive manufacturing	NSV	–17.8%	–0.3%	–0.6%	–0.8%
Transport	TPT	–3.1%	–2.1%	–2.7%	1.0%
Fossil electricity	EFS	–73.5%	–69.4%	0.0%	0.0%
Carbon-free electricity	ECF	0.0%	11.8%	0.0%	0.0%
Forestry	FST	0.0%	–0.4%	–2.1%	1.1%

Table A1.4: Scenario Q3L sector impacts (% change relative to baseline)

CliMAT-DGE Sector	Abbrev.	GHG	Output	Export	Import
Plant-based fibres	PFB	–14.7%	–1.3%	–2.0%	1.1%
Bovine cattle, sheep and goats, horses	CTL	0.1%	0.1%	–0.6%	–0.4%
Dairy (raw milk)	RMK	0.1%	0.2%	0.0%	0.0%
Coal Mining	COA	–44.2%	–44.2%	–44.4%	–61.8%
Oil	OIL	–7.8%	–3.0%	–6.2%	–1.0%
Gas	GAS	–36.2%	–33.0%	0.0%	0.0%
Petroleum, coal products	P_C	–1.1%	–1.2%	–1.9%	–3.7%
Grains, including rice	GRA	0.0%	0.4%	0.1%	–1.9%
Oils and sugar cane	OSC	0.0%	0.0%	0.0%	0.1%
Other crops	CRO	–3.9%	–0.1%	–0.8%	–0.9%
Food products	FOO	–32.2%	0.2%	0.2%	–1.9%
Harvested wood products	HWP	–28.0%	0.0%	0.0%	–2.0%
Energy-intensive manufacturing	EMT	–10.2%	0.4%	0.2%	–2.3%
Non-energy-intensive manufacturing	NSV	–17.8%	–0.3%	–0.6%	–0.9%
Transport	TPT	–3.1%	–2.0%	–2.6%	0.9%
Fossil electricity	EFS	–73.5%	–69.4%	0.0%	0.0%
Carbon-free electricity	ECF	0.0%	11.8%	0.0%	0.0%
Forestry	FST	0.0%	–0.4%	–2.0%	1.1%

Table A1.5: Scenario P1L sector impacts (% change relative to baseline)

CliMAT-DGE Sector	Abbrev.	GHG	Output	Export	Import
Plant-based fibres	PFB	–29.1%	–3.6%	–6.3%	4.1%
Bovine cattle, sheep and goats, horses	CTL	–0.4%	–0.3%	–1.9%	–1.8%
Dairy (raw milk)	RMK	–0.4%	–0.1%	0.0%	0.0%
Coal Mining	COA	–48.6%	–48.6%	–40.7%	–79.7%
Oil	OIL	–20.6%	–6.6%	–12.4%	–3.7%
Gas	GAS	–52.1%	–47.2%	0.0%	0.0%
Petroleum, coal products	P_C	–4.3%	–4.0%	–3.2%	–10.9%
Grains, including rice	GRA	–1.2%	0.5%	–0.8%	–4.9%
Oils and sugar cane	OSC	0.0%	0.0%	0.0%	–0.3%
Other crops	CRO	–9.1%	–0.7%	–3.4%	–3.5%
Food products	FOO	–59.0%	–0.2%	–0.6%	–4.1%
Harvested wood products	HWP	–55.0%	–0.5%	–1.9%	–3.9%
Energy-intensive manufacturing	EMT	–22.6%	–0.3%	–1.1%	–3.9%
Non-energy-intensive manufacturing	NSV	–36.2%	–0.7%	–2.1%	–1.2%
Transport	TPT	–9.8%	–5.7%	–6.9%	3.1%
Fossil electricity	EFS	–89.2%	–84.8%	0.0%	0.0%
Carbon-free electricity	ECF	0.0%	16.3%	0.0%	0.0%
Forestry	FST	0.0%	–1.3%	–5.5%	0.7%

Table A1.6: Scenario U1L sector impacts (% change relative to baseline)

CliMAT-DGE Sector	Abbrev.	GHG	Output	Export	Import
Plant-based fibres	PFB	–42.2%	–9.1%	–14.8%	23.9%
Bovine cattle, sheep and goats, horses	CTL	–0.6%	–0.3%	–0.4%	–1.4%
Dairy (raw milk)	RMK	–0.7%	–0.1%	0.0%	0.0%
Coal Mining	COA	–62.7%	-62.7%	–53.6%	–76.3%
Oil	OIL	–28.2%	–6.2%	26.4%	–33.6%
Gas	GAS	–69.5%	--63.9%	0.0%	0.0%
Petroleum, coal products	P_C	–32.7%	–31.1%	–17.1%	-24.6%
Grains, including rice	GRA	–4.5%	–0.2%	0.3%	-3.0%
Oils and sugar cane	OSC	0.0%	0.0%	0.0%	–0.3%
Other crops	CRO	–13.6%	–0.3%	–0.6%	-1.9%
Food products	FOO	–78.0%	–0.3%	–0.2%	-1.6%
Harvested wood products	HWP	–75.2%	–0.9%	–0.2%	-2.6%
Energy-intensive manufacturing	EMT	–38.8%	–6.7%	–6.3%	4.4%
Non-energy-intensive manufacturing	NSV	–52.2%	–1.1%	0.2%	–3.4%
Transport	TPT	–35.5%	–26.4%	–26.0%	49.3%
Fossil electricity	EFS	–100.0%	–100.0%	0.0%	0.0%
Carbon-free electricity	ECF	0.0%	20.9%	0.0%	0.0%
Forestry	FST	0.0%	–1.4%	–2.7%	1.5%

Appendix 2 – Comparison of CliMAT-DGE and ESSAM* policy scenario estimates

Table A2.1: Policy scenario impacts to New Zealand (% change relative to baseline)

Indicator	ESSAM	CliMAT-DGE	ESSAM	CliMAT-DGE	ESSAM	CliMAT-DGE	ESSAM	CliMAT-DGE	ESSAM	CliMAT-DGE	ESSAM	CliMAT-DGE
	B1	**B1L**	**Q1**	**Q1L**	**Q2**	**Q2L**	**Q3**	**Q3L**	**P1**	**P1L**	**U1**	**U1L**
RGDP	–0.9%	–0.2%	–0.9%	–0.2%	–0.9%	–0.2%	–1.1%	–0.2%	–2.0%	–0.6%	–3.1%	–2.1%
*Consumption^*	*–1.2%*	*0.0%*	*–1.2%*	*0.0%*	*–1.4%*	*–0.1%*	*–1.7%*	*–0.1%*	*–2.5%*	*–0.1%*	*–2.4%*	*–0.1%*
Investment	–1.2%	–1.6%	–1.2%	–1.6%	–1.3%	–1.6%	–1.7%	–1.6%	–2.4%	–2.8%	–2.2%	–5.0%
Exports	–0.3%	–0.6%	–0.4%	-0.6%	–0.2%	–0.6%	0.1%	–0.5%	–0.9%	–2.1%	–4.7%	–4.0%
Imports	–1.3%	–1.1%	–1.3%	–1.1%	–1.5%	–1.2%	–1.8%	–1.3%	–2.6%	–2.3%	-2.4%	–0.1%
RGNDI	–1.2%	–0.6%	–1.2%	–0.6%	–1.3%	–0.6%	–1.7%	–0.7%	–2.5%	–1.4%	–2.4%	–2.3%
Total GHG Emissions	–5.7%	–10.6%	–5.7%	–10.6%	–5.7%	–10.6%	–5.7%	–10.6%	–10.8%	–17.7%	–17.1%	–29.3%

* See Infometrics (2015) for full set of results

^ Includes total private and government consumption

Appendix 3 – Overview of CliMAT-DGE model

The Climate Mitigation, Adaptation and Trade in Dynamic General Equilibrium (CliMAT-DGE) model is a top-down, dynamic, forward-looking multi-sectoral and multi-regional computable general equilibrium (CGE) model that describes the global economy and generation of greenhouse gas (GHG) emissions from energy and non-energy sectors. CliMAT-DGE models the flows of goods and services for the entire world, with a strong focus on New Zealand as a distinct region of the global economy. See Fernandez and Daigneault (2015)[27] for more details.

CliMAT-DGE has been used to assess the impacts of national and regional-level environmental policies on economic output and welfare. For example:

- Changes in GHG emissions reduction targets and socio-economic pathways
- Carbon pricing and purchases of international emissions permits
- Backstop technologies availability for fuel-based energy
- Separate pricing of GHG gases
- Regional abatement costs

Some features of the model are:

- CliMAT-DGE uses the Global Trade Analysis Project (GTAP 8) dataset that accounts for 129 regions and 57 economic sectors[28]
- The base year of the benchmark projection is 2007; the model then develops a benchmark projection of the economic variables and GHG emissions (from human activities), and simulates scenarios to evaluate the impacts of environmental or trade-related policies.
- Coal, oil, gas, petroleum refining, renewable electricity, and fossil electricity sectors are defined as separate sectors. Renewable and fossil electricity generation sectors are disaggregated from the single electricity GTAP sector. Sectors related to land use can be defined covering any combinations of the GTAP agricultural and forestry sectors. Other sectors can be created from combinations of the remaining GTAP 8.1 sectors.
- The model follows a forward-looking dynamic behaviour, that is, the economic agents have a perfect foresight of policy impacts.

Key outputs of the model include:

- RGDP, RGNDI, aggregate consumption, foreign trade
- GHG prices and emissions levels by region and sector
- Gross sector output
- Commodity prices

[27] http://www.landcareresearch.co.nz/__data/assets/pdf_file/0017/87002/CliMATDGE_April_2015.pdf

[28] For further details, see: https://www.gtap.agecon.purdue.edu/databases/v8/

A.2.1 Model Structure

Production functions

Firms are grouped together into production sectors. Producers operate under full competition and maximise profits for given prices, subject to their production technology. The way agents in the model adjust to policy shocks are represented as elasticities of substitution. These elasticities summarize the technical ability or willingness to substitute inputs. All production sectors are modelled using nested constant elasticity of substitution (CES) production functions. The nested-CES functions capture the potential substitution between production technologies. In order to link the production a commodity with GHG emissions, the nesting structures include the interaction between GHGs and sector commodities.

Intermediate Demand

A composite commodity is defined in the following cases:

The oil refining sector (P_C) has a Leontief structure between the capital-labour-energy bundle and the intermediate inputs bundle. Oil enters as an intermediate input and not as part of the energy nest. P_C goods are separated from a sub-nest of coal and gas. Coal and gas interact to create a composite good that interacts with P_C. This structure reflects that P_C goods are mainly used for transport whereas the other fuels are mainly used for industrial heat or power.

All goods in CliMAT-DGE can be traded in world markets. Imports and domestic production are aggregated into an Armington aggregate using an approach that assumes domestic and foreign goods are imperfect substitutes. The extent to which imported and domestic goods differ is determined by the elasticity of substitution between them. The changes in the relative shares of foreign and domestic goods in the composite are determined by changes in the relative prices of these goods at home and overseas, as specified by initial shares of these goods in the benchmark GTAP data and the Armington substitution elasticity.

An intermediate inputs bundle is constructed for non-energy commodities in all production functions. Likewise, an energy-materials bundle is constructed from all energy sectors (fuel-based or carbon-free).

Price determination

CliMAT-DGE is formulated as a mixed complementarity problem (MCP) where an equilibrium is described by a set of prices, activity levels, and incomes. The market clearing condition means that a positive price exists for any good with supply less than or equal to demand. If a good has an excess supply, then its price should be zero. New Zealand is generally assumed to be a globally commodity price-taker.

Consumption Expenditure

Households are aggregated into one representative agent. The government is modelled as a passive entity that collects taxes and distributes the full value of the proceeds to the households, which is captured in an aggregate consumption figure. Consumption is represented by a nested CES structure. The elasticities of substitution determine the substitution possibilities between energy and non-energy goods. The elasticity between non-energy inputs to consumption over time periods is a function of per capita income growth between periods and thus varies over time and regions. Consumption shares in each period are updated as a function of per capita income growth between periods.

Capital Stocks

Capital stocks accumulate through new investment and are reduced by depreciation as they are used over time. Capital can flow freely among regions to equalise the real rates of returns.

Investment

Physical capital evolves through the creation of new capital from investments considering a constant depreciation rate at each period. For baseline calibration and projections, the model determines the price of one unit of capital, the initial capital adjustment price, and the initial rate of return of capital. These serve to construct the initial quantity reference paths for the balanced growth path projections.

The purpose of the sector-specific capital formulation in CliMAT-DGE is to emphasise the irreversibility of the allocation of new capital between sectors. There is no representation of technology vintages in the form of a putty-clay formulation, which typically emphasises technology inflexibility within a sector. Though it has much merit, putty-clay is computationally intensive in the context of a large, forward-looking model.

Exports

All goods in CliMAT-DGE can be traded in world markets. Imports and domestic production are aggregated into an Armington aggregate using an approach that assumes domestic and foreign goods are imperfect substitutes. The use of the Armington specification allows an explicit representation of bilateral trade flows. As a result, regions in the model can be both importers and exporters of a particular good. The model explicitly tracks bilateral trade flows, which include export taxes, import tariffs, and international transport margins.

Supply-Demand Identities

The market clearing condition means that a positive price exists for any good with supply less than or equal to demand. If a good has an excess supply, then its price should be zero. Specifically, for the primary production factors, demand of labour and capital must be equal to total endowments. For produced goods, supply is equal to the amount produced plus imports. Demand is made up of demand by other firms (intermediate deliveries) and demand by households plus exports

Balance of Payments

Because of the forward-looking dynamics, the present value of all future changes (positive and negative) in a region's current account balance must be zero. New Zealand (or any other region) may run a current account surplus or deficit in any period, subject to the constraints that (i) global savings must equal global investment, and (ii) the present value of a region's current and future surpluses must equal the present value of its current and future deficits.

In common with most CGE models, international assets positions are not explicitly modelled in CliMAT-DGE. Financial stocks and flows of financial assets (debt, equity, currency) are not modelled either. Thus, while a current account deficit is financed by a capital account surplus, we cannot say anything about the composition of the capital account. Foreign trade allows countries to temporarily run foreign accounts imbalances in response to policy shocks, as long as those imbalances are made up for in other periods of the model simulation.

Factor Market Balance

The supply of labour in each region is exogenously specified and undifferentiated by skill level. We assume a full employment model closure, where a shock to the economy causes wages and rents to adjust until the fixed supply of each factor is again fully employed.

Similarly, the supply of land and natural resources are assumed to be fixed in each period. Rents vary accordingly to keep full-employment. The total stock of land does not change over time, and thus changes on land resources may be addressed through changes in land productivity or factor usage in each sector or country.

Income-Expenditure Identity

The income-expenditure balance condition restricts the present value of current and future expenditure of each representative household to be equal to or less than the present value of the household's endowments of labour and other factors of production, plus the present value of indirect taxes less subsidies. As households always prefer more consumption to less, income is always completely exhausted by present consumption and saving for future consumption.

Industry Classification

Industries are defined with respect to the GTAP classification of 57 economic sectors. See Appendix 2 of Fernandez and Daigneault (2015) for more details.

Input-Output Table

The model relies on GTAP 8.1 for the construction of input-output tables as well as for the balancing of the social accounting matrices. The latest GTAP input-output table for New Zealand[29] is based on the Inter-Industry Study of 1996 Interim Release of Tables from Statistics New Zealand. An updated NZ I-O table will be included in GTAP v9, which is expected to be released sometime in 2015.

---

[29] https://www.gtap.agecon.purdue.edu/databases/IO/table_display.asp?IO_ID=118

GHG emissions market

CliMAT-DGE can simulate policies such as GHG emissions targets through price or quantity constraints, that is, exogenous GHG prices or emissions cap on specific sectors (e.g. electricity, manufacturing). Any region can meet a specific GHG emissions target through a combination of domestic abatement and purchasing of GHG emission reduction permits from abroad, typically at the same price as the domestic marginal cost of abatement. International purchasing is financed by a combination of an increase in exports and a shift in domestic consumption and investment.