A General Equilibrium Analysis of Options for New Zealand's post-2020 Climate Change Contribution

for Ministry for the Environment

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1. Summary

Infometrics was requested by the Ministry for the Environment to assess the impacts of New Zealand agreeing to participate in an international agreement to reduce GHG emissions, beginning in 2021.

The analysis uses general equilibrium modelling and is complementary to similar analysis being undertaken by Landcare Research.

The key messages to be taken from the analysis are that:

1. For a global price of carbon that reaches NZ$50/tonne by 2030 and a decadal emissions reduction target for New Zealand of 260 Mt (equivalent to -10% on 1990 by 2030[1]), the reduction in real gross national disposable income (RGNDI) is 1.2% relative to business as usual levels. Agricultural non-CO_2 emissions are not priced, but are included in national carbon budgets.

2. Only about one fifth of the target is met through domestic abatement; the rest is met by purchasing emission units from offshore.

3. Raising the target simply means that more emission units need to be bought from offshore – for no change in the carbon price. For every $1m increase in the cost of buying emissions units from offshore as the emissions reduction target is tightened, the loss in real national disposable income is $1.8m.

4. Raising the carbon price in New Zealand above the prevailing global price in order to reduce domestic emissions is not sufficient to achieve an emissions target of -10% on 1990 levels through domestic action alone – at least not within the current limitations of the model. It also has a high economic cost.

5. One of the benefits of participating in international carbon markets through a global agreement is not only that it is cheaper (in terms of national income foregone) to meet a given emission responsibility target, it also means that New Zealand's international competitiveness is largely maintained.

6. From the perspective of household income levels, the distributional effects from a reduction target of 260 Mt over ten years are not large.

All modelling is subject to uncertainty. For example:

- Uncertainty about model parameter values, especially the ease with which consumers and businesses can switch between fuels, and switch out of relatively carbon intensive goods and services.

- Uncertainty about the effects of actions by the Rest of the World (even with a global carbon price) on New Zealand. In addition to trade effects being uncertain, it is assumed that New Zealand is part of a global capital market such that the rate of return to investment has to remain internationally competitive in the face of pressure on it from a carbon price. That is, if carbon

[1] Using a Quantified Emissions Limitation or Reduction Objective (QELRO) approach.

pricing and an international emissions responsibility target reduce New Zealand's inherent competitiveness, it is assumed that investment will decline to prevent a fall in the rate of return.

Of course it may be the case that a global carbon price lowers rates of return to investment everywhere. If this occurs the negative economic effects of a carbon price on New Zealand would be smaller because the decline in investment would be less.

- In our modelling there is no backstop industry such as carbon capture and storage (CCS)[2] that would soften the impact of carbon pricing. Nor is there any allowance for widespread penetration of technologies such as electric cars, wave power, better batteries and so on, which arguably would be incentivised by a carbon price.

Uncertainty should not be a reason for doing nothing. Instead policy should be cognisant of the risks (favourable and unfavourable) and seek to manage those risks.

[2] Carbon capture and storage is a proposed technology for capturing carbon dioxide from combustion – for example in power stations, and storing it in some way to prevent it entering the atmosphere, such as by injecting it into natural underground geological formations.

2. Scenario Specification

We use the ESSAM general equilibrium model of the New Zealand economy to look at six scenarios for the year 2027 as representative of a future commitment period from 2021-2030.[3]

New Zealand can choose the "target year" of its contribution (e.g. 2025 or 2030). To date, some countries have chosen to take a 2025 target-year (e.g. the United States) and others a 2030 target-year (e.g. the European Union and Mexico).

For the same headline number, a target at 2025 or 2030 would mean roughly the same level of modelled "effort" needed by New Zealand per year. For example a 10% reduction below 1990 levels **by 2030** would mean New Zealand would need to reduce emissions by 26.3 million tonnes of greenhouse gas emissions per year over the 2020s, while a 10% reduction below 1990 levels **by 2025** would mean New Zealand would need to reduce emissions by 25.7 million tonnes of greenhouse gas emissions per year out to 2025 – a difference of less than one percentage point when expressed relative to 1990 levels. See Appendix C for more details.

However, setting a 2025 target may increase expectations for New Zealand to set a more ambitious target from 2026-2030, which would mean that New Zealand would face higher overall costs over the 2020s.

Table 1 describes the scenarios.

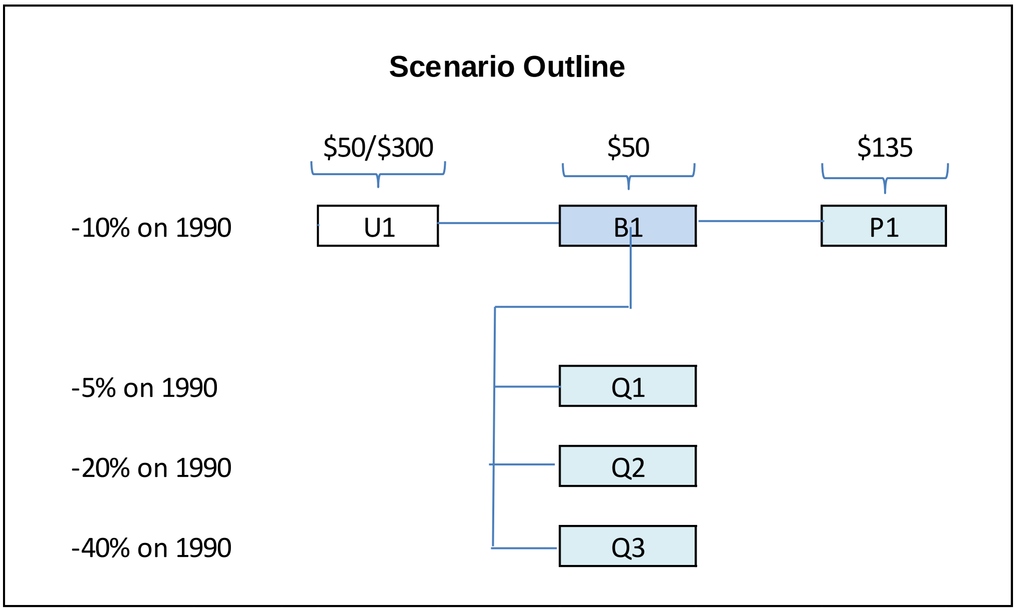
Table 1: Description of Scenarios

No.	Description
Baseline	No action to reduce emissions by any country.
B1	There is a world carbon price that reaches $50/tonne by 2030 (about $46 in 2027). New Zealand participates and has an emissions reduction responsibility target of 260 Mt over ten years, equivalent to 10% below 1990 emissions by 2030. The target can be met by domestic emissions abatement or by purchasing emission units from offshore. Participation means that except when otherwise stated, agricultural non-CO_2 emissions are not priced globally, but do count towards emissions budgets.
U1	As in B1, but without any international trading of emission units by New Zealand, and New Zealand unilaterally raising its carbon price to $300/tonne. The rest of the world maintains a carbon price of $50/tonne by 2030. Note, that $300/tonne is probably higher than can be realistically modelled with existing energy substitution elasticities.
P1	A sensitivity test on B1 with a global carbon price that reaches $135/tonne by 2030, $120 in 2027.
Q1-Q3	Sensitivity tests on B1 with emissions targets of -5%, -20% & -40% on 1990.

[3] Appendix D provides an outline of the ESSAM model.

Figure 1 depicts the scenarios and shows how they relate to each other.

Figure 1: Scenario Outline



All results are expressed relative to a Baseline scenario. So in Scenario B1, which is the central scenario, the results answer the question:

> What is the cost to New Zealand of participating in a global agreement (with a global carbon price and international trading of emission units), relative to a situation where there is no carbon price anywhere, nor any trading of units?

It is straightforward to compare scenarios with each other in any desired combination, but it greatly assists understanding the model's results if all are expressed relative to a common base.

Overarching assumptions

Given time and budget constraints, the scope of this research does not include any analysis of:

1. The net impacts of New Zealand's greenhouse gas emissions on climate change and what the economic and social effects of a changing climate might be.
2. Non-market policies to reduce emissions, such as restrictions on fossil-fuel generation of electricity and biofuels obligations.
3. What action consumers or governments in other countries might take against New Zealand if it was perceived that New Zealand was not doing enough to reduce emissions.
4. Likely trends in global carbon prices.

Forestry

Accounting settings for forestry and land-use under the new agreement have yet to be agreed. These settings are particularly important for New Zealand as its liability under the agreement is highly sensitive to the accounting methodologies applied.

At present New Zealand accounts for forestry and land-use using a framework derived from Articles 3.3 and 3.4 of the Kyoto Protocol. Because New Zealand's forests are characterised by a combination of indigenous and planted forests with particular age class and growth profiles; changes from current accounting settings will have a material effect on determining which emissions and removals count against our target. The accounting settings agreed and applied under the new agreement will determine whether New Zealand's forestry and land-use will be a carbon source or sink for purposes of meeting the target.

Uncertainty in accounting settings makes it difficult to quantify the effect of forestry and land-use emissions and removals for the purpose of the modelling. To avoid distorting the results, mitigation through forestry and land use has not been quantified or included in modelling estimates presented in this report.

Baseline Scenario

The Baseline scenario contains a number of assumptions about changes in energy efficiency, based largely on historic trends and linked to New Zealand's *Sixth National Communication on Climate Change.* These changes in efficiency continue to apply in the carbon mitigation scenarios.

While the Baseline has no carbon pricing in New Zealand or the rest of the world, it does take account of the reduction in fossil electricity generation that has occurred over the last 5-10 years, and which is expected to continue even without a significant price on carbon.

For modelling purposes some current NZ ETS settings have been adjusted so that the pure effects of emissions pricing and an emissions target may be better understood. In particular:

- There is no "one for two" surrender obligation.
- There is no free allocation of emission units to trade-exposed emissions-intensive industries
- There is no $25 price cap.

Other general climate change policy settings that have been assumed are:

- Carbon pricing regimes in other countries are similar to those in the NZ ETS.
- There is free flow of emissions units between New Zealand and the rest of the world.
- Agricultural emissions do not face a surrender obligation in New Zealand nor elsewhere.

As this modelling is focussed on the costs of New Zealand's international contribution (rather than the NZ ETS specifically), making assumptions on carbon price settings in New Zealand and globally could complicate and prejudice the analysis. A simple approach has been used whereby a uniform carbon price exists in New Zealand and in the rest of the world (except in one scenario). The absence of allocations to trade-exposed emissions-intensive firms ensures that all firms globally face the same carbon price, so trade disadvantages as a result of the carbon price are mostly an impact of relative competitiveness[4].

Modelling various ETS settings will be appropriate in the context of decisions on domestic policy settings where competiveness impacts can be considered and addressed.

Agricultural non-CO_2 emissions are not priced in line with current policy settings in New Zealand and the rest of the world. Even in countries that have introduced carbon pricing, experience to date is that alternative policy approaches are being used for agricultural emissions. Of course this does not necessarily mean that alternative approaches are better.

Global carbon price paths were derived from international reports (Intergovernmental Panel on Climate Change Fifth Assessment Report and Reuters).

Modelling Rules

The following closure rules are adopted, consistent with generally accepted modelling practice:[5]

1. The current account balance is fixed as a percentage of GDP. This means that if New Zealand has to purchase international emissions units to meet an emissions responsibility target, that liability cannot be met simply by borrowing more from offshore with deferred repayment.

2. The post-tax rate of return on investment is unchanged between scenarios. This acknowledges that New Zealand is part of the international capital market and ensures consistency with the preceding closure rule.

3. Any change in the demand for labour is reflected in changes in wage rates, not changes in employment. Instead of fixed employment, wage rates could be fixed at Baseline levels. This would imply, however, that the long run level of total employment is driven more by climate change policies than by the forces of labour supply and demand, which we consider unlikely.

4. The fiscal balance is fixed across scenarios. This means for example that if the government has to purchase emission units and if revenue from a carbon price is insufficient, tax rates must rise to secure the necessary finance. We assume

[4] It is uncertain if there is a net positive or negative impact on trade-competiveness as this will depend on the product mix and production technologies in each country.

[5] NZIER and Infometrics (2009): Economic Modelling of New Zealand Climate Change Policy. Report to Ministry for the Environment, May 2009. And Macroeconomic impacts of climate change policy. Impact of Assigned Amount Units and International Trading. Report to Ministry for the Environment, July 2009.

that net personal income tax rates are the equilibrating mechanism, although changing government expenditure is an alternative option.

Section 4 presents the main results, but before that we discuss the methodological approach of general equilibrium modelling.

3. CGE Modelling

This section draws heavily on NZIER and Infometrics (2009)[6].

What is CGE modelling?

Computable General Equilibrium (CGE) models are commonly used tools for policy analysis. Such models typically consist of a database that represents an economy benchmarked for a particular time period based on input-output tables. The database specifies the interactions and relationships between various economic agents including firms, workers, households, the government and overseas markets.

The base case model is then 'shocked' by changing a policy variable or an assumption about one or more parameters outside the model (exogenous variables). Values for all other variables inside the model (endogenous variables) are calculated from equations describing the economy, given numerical values for the parameters and the variables outside the model (Peterson, 2003).[7]

Typically in such models:

- Consumers maximise their utility subject to their budget constraints. They purchase goods and services from firms, and provide firms with their labour inputs.
- Producers maximise their profits by buying intermediate goods and inputs (labour and capital) and selling outputs to other domestic and international firms, households and government.
- There is a market for each commodity (goods and intermediates) and in equilibrium market prices are such that demand equals supply in all input and output markets.
- Firms earn zero pure profit (i.e. enough to remain in business but not enough to induce new firms to enter the market).

By comparing the pre- and post-shock model output we can observe the effects of the shock in question in terms of changes to GDP, employment, wages, etc. In static CGE models, we observe the economy after all adjustments have taken place. Dynamic models such as Landcare's CliMAT-DGE model on the other hand, allow one to examine in each intervening period how variables adjust from the time when a shock is implemented to the time when all of its effects have worked through the economy (which may be a number of years or decades).

Strengths of CGE modelling

The most important advantage of CGE modelling is that it considers how policy shocks 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

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[6] NZIER and Infometrics, op cit.

[7] Peterson, S. (2003): 'CGE models and their application for climate change policy analysis'. Presentation to 1st International Workshop on Integrated Climate Models: An interdisciplinary assessment of climate impacts and policies, 30 September – 3 October 2003, ICTP, Trieste, Italy.

changes might affect the structure of an economy. Concept Economics (2008, p4)[8] note that "high quality CGE modelling is a powerful tool that can assist policy makers and stakeholders in understanding the effects of mitigation actions, especially at an economy wide level". Such models "examine complex issues rigorously and in an internally consistent way across long timeframes" (Australian Treasury, 2008, p21).[9] CGE models have been used extensively for climate change policy because they can examine adjustments across all sectors of the economy in response to changes in energy supply and prices through changes in factor proportions and sectoral output levels.

Industry-specific partial equilibrium or econometric models, on the other hand, tend not to consider what happens to resources outside of the industry in question. While they can be useful for more disaggregated industry analysis, they are not well-suited for capturing the inter-sectoral and inter-sectoral resource re-allocation that stems from policy changes such as the Emissions Trading Scheme (ETS).

Limitations of CGE modelling – generic

One important aspect of CGE modelling is 'database dependency'. By this we mean that the accuracy of CGE modelling results is highly dependent on the quality and suitability of the initial database employed in the base case scenario. To the extent that there are problems with the database, there may also be problems with the results. For the modelling in this paper the underlying input-output table is provided by Statistics NZ and relates to 2006/07. Structural changes to the economy over the last eight years are therefore not captured in the model database, but are captured to some extent in the Baseline scenario.

An oft-used criticism of CGE models, at least historically, is that, given the vast amount of data, parameters, equations and assumptions required to compute outcomes, such models can be somewhat of a "black box" in nature. That is, it is sometimes difficult to identify exactly how certain results were obtained. This is true only to the extent that modellers are not transparent regarding what data they have put into the model, how they have modelled policy changes and how they have interpreted the results.

A more valid criticism is that CGE model estimates are not often 'tested' ex-post against actual outcomes. This makes it difficult to ascertain how 'accurate' CGE modelling results are in practice (Kehoe, 2003)[10]. Such ex-post testing is rare because retrospectively isolating the specific effects of any individual policy changes from other economic changes is very difficult. In CGE modelling, we generally have to assume that apart from policy shocks, everything else remains constant (or at least behaves according to the model's parameter settings). In reality of course economies adjust constantly in response to good or bad news, relative price changes, availability

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[8] Concept Economics. (2008): 'A peer review of the Treasury modelling of the economic impacts of reducing emissions'. Report for Australian Senate Select Committee on Fuel and Energy.

[9] Australian Treasury. (2008). *Australia's low pollution future: the economics of climate change mitigation*. Online at http://www.treasury.gov.au/lowpollutionfuture/report/default.asp

[10] Kehoe, T.J. (2003): 'An Evaluation of the Performance of Applied General Equilibrium Models of the Impact of NAFTA'. Federal Reserve Bank of Minneapolis, Research Department Staff Report 320.

of resources, exchange rate movements, shifts in preferences, changes to global markets, other policy changes and so on.

Partly as a result of not knowing whether or not previous studies have been accurate, there is relatively little focus on ensuring that the parameters contained within a model remain appropriate. Econometrically estimating these parameters is a complex and expensive process, but it is widely accepted that "in order for CGE models to gain prominence in policy analysis, more must be done to ensure the model is an accurate representation of the real economy" (Beckman and Hertel, 2009, p7)[11].

As noted above, CGE models typically assume a neoclassical world. If these neoclassical assumptions are not believed to hold true in reality, then the model results could be seen as not portraying likely outcomes. However, alternative representations of economic behaviour can be incorporated into CGE models if judged to be more appropriate.

Another limitation of (static) CGE models, such as those employed in this report, is that they usually assume that economic variables adjust smoothly to policy shocks. Such models do not capture step-wise industry adjustments, but assume smooth and continuous changes. In reality, industries with large capital resources face discrete production and investment decisions. Along similar lines, comparative static models report the likely change in the economy at a given point in time; they do not capture the gradual implementation effects of a shock as the economy adjusts over time. This is more of a concern for short run modelling scenarios. In the long run, it is assumed that the economy can adjust to the desired point, although different models use different approaches to the movement of labour and capital to allow this adjustment (also see Australian Treasury, op cit p22, who note that the three CGE models used in their analysis "provide a more robust analysis of the post-transition economy than of the transitional process [itself]").

Limitations of CGE modelling of climate change policy

The application of CGE modelling to climate change mitigation policy scenarios is now widespread (Beckman and Hertel, op cit p1). This is because CGE models are well suited to examining the inter-sectoral and inter-country effects of pricing carbon dioxide and other greenhouse gases. However, a number of common challenges face modellers of climate change policies, including:

- Accurately accounting for land use changes – although CGE models to asses 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 (Australian Treasury, op cit).

- Estimating abatement costs – the costs to individual sectors (and hence the macroeconomic costs and benefits) of mitigating climate change vary depending on the ability of firms to reduce emissions in an economically

[11] Beckman, J., and T. Hertel. (2009). 'Why Previous Estimates of the Cost of Climate Mitigation are Likely Too Low'. GTAP Working Paper No. 54, 2009.

efficient way. The ability of firms to adjust is largely dependent on the possibility of substituting towards 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.

- In general, endogenous technological improvements are not modelled, but scenarios in which technological change is induced by a carbon price can be examined. Similarly there are no 'disruptive' technological changes.
- By default there are no negative cost abatement opportunities, although modelling them is not impossible.

Another source of potential bias relates to the fact that CGE models do not incorporate full marginal income tax schedules. As a result the models will underestimate the welfare gains from lower taxation to households.

Non-economic costs and benefits are generally not captured in CGE models. 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.

Summary

Despite the caveats outlined above, we firmly believe that CGE modelling remains the most appropriate tool for assessing the broad economic effects of climate change mitigation policies in New Zealand. As with any model, CGE models can only be an approximation of the highly complex real economy. CGE models are dependent on the database used, the credibility of the assumptions incorporated into the base case and policy scenarios and the 'closure' framework employed (Concept Economics, 2008, p4). **Therefore the results can only ever be indicative. The interpretation of CGE results should centre on their direction (up or down) and broad magnitude (small, medium or large), rather than on the precise point estimates that the model produces**. Essentially we are modelling scenarios: such modelling "does not predict what will happen in the future. Rather, it is an assessment of what could happen in the future, given the structure of the models and input assumptions" (Australian Treasury, op cit p16).

CGE modelling can usefully be augmented with sector-specific partial equilibrium modelling and other quantitative and qualitative research approaches, particularly in difficult areas such as forestry, to develop a deeper base of knowledge for policy makers. It is outside the scope of this report to undertake such research.

4. Model Results

Table 2 summarises the macroeconomic results including the changes in domestic emissions, in real GDP and in Real Gross National Disposable Income (RGNDI). [12] Table 3 presents a disaggregation of the changes in emissions for Scenario B1.

While GDP is a commonly used macroeconomic measure, RGNDI is a better measure of economic welfare for two reasons. Firstly it captures the effect of changes in the terms of trade. If the price of a bale of wool rises on international markets New Zealand can import more consumer goods and services with almost no effect on GDP. Secondly, RGNDI includes the effect of income flows that are not directly tied to trade. As in previous modelling by NZIER and Infometrics the cost of emission units purchased from offshore is treated as a reduction in income available to New Zealanders. In contrast GDP would show only a second order effect as resources are directed into producing exports rather than consumer goods and services.

Table 2: Summary Results

	B1	P1	Q1	Q2	Q3	U1
			% Δ on Baseline			
Private consumption	-1.6	-3.1	-1.5	-1.7	-2.1	-3.1
Investment	-1.2	-2.4	-1.2	-1.3	-1.7	-2.2
Exports	-0.3	-0.9	-0.4	-0.2	0.1	-4.7
Imports	-1.3	-2.6	-1.3	-1.5	-1.8	-2.4
GDP	-0.9	-2.0	-0.9	-0.9	-1.1	-3.1
RGNDI	-1.2	-2.5	-1.2	-1.3	-1.7	-2.4
Real wage rates	-1.6	-3.2	-1.5	-1.6	-1.8	-5.4
Terms of Trade	0.1	0.4	0.1	0.0	-0.1	2.5
Domestic Gross Emissions	-5.7	-10.8	-5.7	-5.7	-5.7	-17.1

Table 3: Emissions Profile in 2027 (Mt CO_2e)

	Baseline	Scenario B1
QELRO for -10%		-26.0
Implied Net Target		57.6
CO_2e emissions (AR4 metrics)	83.6	78.8
Deficit		21.2
CH_4 and N_2O (incl waste)	45.5	45.3
CO_2	38.1	33.5
Cost of deficit @$46/tonne ($m)		$975m

[12] Real Gross National Disposable Income is GDP adjusted for net offshore factor payments (such as interest and dividend flows) and for changes in the terms of trade.

Participation (Scenario B1)

Scenario B1 presents the cost of participating in a global agreement to reduce emissions. There is a global price on carbon that reaches $50/tonne by 2030 and countries may trade emission units. New Zealand takes on an emissions reduction responsibility target (QELRO) of 260 Mt over the decade 2021-2030, equivalent to a reduction of 10% on 1990 emissions by 2030.

As the model relates only to New Zealand, action by the rest of the world to reduce emissions is simulated by changes in international commodity prices. We assume that if all countries implement the world-wide carbon price New Zealand's trade exposed industries would suffer no competitive price disadvantage. Of course to the extent that industrial processes differ across countries New Zealand's competitiveness could still change – in either direction. However, for the sorts of commodity industries that are trade exposed; notably coal, oil refining, pulp, base metals and cement, lime etc, international differences in the carbon intensity of production processes are hopefully of second order.[13]

Insofar as other countries do not expose all of their traded industries to a full carbon price, the model's results will under-estimate the negative effects on New Zealand of introducing a carbon price. The extreme version of such a scenario is where New Zealand acts unilaterally. See Scenario U1.

In Scenario B1 the estimated loss in RGNDI is -1.2%. This is larger than the loss in GDP due to the need to use some of the nation's income to purchase offshore emission units. With a reduction in domestic emissions of 5.7% relative to Baseline, about 21 Mt per annum needs to be covered by offshore purchasing. At a carbon price averaging $46/tonne this implies a direct annual cost of $975m.

Higher Carbon Price (Scenario P1)

Scenario P1 looks at the effect of a higher carbon price globally and in New Zealand, holding New Zealand's target the same. In other respects its specification is the same as in Scenario B1. As forest sequestration is not considered, changes in emissions caused by sector behaviour in forest planting and management driven by the higher carbon price are not captured in these results, which could mean that the results are overly pessimistic.

The reductions in GDP and RGNDI are both about twice the reductions in Scenario B1. Industries and households move further up their marginal abatement curves, while at the same time the cost of offshore emission units is also higher.

Interestingly, while the carbon price is more than three times as high as in B1 (averaging $120/tonne over the commitment period) there is only a doubling of the macroeconomic cost. This discrepancy is likely to be linked to what happens, or what is simulated would happen, in the Rest of the World.

A tripling of the carbon price has a greater effect on the average price of the Rest of the World's exports than on the average price of New Zealand's exports, as such a large share of emissions associated with New Zealand's exports do not face a carbon

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[13] Agricultural commodities are excluded from a carbon price by assumption.

price due to agricultural non-CO_2 emissions not facing a carbon price. Thus although there is an unambiguous loss in economic welfare from a higher carbon price, this loss is ameliorated by a relative gain in overall competitiveness.

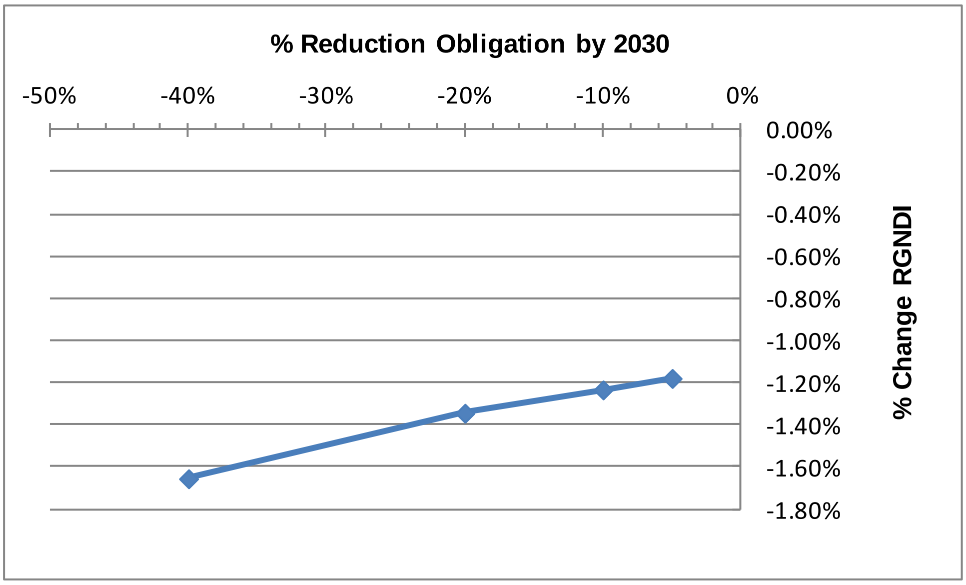
However, we cannot totally discount the possibility that imperfections in how we model the Rest of World are influencing the results, so further research with a multi-region world model is advisable before this 'concave' result is accepted as being robust.

Different Emissions Targets (Scenarios Q1-Q3)

Scenario B1 has a QELRO target of 260 Mt over the commitment period (2021-2030), which is equivalent to a reduction of 10% on 1990 emissions by 2030. Scenarios Q1-Q3 look at reductions of 5%, 20% and 40% respectively, all with the same carbon price as in Scenario B1. The results are in Table 2.

Because the carbon price does not change there is no change in domestic abatement, not even a second order effect (to within 1 decimal place in percentage changes) from having to redirect resources out of producing goods and services for household consumption and into producing exports, to generate the foreign exchange needed to purchase offshore emission units. Lower imports also contribute to the need for more foreign exchange.

Figure 2: RGNDI v Emissions Target



Given a carbon price reaching $50/tonne in 2030 the ratio of the change in RGNDI (in 2006/07 prices) to the change in the cost of international emission units as the QELRO is raised, averages about 1.80. In other words each $1 spent on international emission units reduces national income by about $1.80. A small part of the 80c premium is due to the relative decline in the terms of trade as exporters move down their demand curves in order to sell more product. Most, however, is simply attributable to resources being less efficiently used in export industries.

Note that the 1.80 ratio would be higher if the change in RGNDI (the numerator) is expressed in current 2015 dollars rather than in 2006/07 dollars.

Appendix B shows the effects of the different QELRO on the implied growth rates of GDP, RGNDI and Private Consumption.

Unilateral Action (Scenario U1)

In Scenario U1 the Rest of World has a carbon price of $50/tonne (as in Scenario B1), but there is no international trading of emission units, or at least New Zealand is not part of any trading arrangement.

Instead the carbon price in New Zealand is unilaterally set much higher in order to try and approach the reduction in emissions implied by the 260 Mt QELRO purely through domestic abatement. We imposed a maximum carbon price of $300/tonne, but this proved insufficient (given the model's limitations) to reduce domestic emissions by the required 27% from business as usual levels, achieving only 17%.

With the loss in competitiveness GDP falls by 3.1% and RGNDI by 2.4%. Real wage rates decline by 5.4%, with the effect of this on private consumption being softened by recycling revenue from the carbon charge back to households in the form of lower income taxes.

A high carbon price would be expected to lead to more investment in energy efficiency and renewable technologies, which we have not included here. However, whether this would markedly reduce the negative effect of a domestic emissions target on GDP or RGNDI is unclear. Arguably if more resources are devoted to improving energy efficiency and reducing carbon intensity, other areas of technological development (such as biotechnology, computing and communications) could see a reduction in resourcing. Hence the average rate of technological progress in the economy may not change.

Other Model Results

Energy

Table 4 shows the changes in energy consumption for Scenario B1. While there is clear shift out of fossil fuel electricity and into renewables (including geo-thermal), it needs to be recalled that a large amount of substitution away from fossil fuel electricity generation has already occurred over the last decade. Some would likely continue even without a significant price on carbon. Thus the additional substitution between fossil fuel generation and renewables generation is relatively more expensive, so causing an increase in the price of electricity when a carbon charge is imposed and a consequent reduction in demand.

Table 4: Scenario B1: Changes in Energy Output (PJ)

	% ∆ on Baseline
Coal	-38.1
Oil	-5.3
Gas	-17.0
Fossil fuel electricity	-16.9

Renewables electricity	0.7
Total electricity	-3.2

There is a small decline in oil demand, which is to be expected as there is little substitution between oil in its major use – transport - and other fuels such as electricity, something that might change with more widespread penetration of electric vehicles. This is the kind of enhanced penetration of new technology that might be relevant to a high carbon price scenario such as in Scenarios U1 or P1.

Industry Gross Output

Appendix Table A1 presents the changes in real gross output for each industry for Scenario B1. Changes are small with total gross output declining by only 1.1%. Unsurprisingly the energy industries suffer the largest falls in output, reaching just over 5% in the case of the Coal industry. As with the other results this does not necessarily mean that Coal output sees an absolute decline in output; rather that over the ten year commitment period the Coal industry expands by approximately half a percentage point less per annum than it would in the Baseline.

Agriculture and service industries perform relatively well. Recall that emissions of methane and nitrous oxide which constitute about 96% of emissions from agriculture are exempt from the carbon price (though emissions from energy use are still priced), while service industries are not emissions intensive.

Household Effects

In the ESSAM model the government sector is separate from the household sector. The latter is split into income quintiles with different average net tax rates (tax paid on income less Working for Families etc) and different benefit rates (unemployment and other) for each quintile. Thus although the model does not fully capture improvements in efficiency from reducing the most distortionary tax rates, it does have some capacity to look at the effects of changing household tax rates in response to changes in other fiscal flows, notably revenue from a carbon price.

In particular, if a price on carbon (whether a tax or auctioned permits) raises more revenue than is required to pay foresters for emissions absorption and to cover the cost of purchasing emission units from offshore, the surplus is assumed to be returned to households via lower net tax rates. There are of course other ways of recycling revenue from a carbon price. Infometrics (2011)[14] explores a number of options such as changes in corporate tax rates.

Note that it makes no difference to either the government's fiscal position or to the net cost to New Zealand whether private companies buy emission units directly from offshore and surrender them to the government, or whether the government purchases the offshore units.

In all scenarios the net quintile tax rates inclusive of benefits are adjusted pro rata, which could be consistent with any number of combinations of changes in marginal tax rates, tax thresholds, and WFF abatement profiles. Table 5 looks at changes in real consumption by household income quintile for Scenarios B1 and Q3.

[14] Infometrics (2011): Distributional Effects of Options for Recycling Carbon Price Revenue. Report to Motu.

In Scenario B1 the carbon price raises about $1500m in revenue (recalling that agricultural CH_4 and N_2O are exempt). Almost $1000m is needed to purchase offshore units. After netting out the effect of the lower level of economic activity on other tax revenue flows to the government, there is less than $400m left to distribute to households.

Table 5: Household Consumption by Income Quintile

	Baseline $m 06/07	Scenario B1	Scenario Q3
2027 Quintiles		% Δ on Baseline	
Lowest quintile	14,800	-1.4	-1.8
2nd quintile	23,600	-1.6	-2.1
3rd quintile	30,300	-1.5	-2.0
4th quintile	37,600	-1.4	-1.9
Highest quintile	64,900	-1.7	-2.3
Total or average	171,300	-1.6	-2.1

In Scenario Q3 with the higher emissions responsibility target, the amount left for reducing household taxes is less than $200m as much more of the revenues is required to purchase offshore emission units.

The differences by quintile are small, reflecting a number of effects that could be mutually reinforcing or offsetting; differences in the carbon intensity of consumption bundles, differences in the share of income from various sources (wages, benefits, capital) and differences in the effects of changes in tax rates. Overall the results do not suggest a major redistributive effect of a price on carbon combined with an emissions responsibility reduction target.

Appendix A: Industry Results

Table A1 shows the changes in real gross output by industry for Scenario B1 relative to the unadjusted Baseline, from the ESSAM model.

Abbrev	Description	Scenario B1
		% change on Baseline
HFRG	Horticulture and fruit growing	-1.1%
SBLC	Sheep, beef, livestock and cropping	-0.6%
DAIF	Dairy and cattle farming	-0.4%
OTHF	Other farming	-0.8%
SAHF	Services to agriculture, hunting and trapping	-0.4%
FOLO	Forestry and logging	-0.9%
FISH	Fishing	-0.5%
COAL	Coal mining	-5.1%
OIGA	Oil and gas extraction, production & distribution	-2.7%
OMIN	Other Mining and quarrying	-1.7%
MEAT	Meat manufacturing	-0.5%
DAIR	Dairy manufacturing	-0.7%
OFOD	Other food manufacturing	-0.8%
BEVT	Beverage, malt and tobacco manufacturing	-0.9%
TCFL	Textiles and apparel manufacturing	-0.8%
WOOD	Wood product manufacturing	-1.0%
PAPR	Paper and paper product manufacturing	-1.1%
PRNT	Printing, publishing and recorded media	-1.1%
PETR	Petroleum refining, product manufacturing	-3.4%
CHEM	Other industrial chemical manufacturing	-1.4%
FERT	Fertiliser	-1.2%
RBPL	Rubber, plastic and other chemical product manufacturing	-1.3%
NMMP	Non-metallic mineral product manufacturing	-1.3%
BASM	Basic metal manufacturing	-1.4%
FABM	Structural, sheet and fabricated metal product manufacturing	-1.4%
MAEQ	Machinery and other equipment manufacturing	-0.6%
OMFG	Furniture and other manufacturing	-0.9%
EGEN	Electricity generation	-2.9%
EDIS	Electricity transmission and distribution	-1.6%
WATS	Water supply	-1.3%
WAST	Sewerage, drainage and waste disposal services	-2.3%
CONS	Construction	-1.1%
TRDE	Wholesale and retail trade	-1.1%
ACCR	Accommodation, restaurants and bars	-0.8%
ROAD	Road transport	-1.1%
RAIL	Rail transport	-1.1%
WATR	Water transport	-1.3%
AIRS	Air Transport	-1.5%
TRNS	Transport services	-0.7%
PUBI	Publication and broadcasting	-1.0%
COMM	Communication services	-0.9%
FIIN	Finance and insurance	-1.1%
HIRE	Hiring and rental services	-0.6%
REES	Real estate services	-1.4%

OWND	Ownership of owner-occupied dwellings	-1.7%
SPBS	Scientific research and computer services	-0.7%
OBUS	Other business services	-0.7%
GOVC	Central government administration and defence	0.3%
GOVL	Local government administration	-0.1%
SCHL	Pre-school, primary and secondary education	-0.3%
OEDU	Other education	-0.3%
MEDC	Medical and care services	-0.4%
CULT	Cultural and recreational services	-1.1%
REPM	Repairs and maintenance	-1.2%
PERS	Personal services	-1.2%
	Total	-1.1%

Appendix B: Implied Growth Rates

Table B1 shows the effects on GDP, RGNDI and Private Consumption in 2027 of changing the QELRO, and the implied effects on the growth rates of those variables over the commitment period.

Note that:

1. The model is not calibrated to pick up differences between scenarios that are smaller than 0.1% (that is ±0.05%). This means that the implied growth rates are also rounded to ±0.1%.

2. The values for the 30%-based QELRO are linearly interpolated.

It is assumed that the level shifts in activity estimated by the model for 2027 apply to all years of the commitment period. Thus the implied growth rates are calculated as the level of (say) GDP in 2030 with a carbon price and QELRO, compared to GDP in 2020 without a carbon price and QELRO.

The key message is that in terms of macroeconomic growth rates the effects of a $50/tonne carbon price and QELRO are very small, generally amounting to less than one month of economic growth.

Table B1: Implied Growth Rates

	Average impact on GDP versus baseline, 2021-30	Annual GDP growth in 2020s	Average impact on RGNDI versus baseline, 2021-30	Annual RGNDI growth in 2020s	Household consumption impact	Annual household consumption growth in the 2020s
No target		2.2%		2.4%		2.3%
-5%	-0.9%	2.1%	-1.2%	2.3%	-1.5%	2.1%
-10%	-0.9%	2.1%	-1.2%	2.3%	-1.6%	2.1%
-20%	-0.9%	2.1%	-1.3%	2.3%	-1.7%	2.1%
-30%	*-1.0%*	*2.1%*	*-1.5%*	*2.3%*	*-1.9%*	*2.1%*
-40%	-1.1%	2.1%	-1.7%	2.3%	-2.1%	2.1%

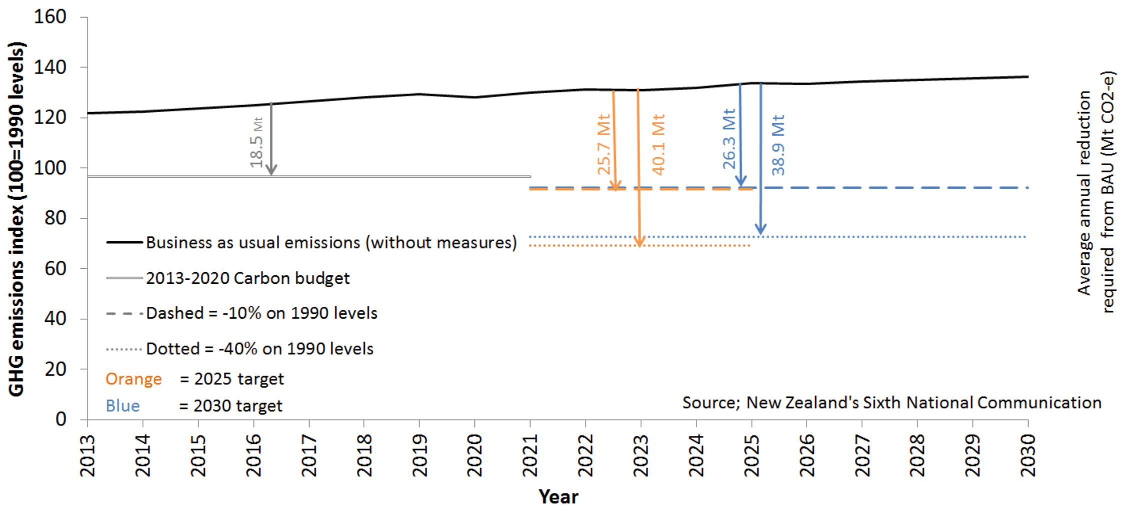
Italicised numbers indicate these results are interpolated from model results.

Appendix C: 2025 vs 2030 targets

Modelling is undertaken for the year 2027. New Zealand's emission reduction target is likely to be set for a target year of either 2025 or 2030. New Zealand will be responsible for emissions over the period 2021 to the target year (the "commitment period"). Changing between 2025 and 2030 target years has little impact on the average annual emissions reductions required over the commitment period, which means that the modelled costs presented in this report are a useful estimate of costs for either target year. This is due to a combination of the QELRO calculation method for New Zealand's average allowable emissions ("carbon budget") and the slope of gross emissions in a Business as Usual scenario (without climate change policies and measures).[15]

For example, setting an emission reduction target of 10% below 1990 levels corresponds to an average annual reduction from 2021-2025 of 25.7 million tonnes of CO_2-e if the target is set at 2025, or an average annual reduction from 2021-2030 of 26.3 million tonnes of CO2-e if the target is set at 2030.

Figure C1: Emissions Path



Beyond modelling considerations presented here, there may be valid economic or strategic reasons to opt for either a 2025 or 2030 target year. Further, setting a 2025 or 2030 target year may lead to different expectations regarding what New Zealand should set in subsequent contributions. However, these issues are outside the scope of this report.

[15] https://unfccc.int/files/cancun_agreements/green_climate_fund/application/pdf/awgkp16.3_0310111.pdf

Appendix D: The ESSAM Model

The ESSAM (Energy Substitution, Social Accounting Matrix) model is a general equilibrium model of the New Zealand economy. It takes into account the main inter-dependencies in the economy, such as flows of goods from one industry to another, plus the passing on of higher costs in one industry into prices and thence the costs of other industries.

The ESSAM model has previously been used to analyse the economy-wide and industry specific effects of a wide range of issues. For example:

- Analysis of the New Zealand Emissions Trading Scheme and other options to reduce greenhouse gas emissions
- Changes in import tariffs
- Faster technological progress
- Funding regimes for roading
- Release of genetically modified organisms

Some of the model's features are:

- 55 industry groups, as detailed in the table below.
- Substitution between inputs into production - labour, capital, materials, energy.
- Four energy types: coal, oil, gas and electricity, between which substitution is also allowed.
- Substitution between goods and services used by households.
- Social accounting matrix (SAM) for tracking financial flows between households, government, business and the rest of the world.

The model's output is extremely comprehensive, covering the standard collection of macroeconomic and industry variables:

- GDP, private consumption, exports and imports, employment, etc.
- Demand for goods and services by industry, government, households and the rest of the world.
- Industry data on output, employment, exports etc.
- Import-domestic shares.
- Fiscal effects.

Model Structure

Production Functions

These equations determine how much output can be produced with given amounts of inputs. For most industries a two-level standard translog specification is used which distinguishes four factors of production – capital, labour, and materials and energy, with energy split into coal, oil, natural gas and electricity.

Intermediate Demand

A composite commodity is defined which is made up of imperfectly substitutable domestic and imported components - where relevant. The share of each of these components is determined by the elasticity of substitution between them and by relative prices.

Price Determination

The price of industry output is determined by the cost of factor inputs (labour and capital), domestic and imported intermediate inputs, and tax payments (including tariffs). World prices are not affected by New Zealand purchases or sales abroad.

Consumption Expenditure

This is divided into Government Consumption and Private Consumption. For the latter eight household commodity categories are identified, and spending on these is modelled using price and income elasticities in an AIDS framework. An industry by commodity conversion matrix translates the demand for commodities into industry output requirements and also allows import-domestic substitution.

Government Consumption is usually either a fixed proportion of GDP or is set exogenously. Where the budget balance is exogenous, either tax rates or transfer payments are assumed to be endogenous.

Stocks

The industry composition of stock change is set at the base year mix, although variation is permitted in the import-domestic composition. Total stock change is exogenously set as a proportion of GDP, domestic absorption or some similar macroeconomic aggregate.

Investment

Industry investment is related to the rate of capital accumulation over the model's projection period as revealed by demand for capital in the horizon year. Allowance is made for depreciation in a putty-clay model so that capital cannot be reallocated from one industry to another faster than the rate of depreciation in the source industry. Rental rates or the service price of capital (analogous to wage rates for labour) also affect capital formation. Investment by industry of demand is converted into investment by industry of supply using a capital input- output table. Again, import-domestic substitution is possible between sources of supply.

Exports

These are determined from overseas export demand functions in relation to world prices and domestic prices inclusive of possible export subsidies, adjusted by the exchange rate. It is also possible to set export quantities exogenously.

Supply-Demand Identities

Supply-demand balances are required to clear all product markets. Domestic output must equate to the demand stemming from consumption, investment, stocks, exports and intermediate requirements.

Balance of Payments

Receipts from exports plus net capital inflows (or borrowing) must be equal to payments for imports; each item being measured in domestic currency net of subsidies or tariffs.

Factor Market Balance

In cases where total employment of a factor is exogenous, factor price relativities (for wages and rental rates) are usually fixed so that all factor prices adjust equi-proportionally to achieve the set target.

Income-Expenditure Identity

Total expenditure on domestically consumed final demand must be equal to the income generated by labour, capital, taxation, tariffs, and net capital inflows. Similarly, income and expenditure flows must balance between the five sectors identified in the model – business, household, government, foreign and capital.

Industry Classification

The 55 industries identified in the ESSAM model are defined on the following page. Industries definitions are according to Australian and New Zealand Standard Industrial Classification (ANZSIC06).

Input-Output Table

The model is based on Statistics New Zealand's latest input-output table which relates to 2006/07.