Zero Carbon Bill

Review of economic modelling for regulatory impact statement

NZIER report to MEUG

08 July 2019

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NZIER was established in 1958.

Authorship

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The comments in this report on the NZIER modelling are made independently of the NZIER team involved in the modelling. The author of this report was not involved in the NZIER modelling for the Ministry for the Environment (MfE) and the report is not informed by any information on the NZIER modelling other than information published by MfE.

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Executive summary

Review of zero net emissions impact models

This report is a review of the published modelling quoted in the regulatory impact statement (RIS) of the Climate Change Response (Zero Carbon) Amendment Bill (Zero Carbon Bill). The RIS relies on three types of modelling:

- Quantitative estimates of the macroeconomic impact completed by NZIER
- Quantitative modelling of the potential for reduction in GHG emissions through change in land use and electrification of transport and industry process heat (the core of the Concept and Motu (CMV) modelling used by the Productivity Commission)
- Qualitative description of the co-benefits of the lower GHG emissions.

The purpose of the report is to compare the estimates of the effectiveness and costs of the proposed adjustments within and across the economy and consider the adequacy of the quantitative modelling as a guide to the trade-offs decision-makers will face in setting carbon budgets.

As this report was commissioned by the Major Electricity Users' Group (MEUG) it includes both general comments on the models and specific observations that are relevant to electricity supply and demand.

Quantitative modelling of costs leaves key questions unanswered

The rationale for the Zero Carbon Bill in the regulatory impact assessment (RIA)[1] provides a partial quantitative estimate of the costs (slower economic and household income growth) and a qualitative description of benefits. The review comments in the RIS state:

> *The modelled finding that the economic impact under all scenarios is expected to be substantial leaves the case for the options proposed dependent on convincing non-economic arguments.*
>
> *The case is made that a clear institutional and policy framework around emissions reductions is required to guide investment decisions, although it is acknowledged that the arrangements discussed in the RIS are not in themselves sufficient for that purpose.*[2]

The NZIER and CMV models, which are part of the starting point for developing those policy instruments, forecast very different carbon prices associated with reducing GHG emissions.

RIS best practice guidelines-which are watermarked 'INTERIM VERSION - UNDER REVISION**'** [3] suggest that the options analysis should aim to state the distributional implications of the options – who wins and who loses – and by how much. The CMV

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1 The 'regulatory impact assessment' is a component of the Zero Carbon Bill Regulatory Impact Statement

2 'Regulatory Impact Statement Zero Carbon Bill' page 15

3 Guidance Note, Best Practice Impact Analysis, June 2017, The Treasury, p 12 section 2.5 An important caveat on this comment is this document is watermarked **'INTERIM VERSION - UNDER REVISION'.**

modelling does not address this question and the second round NZIER modelling only compares changes in industry sector growth rates. The first round of NZIER modelling got closer to answering the question as it considered effects on income for different groups of households.

Over-reliance on one model for key issues and need for update

Modelling the economic effects of climate change is challenging because it requires predictions of structural change in the economy and technological innovation within sectors over a long period of time – a notoriously difficult task. The NZIER and CMV models complement each other so generally there is only one view on key impacts such as change in GDP and land use (afforestation) or electrification.

For two of the three main GHG reduction drivers – afforestation and electrification there is effectively only one source of detailed analysis of:

- sector level reduction in GHG adjustment (Concept for electrification and Motu for afforestation)
- macroeconomic effect of adjustments to lower GHG emissions (NZIER).

For the third driver – methane emissions NZIER has less optimistic assumptions than CMV (Motu) but there is no discussion of the reasons for the difference.[4]

There is no easy method to reconcile the top-down and bottom-up forecasts of change in industry structure for areas where both models provide a view. The NZIER model measures change in value added or final income and consumption (for assessing consumer wellbeing as it links to GDP and income measures). The CMV model measures gross output or inputs (price multiplied by volume) which makes sense when considering a single product but leads to double counting when considering the whole economy.

However future iterations of the NZIER and CMV models or other new models could be made easier to compare by more clearly:

- explaining the similarities and differences between the definitions of sectors in the two models – particularly, agriculture, forestry, transport and electricity supply and demand
- comparing the core assumptions about opportunities for emissions reductions and responses to change in carbon prices.

The major difference in carbon prices generated by the CMV models and the NZIER model suggests a major difference in incentive required to lower GHG emissions and therefore implies uncertainty for policy makers about the feasibility of carbon budgets.

Different rates and types of technological change

The NZIER and CMV models assume similar types of technological change but at different rates to: replace fossil fuel energy with electricity in transport, reduce use of

[4] Three of the NZIER November 2018 scenarios assume a methane vaccine is available from 2030 that reduces dairy emissions by 15 percent and sheep and beef emissions by 10 percent and has a 70 percent adoption rate. The core CMV scenarios assume a year-on-year reduction in GHG emissions per unit of agricultural output and the Techn-optimist scenario assumes a methane vaccine is available from 2030 that reduces dairy emissions by 30 percent and sheep and beef emissions by 20 percent and has a 100 percent adoption rate.

fossil fuels in electricity generation, improve energy efficiency and in some scenarios reduce methane emissions from livestock.

In addition, the CMV model assumes constant (compounding) falls in the cost of electricity generation and falls in emission intensity for agricultural output.

NZIER and CMV do not model the cost of implementing the technological change.

Model runs are dated

The models were completed over 2018 (the latest CMV results were published in July 2018 and the second round of the NZIER modelling was completed in October 2018). Therefore, the model results do not reflect the:

- Government's subsequent announcement of a target to reduce gross emissions of biogenic methane to 10 percent below 2017 levels by 2030 and at least 24 to 47% below 2017 levels by 2050 which apparently needs to be achieved within the agricultural sector[5]. (Two of the NZIER model scenarios – BNF 50 and BNF 75 achieve methane reductions similar to the Government's 2050 target but it is not clear if they achieve the 2030 interim target. The CMV model pathways do not achieve the new target.)
- recent increases in wholesale electricity prices (triggered by temporary gas supply constraints in Spring 2018) that have been sustained after gas supply returned to normal.

Optimistic outlook for electricity prices

CMV's outlook for flat or falling wholesale electricity prices looks optimistic compared to the recent history of electricity prices and is inconsistent with the Sapere[6] assessment that wholesale electricity prices would increase by 30 to 50 percent over the period 2020 to 2050. The Sapere analysis was commissioned by the Productivity Commission, was based on a review of existing electricity demand and supply forecasting models and seems to have been used primarily to consider:

> *"opportunities and risks for electricity supply in New Zealand that arise from moving to an electricity system with very low emissions."*[7]

The Productivity Commission report does not seem to have commented on the difference between the CMV modelling of wholesale electricity price forecasts and the Sapere analysis.

New models are available

The Government has not published the report of the Interim Climate Change Committee (ICCC) in which it was asked to explore how to achieve 100% renewable

5 The CMV modelling assumes agriculture is included in the emissions trading scheme (ETS) and one pathway assumes a methane vaccine while the NZIER scenarios for agriculture non-fungible targets assume a methane vaccine.

6 'Transitioning to zero net emissions by 2050: moving to a very low-emissions electricity system in New Zealand', Toby Stevenson, Dr Stephen Batstone, David Reeve, Matt Poynton, Corina Comendant, 27 April 2018, Prepared for the New Zealand Productivity Commission by Sapere, page viii, available at https://www.productivity.govt.nz/sites/default/files/Transitioning%20to%20zero%20net%20emissions%20by%202050_Sapere.pdf

7 'Low-emissions economy, Final report, August 2018', New Zealand Productivity Commission, page 391

electricity generation in a normal hydrological year. This report would provide an alternative view to the CMV modelling on the potential for electrification to contribute to emission reductions.

The ICCC also considered how agricultural emissions could be incorporated into the Emissions Trading Scheme (ETS). The Government has not published this report either but has set targets for the reduction of biogenic methane emissions (10 percent by 2030, and 24 to 47 percent by 2050 relative to 2017 levels) within the agricultural sector.

The Business Energy New Zealand Council with funding from several government agencies and private sector entities is developing a TIMES[8] model of GHG abatement opportunities for the New Zealand economy.

Improving information for carbon budget setting

The output from the quantitative models leaves the Climate Change Commission (CCC) and policy makers with some difficult questions to consider in setting the initial carbon budgets.

The models:

- agree that a massive increase in tree planting is required to meet GHG emission reduction GHG targets. However, the carbon prices associated with this increase are much lower in the CMV model than in the NZIER model. This implies a high level of uncertainty about how the reduction in net GHG emissions will be split between change in land use and electrification and therefore how the initial adjustment cost will be distributed across different sectors of the economy
- focus on electrification of transport and some other industrial processes. This change is much less sensitive to carbon prices than forestry but appears to be based on falling or flat electricity prices – an optimistic assumption. There is doubt whether technological advances are possible for economic electrification of existing thermal fuelled high temperature process heat load.

In addition, the Zero Carbon Bill) sets out matters that the CCC must consider where relevant.[9] Of the six items listed, at least five have an economic dimension. Two: 'technology that could be efficiently adopted' and 'likely economic effects' are partly covered by the existing models. The remaining three:

- social, cultural and environmental circumstances including regional and sectoral differences
- distribution of costs and benefits between generations
- responses to climate change by parties to the Paris Agreement

are not addressed by the models but discussion of these issues could be informed by economic and choice[10] modelling.

8 TIMES is an acronym for 'The Integrated MARKAL-EFOM System' which was developed as part of the International Energy Agency's 'Energy Technology Systems Analysis Program. More detail is available at

9 See E.1 of this report for a more detailed analysis of the match between the matters for consideration and the coverage of the NZIER and CMV models.

10 Choice modelling uses structured questions to measure consumer preferences can be used to assess the 'willingness to pay for' or 'willingness to pay to avoid'.

Policy on international credits needs to be clarified

The RIS emphasises the goal of achieving zero net emissions (ZNE) through domestic GHG emission reductions or sequestration. However, the Zero Carbon Bill appears to allow the use of international credits (offshore mitigation) but requires 'as much as possible'[11] of the reduction to be based on domestic action. NZIER modelling of the use of international credits shows they allow higher rates of growth and income levels for given level of GHG reductions if afforestation rates rise more slowly than expected or remain low (30Mt by 2050 rather than 40 Mt by 2050).

Need to consider cost of climate change adaptation

The NZIER and CMV models do not consider the cost of adaption to climate change or the capacity of the economy to make these changes. A detailed review of the costs of climate adaptation is beyond the scope of this report. However, the following general points are relevant to the review of the models:

- The probability that New Zealand will incur a particular level of climate change adaptation costs is independent of the GHG reduction action taken by New Zealand but is dependent on global GHG reduction pathways
- As the models do not consider the cost of climate change adaptation, they will over-estimate the capacity and resilience of the economy to shocks caused by climate change
- The NZIER modelling of the impact of GHG reduction emissions was directed away from considering the global GHG reductions in the second round of modelling.

Conclusion

The modelled feasibility and impact of achieving net zero emissions by 2050 varies widely depending on the model used and for two key components – economic impact and afforestation there is only one model.

Both the CMV and NZIER models show that the change in the economy required to reduce GHG emissions requires significant change in land use and increased electrification of transport and industry. However, the NZIER model estimates of the carbon prices required to reduce GHG emissions are about four to ten times above the carbon prices estimated in the CMV model while the reduction in agricultural land use in the NZIER model is more than twice that of the CMV model. These differences are due to the uncertainty of modelling impact of the radical changes required to meet the ZNE targets by trying to extrapolate from recent experience. They cannot be resolved by more modelling using the same set of information.

The NZIER model provides the only estimate of the impact of GHG emission reduction on economic activity and income while the CMV models provide the only view of afforestation in response to different carbon price levels.

The uncertainty around model forecasts and reliance on a single model suggests that five to 15-year carbon budgets based on these models will be exposed to a high risk of error and the budget setting process will need much more flexibility than the very

[11] 'Climate Change Response (Zero Carbon) Amendment Bill' page 15 section 5W.

limited review of the six to 10-year budget and limited review of the 11 to 15-year budget.

Recommendations

To deliver feasible and durable GHG emission reductions through the carbon budget setting process:

- The relevance and usability of the modelling completed to date for carbon budget setting needs to be improved by testing the likelihood of the afforestation and electrification scenarios at forecast carbon prices
- Research and analysis are required on the 'matters of interest the CCC must consider' listed in Appendix E of this report that are not covered by the existing modelling.

To achieve these objectives the CCC should:

- Consult with forest owners, famers and to assess how their tree-planting intentions would respond to a change in carbon prices (level and length of time the change must be sustained) and compare this to recent experience including the One Billion Trees initiative
- Compare the modelling assumptions for the take-up of electric vehicles with recent and current vehicle purchases to assess the likelihood that electrification of the transport fleet will occur as modelled
- Commission economic analysis of the effects of ZNE on regions and income distribution, research including choice modelling on the social, cultural and environmental effects of ZNE and intergenerational transfers attributable to ZNE.

In addition, the carbon budget setting process needs to allow much more flexibility for all the five-year budgets to be adjusted in response to the actual experience of the cost, efficiency and effectiveness of policies to lower GHG emissions.

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1. What has been modelled

1.1. Information used in this report

The reporting and analysis of the models is limited to published data. For the NZIER models these are the reports describing the model results and for the first model only spreadsheets of the model results obtained through an Official Information Act request. The comments in this report are made independently of the NZIER team involved in the modelling. The author of this report was not involved in the NZIER modelling for the Ministry for the Environment (MfE) and the report is not informed by any information on the NZIER modelling other than information published by MfE.

For the CMV model these are the reports and a spreadsheet providing details of the model results released by the Productivity Commission. The reports are published on the Productivity Commission[12] (and MfE) websites. The spreadsheet is available on request[13] from the Productivity Commission.

This report does not comment on the regulatory impact statement (RIS) estimates of the benefits of a zero net emissions (ZNE) target. In Appendix C we quote comments from the quality assurance review of the RIS by the Regulatory Quality Team at Treasury and the Regulatory Impact Analysis Panel at MfE. These comments indicate the quality assurance assessors were not convinced that the RIS provided strong evidence of the benefits of a ZNE target. However, the comments did not suggest any specific remedial action.

1.2. Top down vs bottom-up

The NZIER computable general equilibrium model takes a top-down approach and models how the economy would adjust to the change in use of inputs and outputs caused by policies to reduce greenhouse gas (GHG) emissions based on the current structure of the economy and technological adaptation imposed on the model. This type of modelling allows the calculation of macroeconomic impacts (change in in Gross Domestic Product (GDP) and Gross National Income (GNI) and industry impacts of GHG reduction polices.

The CMV sector-based models are a bottom-up approach to model how sources of GHG emission or sequestration could respond to changes in the price of GHG emissions based on changes in the adoption rate of technologies that reduce GHG emissions. The advantage of this model is that it allows more detailed modelling of the changes in business and household activity that are most likely to contribute to GHG reductions.

12 See 'Downloads' section of https://www.productivity.govt.nz/inquiry-content/3254?stage=4

13 The spreadsheet is available on request from info@productivity.govt.nz . The document offering access to the spreadsheet is listed as 'Cover sheet for final workbook – Concept, Motu, Vivid' in the 'Downloads' section of https://www.productivity.govt.nz/inquiry-content/3254?stage=4 .The document attached to this link is titled 'Modelling the transition to a lower net emissions New Zealand: Final results workbook' and is available at https://www.productivity.govt.nz/sites/default/files/Cover%20sheet%20for%20final%20results%20workbook%20-%20Concept%2C%20Motu%2C%20Vivid.pdf

1.3. Results are different – no surprise

Unsurprisingly the different modelling approaches yield different results. Both the Productivity Commission and the NZIER November 2018 reports include sections explaining why the differences in the modelling approaches lead to different results and how the models play different roles in assisting policy makers. The NZIER modelling estimates the effect on economic growth and income of GHG emission reduction scenarios. The CMV models show where in the economy GHG emission reductions can be achieved at least cost through electrification (Concept) and how land use is expected to switch from agriculture to forestry (Motu) as changes in the price of carbon alter the returns to forestry relative to those of existing land use.

A quote in the NZIER November 2018 report compares the effect on model results of the choice of modelling technique:

> *"Models which include many low-carbon technology options and weak constraints on adoption (e.g., GCAM[14]) will react flexibly in response to a carbon price, substituting technologies quickly and dramatically to reduce [carbon intensity] and emissions.*
>
> *Other models with fewer low-carbon alternatives and stronger constraints on adoption (e.g., EPPA[15]) are comparatively rigid, and the energy structure will transform less significantly and more gradually. Neither is likely 'correct' but together they bound the possible solutions"*[16]

1.4. Improving the 'usability' of models

While these comments are helpful in explaining why the model results diverge, they do not help policy makers and stakeholders in the economy compare the feasibility or relative cost of GHG emission reduction pathways. The reduction of GHG emissions to meet a ZNE target in 2050 relies first on afforestation and second on electrification of the energy sector. To improve the usability of the models for policy-making advice is needed on how to reconcile the two sets of model results (and assumptions) into an assessment of the likelihood and relative cost of alternative adjustment pathways.

1.4.1. Afforestation and carbon prices

According to the CMV modelling, an average carbon price over the period 2020 to 2050 between \$NZ/tCO_2-e 63 and \$NZ/tCO_2-e 105 will lead to sequestration of 32 MtCO_2-e to 52 MtCO_2-e in 2050.

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14 Global Change Assessment Model (GCAM) is a partial equilibrium global model with 15 regions with three sub modules: core energy, agriculture & land use, and a model of GHG induce climate change. The model assumes energy efficiency improvement over time and solves for the least-cost path to meet a specified global atmospheric CO2 concentration target

15 Emissions Prediction and Policy Analysis (EPPA) is a general equilibrium model of the world economy split into 16 regions representing all production sectors and households but with emphasis on energy resources, electricity, and agriculture. The model does not include a climate change sub-module.

16 Wilkerson, J.T, Leibowicz, B.D., Turner, D. D. and Weyant J.P. 2015. 'Comparison of integrated assessment models: Carbon price impacts on U.S. energy'. Energy Policy 76 (2015), pp.18-31 available at https://www.researchgate.net/publication/267393055_Comparison_of_Integrated_Assessment_Models_Carbon_Price_Impacts_on_US_Energy#pfd

However according to the NZIER November 2018 modelling carbon sequestration of:

- 30 $MtCO_2$-e in 2050 would imply an average carbon price over the period 2020 to 2050 of $NZ 940 /$tCO_2$-e
- 40 $MtCO_2$-e in 2050 would imply an average carbon price over the period 2020 to 2050 of $NZ 406 /$tCO_2$-e.

The CMV model treats carbon prices as one of several drivers of change in land use. The NZIER model imposes carbon sequestration on the model and then calculates the carbon price that is required to secure the rest of the reduction in GHG emissions from the rest of the economy. The difference in method goes some way to explaining why the difference in carbon prices might be so high but it is not very helpful in answering the question of what mix of economic impact and GHG emission reductions would arise if the carbon price increased from $NZ 50 to 100 /$tCO_2$-e.

1.4.2. Electrification and carbon prices

Modelling of electrification – the second main contributor to GHG emission reduction – illustrates another area for improvement in the usability of the modelling for policy decisions, namely – reliance on one model.

The NZIER model applies some of the key electrification changes as assumptions such as the switch to electric vehicles. It is difficult to extract either electricity demand or wholesale electricity price forecasts from the model. This leaves the Concept models of electricity demand and generation as the only ‘accessible’ published set of model results on electrification. The Concept model forecasts suggest:

- that electrification is relatively insensitive[17] to changes in the carbon price – a 40 to 90 percent increase in average carbon prices over the period 2020 to 2050 lowers average emissions over the same period by 5 to 8 percent
- wholesale[18] electricity prices will remain flat or fall over the period 2020 to 2050 – new generation will match demand at or below $80 per MWh.

17 The sensitivity is estimated by comparing the average carbon prices and GHG emissions for the 25 $MtCO_2$-e in 2050 and ZNE in 2050 targets for each of the three CMV pathways – PD, D and TO. Admittedly this is a crude measure.

18 Wholesale electricity prices are the price for the generation of electricity set in the electricity market and are one component of the total electricity price paid by consumers. Electricity prices for large consumers directly connected to the transmission grid will also include transmission prices. Electricity prices for all other consumers will include an average of the wholesale price, transmission costs and distribution costs. As electricity demand (measured in energy hours) rises consumers may also face increases in per energy hour transmission and distribution costs depending on how the increase in demand affects levels of peak energy demand.

2. Key model results

2.1. Overview

Both models rely on tree planting to achieve the bulk of the offset of GHG emissions followed by electrification of transport and generally assume that the GHG reduction target must be met through domestic initiatives alone. (Purchase of International emission units is not considered in the NZIER 'base case' or 'status quo' but Is considered in one of the sensitivity modelling scenarios.)

The main differences in the modelling results (where the models can be compared) are the:

- level of carbon prices required to secure a similar reduction – the NZIER modelled averages are about four to ten times higher than those for the CMV model. (The NZIER estimates the level of carbon prices required to deliver the required reduction in emissions in the rest of the economy after an assumed level of forestry sequestration. Carbon prices in the CMV models were set exogenously until 2030 and then set at the level required to deliver an emission reduction target.)
- treatment of agriculture – the first round of the NZIER modelling assumed the introduction of a methane vaccine and the second round replaced this assumption with fungible (no methane vaccine) and non-fungible (methane vaccine) biogenic gas emission targets. The CMV model is based on changes in returns for different land uses based primarily on changes in carbon prices (but also assumes a continuous reduction in emissions intensity for agriculture and a methane vaccine in one pathway). The maximum reduction in agricultural GHG emissions over 2017 to 2050 was about 20 percent in the CMV model, just below the lower end of the Government target range. The second round of NZIER modelling included a scenario similar to the Government targets for 2050.

2.2. NZIER

NZIER completed two modelling runs for MfE, in June 2018 and November 2018. The November 2018 model was designed to improve the relevance of the modelling results to the assessment of GHG reduction options by:

- making innovation assumptions economy wide rather than sector specific
- modelling the reduction in agricultural land use attributable to increased forestry
- aligning the treatment of biogenic[19] gases more closely with the options considered by including a non-fungible reduction target. (The modelling also included a fungible target, but it now seems this option is redundant[20].)

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19 The Zero Carbon Bill 2050 target for biogenic methane includes methane produced by agriculture and biological (plant and animal) waste. The majority (88% in 2017) of biogenic methane is from agriculture. Almost all the methane from agriculture is from ruminant livestock (released in sheep and cow burps).

20 The fungible target assumed that agricultural emissions could be offset by emission reduction in other industries, but the methane reduction targets announced by the Government seem to require the reduction in methane emission need to be achieved within the agricultural sector.

- correcting an underestimation of the reduction required for the status quo target and using a new slightly lower baseline for economic growth.

In addition, the model also assumed a lower level of forest sequestration than either the CMV modelling or the June 2018 modelling – 30 $MtCO_2e$ instead of 40 to 50 $MtCO_2e$ in the June 2018 modelling.

The model results show the estimated reduction in GDP, value added by sector and household income for various GHG reduction targets compared to a status quo of reducing GHG emissions to 50 percent of 1990 levels without access to international credits.

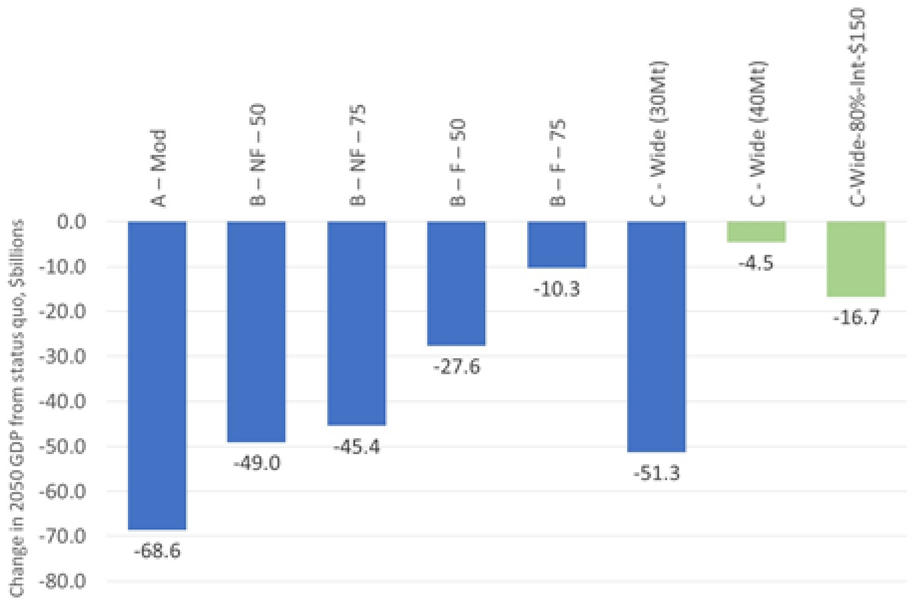
The application of the status quo is the technically correct approach for the RIS in assessing the additional impact of adopting the 'ZNE by 2050' target. However, lowering GHG emissions from the base case level (which was declared to be untenable) to the level assumed in the status quo also imposes a cost on the economy. The CMV models can manage this issue more transparently as they apply assumptions about a rate of change to the current actual position of the economy.

The following three charts are copied from the NZIER November 2018 report.

2.2.1. NZIER November 2018 – results

Figure 1 Reduction in 2050 real GDP, $ billions

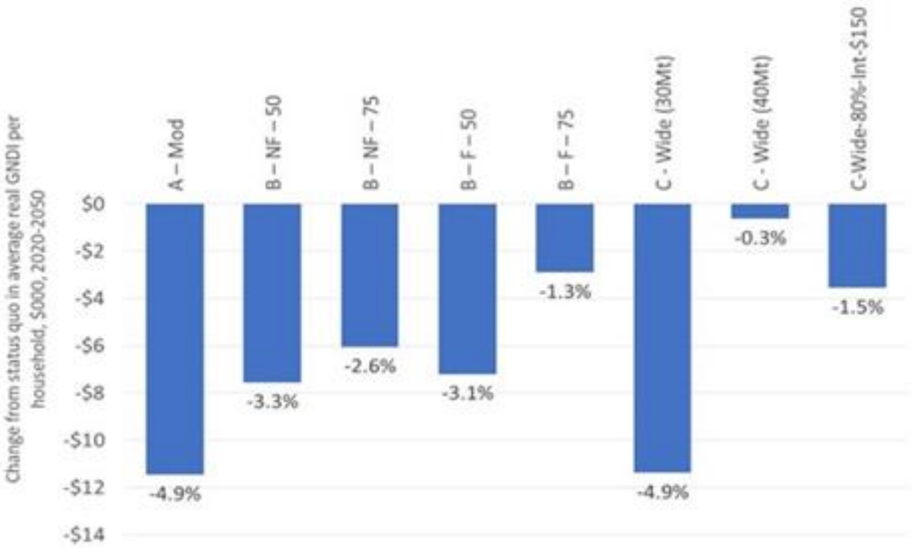
Change in 2050 real GDP from the status quo of $536 billion



Source: NZIER Economic impact of meeting 2050 emissions targets, Stage 2 modelling November 2018

Figure 2 Change in per household purchasing power

Change in average annual RNGDI per household between 2020 and 2050, relative to the status quo, $000s; labels show % change from status quo



Source: NZIER

2.2.2. Technological change

The NZIER November 2018 model includes two scenarios for technological change – 'Moderate' and 'Wide'. The rate of innovation is slower in the 'Moderate' than in the 'Wide' scenario and the model assumes that the rate of innovation will be faster for the more ambitious emission reduction targets. The two innovation scenarios are summarised in the following table based on a table in the NZIER November 2018 report.[21]

21 'Economic impact of meeting 2050 emissions targets, Stage 2 modelling. 9 November 2018', NZIER final report to Ministry for the Environment, Table 4 page 14

Table 1 NZIER innovation scenarios

Comparison of speed of innovation by type and link to modelling scenario

Innovation	Moderate	Wide
Model scenario	**SQ-Mod; A-Mod; All B-F**	**B-NF, C-Wide, C-Wide-Intl**
Methane vaccine	No methane vaccine	Reduces dairy emissions by 15%; S&B by 10%; 70% adoption; spread over 20 years (2030-2050)
Electric vehicles (EVs)	80% light vehicle fleet; 25% heavy vehicle fleet by 2050	95% light vehicle fleet; 50% heavy vehicle fleet by 2050
Renewable electricity generation	92% renewables from 2035-2050; remainder gas	98% renewables from 2035-2050; remainder gas
Energy efficiency improvements	1.5 times the baseline energy efficiency trends	Double the baseline energy efficiency trends

Source: NZIER

2.2.3. Model limitations

The NZIER model enables full consideration of the interdependencies between sectors and the budget and resource constraints that affect the whole economy. However, this is achieved at the cost of granular analysis of the key drivers of the adjustment to a low carbon economy. The NZIER model has:

- forestry sequestration imposed on the model from outside the model although the reduction in agricultural land use due to forestry is included in the second-round model
- minimal electricity market insight. The model included five generation types and assumed 98% renewable from 2035. However, the model does not estimate the volume of electricity generated/used or the wholesale electricity prices in $/MWh (which would allow interested parties to assess if the outcomes are feasible and reasonable).

2.3. CMV

2.3.1. CMV model overview

The CMV models consider two targets for 2050 emissions: 25 Mt CO_2 and ZNE achieved through three decarbonisation pathways for each target:

- Policy driven (PD) - Increase price of emissions intensive products and processes
- Disruptive (DD) – Supply-side response to new technology
- Stabilising (SD) – renamed Technological Optimist (TO), technology reduces emission of existing industries.

The scenarios are referred to as the name of the path followed by:

- ‘25’ for the net emissions target of 25 Mt CO_2 in 2050 – PD25, DD25 and TO25
- ‘0’ for the target of ZNE in 2050 – ‘PD0’, ‘DD0’ and ‘TO0’.

(CMV model carbon prices are set exogenously until 2030.)

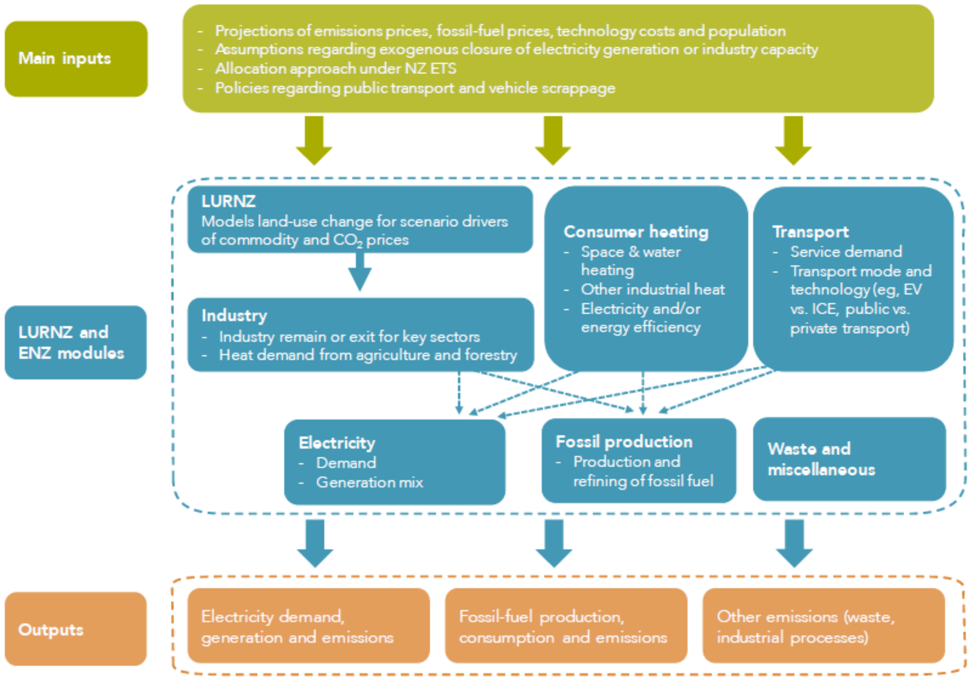
2.3.2. CMV model structure

The CMV model focuses primarily on energy (by Concept Consulting) and land use (by Motu).

Figure 3 CMV model structure overview

Linkages between inputs, models (land use and & energy) and outputs

Figure 3-5 How the models, sectors and modules are linked



Source: Concept Consulting et al. (2018a).

Source: Productivity Commission Report

The Concept Consulting Energy NZ model contains many sub-models with varying levels of granularity of the major forms of generation and use of energy. The sub-models estimate the least cost way to meet demand given:

- market drivers – population, emission and fuel prices, technology etc.
- exogenous factors – policy etc.

The model for electrification of transport distinguishes between light and heavy vehicles while the electricity generation model allows for the intermittency of renewable sources.

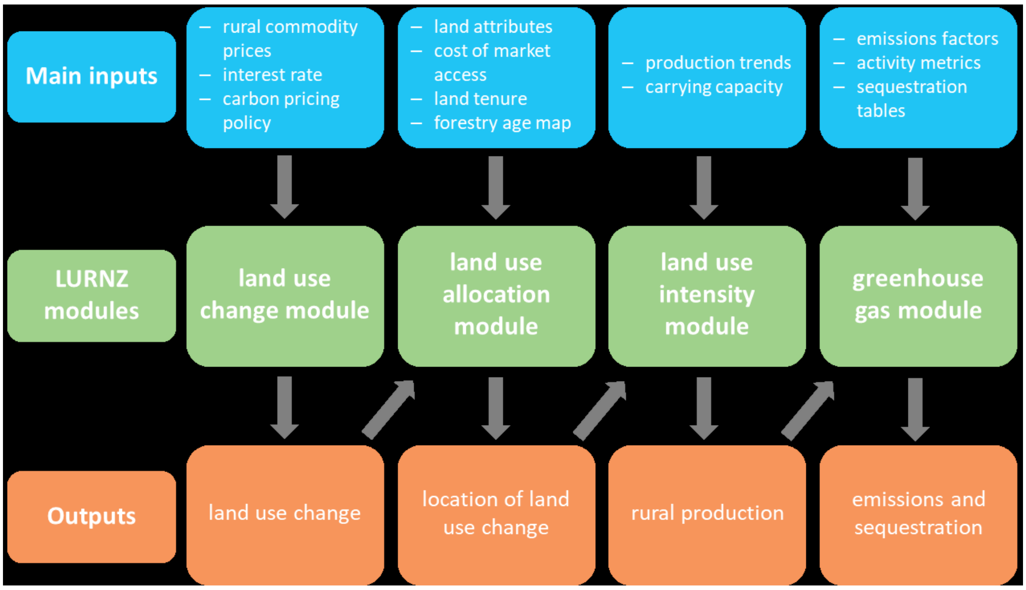
Motu uses two econometric models of land use drivers and outcomes in its Land Use in Rural New Zealand (LURNZ) model:

- land use response to economic drivers (national)
- spatial model of land use down to 25ha blocks based on:

- Geo-physical characteristics
- Proxies for land cost, yields and tenure.

Figure 4 LURNZ model (Motu)

Linkages between inputs, land use model module and outputs



Source: Productivity Commission

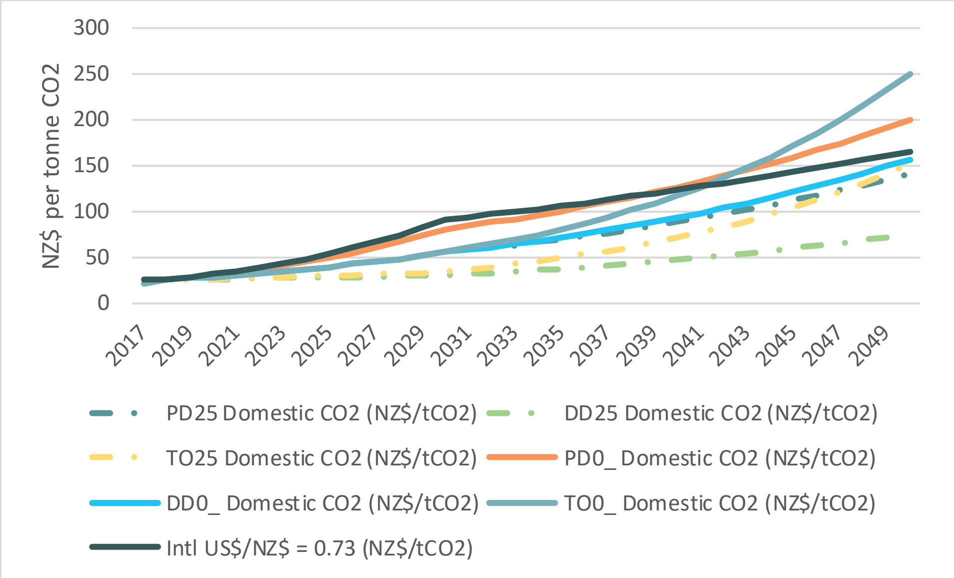
2.3.3. CMV model outputs

Carbon price forecasts

The forecast domestic carbon prices for the CMV model all increase gradually over the period 2020 to 2050. The upper range of carbon prices for the '25 Mt CO_2 in 2050 target' overlaps with the lower range carbon prices for the 'ZNE in 2050 target' as shown in Figure 5 below.

Figure 5 CMV carbon price forecasts

CMV pathways for '25 Mt CO_2 in 2050' and 'ZNE in 2050' targets



Source: NZIER

To enable comparison with how the second NZIER report lists carbon prices, the average carbon prices for 2020 to 2050 (and shorter intervals) are listed in Table 2 below. The percentage difference in the carbon price for the '25 Mt CO_2 in 2050' and the 'ZNE in 2050' targets for each of the pathways, 'PD', 'DD' and 'TO' provides a very rough indication of the responsiveness of reduction in emissions to changes in the carbon price for that pathway.

The CMV international carbon price assumption in the 'PD', 'DD' and 'TO' scenarios is higher than the domestic carbon price for all the '25 Mt CO_2 in 2050' scenarios and DD0 over the forecast period and PD0 and TO0 until about 2040. This assumption was changed in the 'uncertainty analysis' and is explained in more detail in section 5.2 .

Table 2 CMV average forecast carbon prices

Average carbon price over period shown

Path	Average 2022-2030		Average 2031-2040		Average 2041-2050		Average 2020-2050	
	$NZ/t	Change	$NZ/t	Change	$NZ/t	Change	$NZ/t	Change
PD25	43		72		96		75	
DD25	28		39		51		42	
TO25	30		52		84		63	
PD0	56	31%	104	44%	137	43%	105	40%
DD0	43	52%	74	92%	102	100%	79	87%
TO0	43	41%	85	64%	138	64%	101	60%

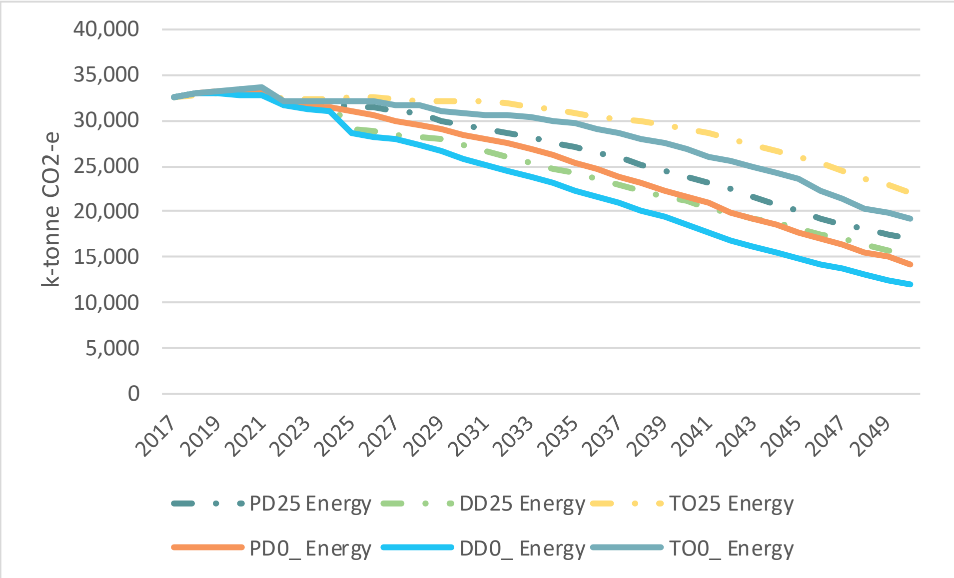
Source: NZIER

Emissions reductions

The CMV model reports on emissions for five broad sectors: 'energy' (which includes transport), 'IPPU' (industrial processes and product use), 'agriculture', 'waste' and 'LULUCF' (land use, land use change and forestry). The main drivers of GHG emissions reduction are energy and LULUCF (mainly though forestry). Agriculture is a major source of emissions but the reduction in emission under each of the CMV pathways is relatively modest as shown in the following charts and tables.

Figure 6 CMV (Concept) energy emissions

Forecast reduction by core pathway



Source: NZIER

Table 3 CMV (Concept) average energy emissions

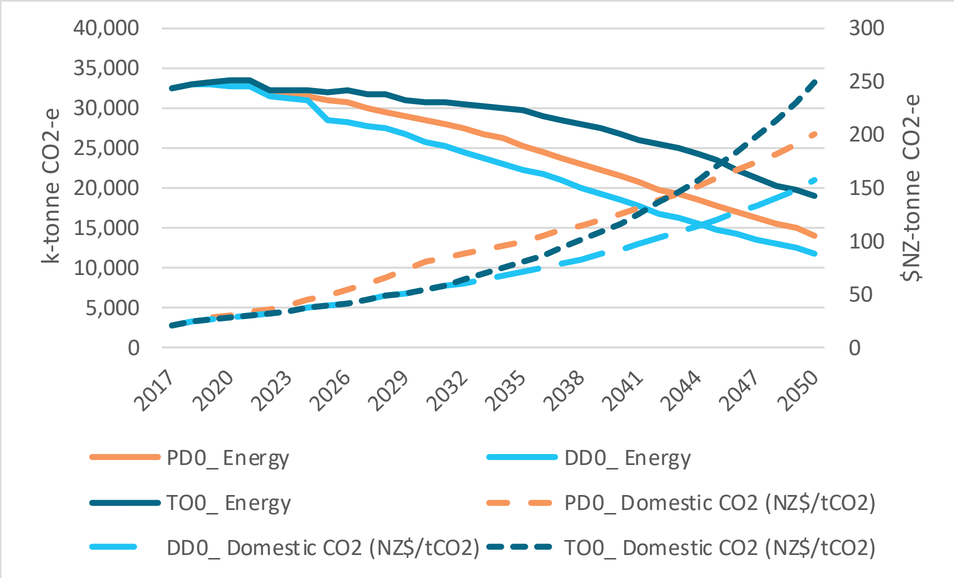
Average GHG emissions over period shown, 'Change' compares ZNE to net 25,000 $ktCO_2$-e pathways

Path	Average 2022-2030		Average 2031-2040		Average 2041-2050		Average 2020-2050	
	$ktCO_2$-e	Change	$ktCO_2$-e	Change	$ktCO_2$-e	Change	$ktCO_2$-e	Change
PD25	31,120		26,663		22,950		26,195	
DD25	29,501		23,869		20,528		24,159	
TO25	32,373		30,653		27,884		29,670	
PD0	30,395	-2%	24,932	-6%	20,801	-9%	24,612	-6%
DD0	28,730	-3%	21,961	-8%	17,938	-13%	22,265	-8%
TO0	31,811	-2%	29,131	-5%	25,685	-8%	28,133	-5%

Source: NZIER

Figure 7 CMV (Concept) ZNE in 2050 energy emissions and carbon prices

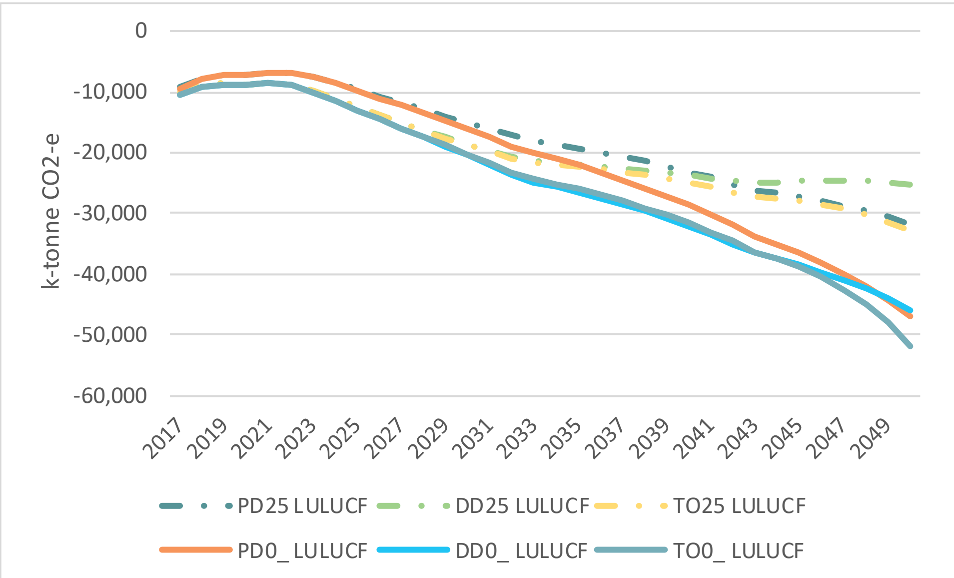
Forecast reduction by core pathway



Source: NZIER

Figure 8 CMV (Motu) 'Land Use, Land Use Change and Forestry (LULUCF) emissions

Forecast reduction by core pathway



Source: NZIER

Table 4 CMV (Motu) average LULUCF emissions

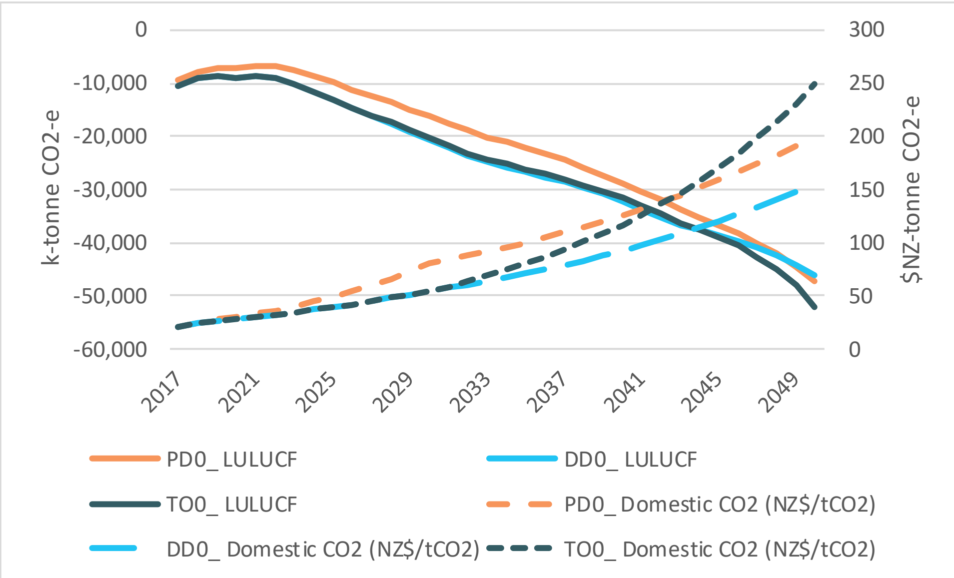
Average GHG emissions over period shown. 'Change' compares ZNE to net 25,000 $ktCO_2$-e pathways

Path	Average 2022-2030		Average 2031-2040		Average 2041-2050		Average 2020-2050	
	ktCO2-e	Change	ktCO2-e	Change	ktCO2-e	Change	ktCO2-e	Change
PD25	-10,740		-19,668		-24,144		-18,885	
DD25	-13,707		-22,052		-23,595		-19,633	
TO25	-13,772		-22,573		-25,947		-21,099	
PD0	-11,154	4%	-22,886	16%	-31,101	29%	-23,316	23%
DD0	-14,517	6%	-27,146	23%	-33,858	43%	-26,241	34%
TO0	-14,436	5%	-26,627	18%	-34,367	32%	-26,519	26%

Source: NZIER

Figure 9 CMV (Motu) LULUCF ZNE in 2050 emissions and carbon prices

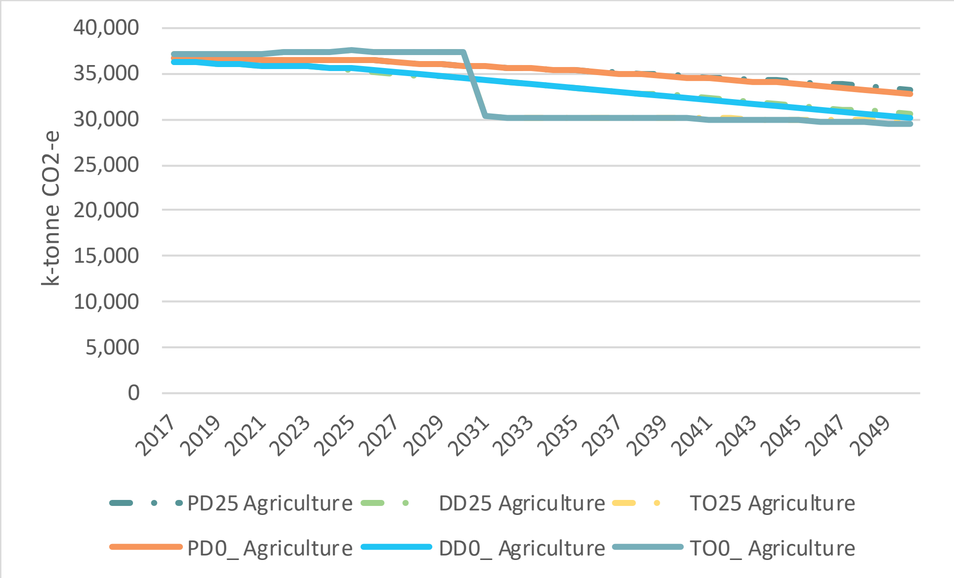
Forecast reduction by core pathway



Source: NZIER

Figure 10 CMV (Motu) agricultural emissions

Forecast reduction by core pathway



Source: NZIER

Table 5 CMV (Motu) average agricultural emissions

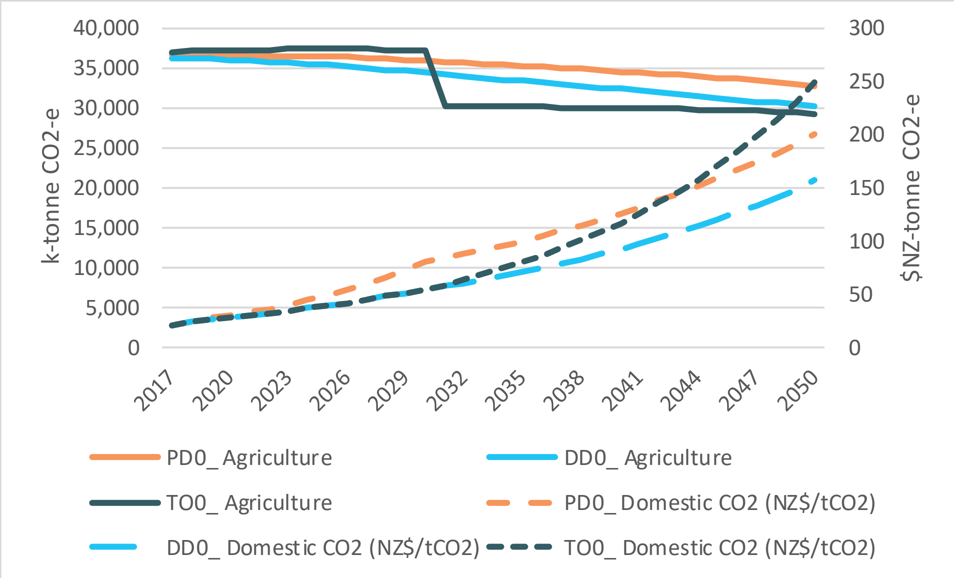
Average GHG emissions over period shown, 'Change' compares ZNE to net 25,000 $ktCO_2$-e pathways

Path	Average 2022-2030		Average 2031-2040		Average 2041-2050		Average 2020-2050	
	ktCO2-e	Change	ktCO2-e	Change	ktCO2-e	Change	ktCO2-e	Change
PD25	36,364		35,307		34,594		35,280	
DD25	35,250		33,383		32,315		33,469	
TO25	37,419		30,202		30,073		32,677	
PD0	36,367	0%	35,271	0%	34,423	0%	35,177	0%
DD0	35,255	0%	33,350	0%	32,183	0%	33,390	0%
TO0	37,423	0%	30,185	0%	29,975	0%	32,618	0%

Source: NZIER

Figure 11 CMV (Motu) agricultural ZNE in 2050 energy emissions and carbon prices

Forecast reduction by core pathway



Source: NZIER

2.3.4. Electricity market impact

Concept

Concept Consulting modelling of the electricity market shows the following results:

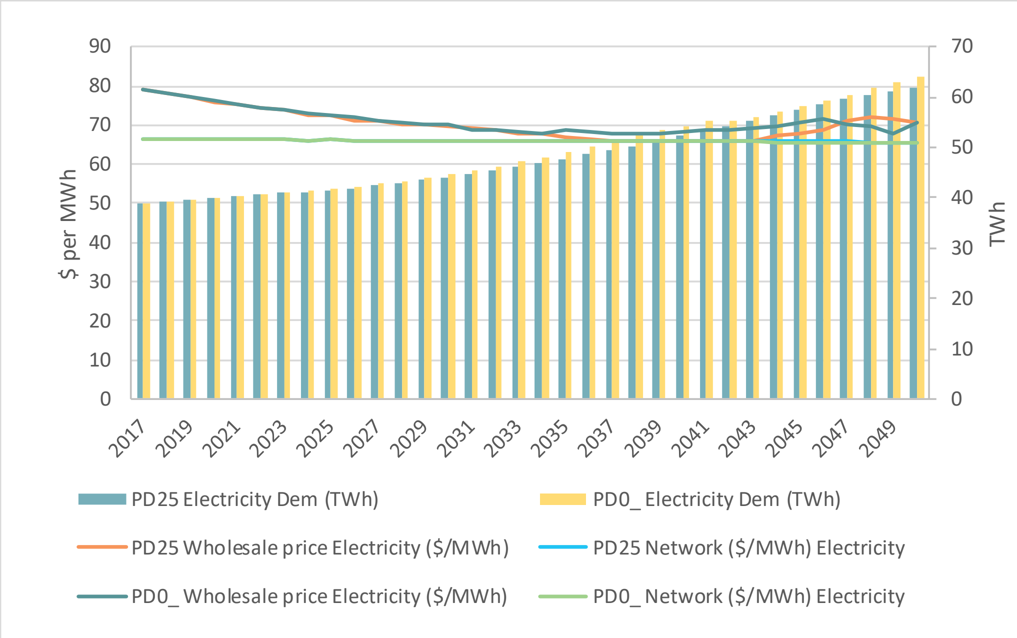
- increase in electricity generation and demand is similar for both the '25 Mt CO_2 in 2050' and 'ZNE in 2050' targets and for each of the three pathways
- wholesale electricity prices are expected to remain flat or fall over the forecast period while network costs per MWh remain flat
- hydro generation declines in absolute terms and is replaced by wind.[22]

These points are illustrated in the following charts.

[22] The Concept generation model assumes an annual cost improvement for wind of 1.25 percent, solar of 2.5 percent and geothermal of 0.25 percent under the 'Policy Driven' (PD) scenario. For the 'Disruption Driven' (DD) scenario the annual cost improvements are 1.5 times the rates in the PD scenario: implying an annual cost improvement for wind of 1.875 percent, solar of 3.75 percent and geothermal of 0.375 percent. For the 'Techno-optimist' (TO) scenario the annual cost improvements are 0.5 times the rates in the PD scenario: implying an annual cost improvement for wind of 0.625 percent, solar of 1.25 percent and geothermal of 0.125 percent. See 'Modelling the transition to a lower net emissions New Zealand, Interim results, April 2018' p17. These assumptions to wide variation in the cost of generation. For example, wind generation cost is forecast to be 13 to 30 percent lower in 20 years' time.

Figure 12 CMV (Concept) forecast electricity demand and wholesale prices

PD25 and PD0 – pathways with the highest increase in electricity demand

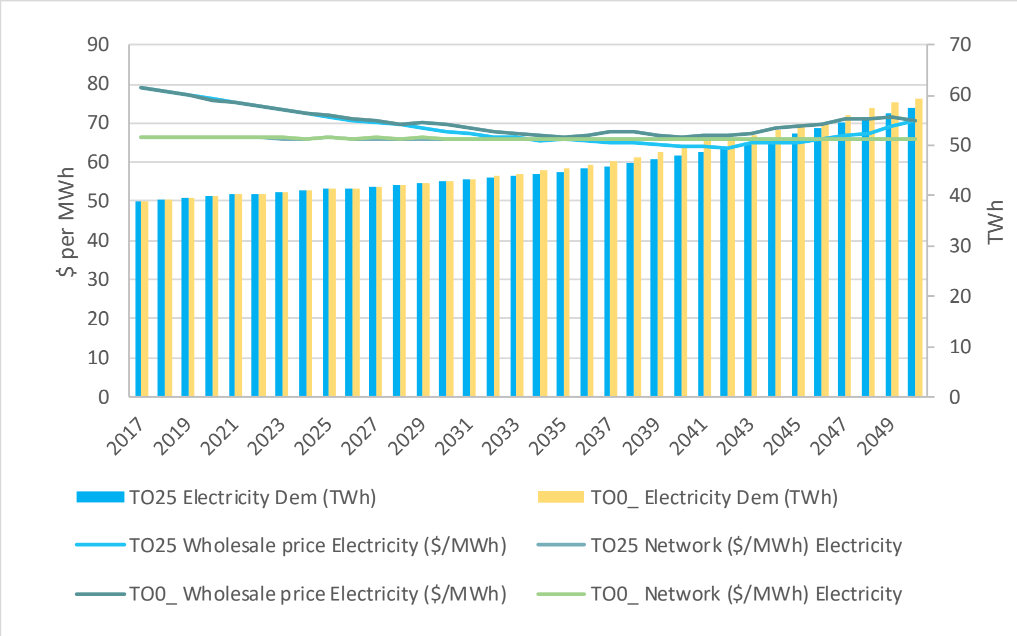


Source: NZIER

The PD pathway has the highest overall increase in electricity demand and the TO pathway has the lowest overall increase in electricity demand. However, the maximum difference in demand between the two pathways is about 11 percent compared with an increase over the period 2020 to 2050 of at least 48 percent.

Figure 13 CMV (Concept) forecast electricity demand and wholesale prices

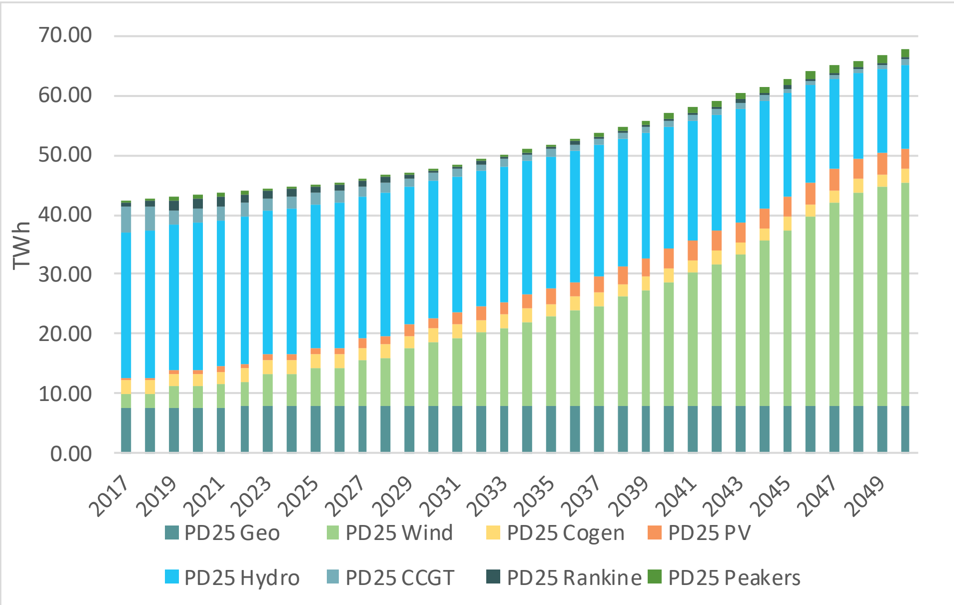
TO25 and TO0 – pathways with the lowest increase in electricity demand



Source: NZIER

Figure 14 CMV (Concept) electricity generation mix for PD25

Electricity output (TWh) by type of plant



Source: NZIER

All the CMV electricity generation scenarios show an absolute decline in hydro generation with most of the increased generation requirements being met by wind.

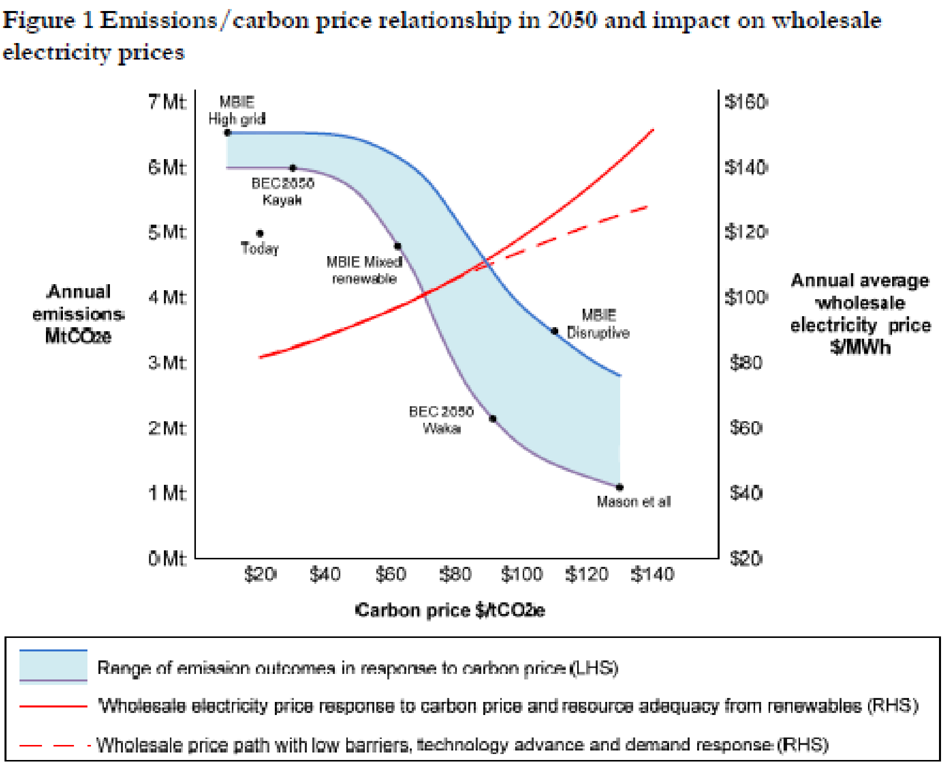
Sapere

The Sapere analysis was commissioned by the Productivity Commission to consider the opportunities and risks to New Zealand's electricity supply of reducing GHG emissions from electricity generation.

As part of the modelling for the Productivity Commission, Sapere analysed existing models of electricity demand and likely generation response and concluded that wholesale electricity prices were likely to rise by $25-$40/MWh by 2050. This is equivalent to an increase of approximately 25 to 50 percent in wholesale electricity prices by 2050. Based on the current share of 'energy' in electricity prices, about 60[23] percent of this increase in wholesale prices would be expected to translate to an increase is residential electricity prices of approximately 15 to 30 percent by 2050.

Figure 15 Sapere electricity price forecast

Potential response of electricity prices to carbon prices



Source: Sapere report to the Productivity Commission[24]

23 The 'energy' and 'lines' components of retail electricity prices are reported in the 'Quarterly Survey of Domestic Electricity Prices' completed by the Ministry of Business Innovation and Employment. For the quarterly surveys over the ten-year period to February 2018, on average the energy component was 60.33 percent of retail electricity prices.

24 'Transitioning to zero net emissions by 2050: moving to a very low-emissions electricity system in New Zealand', Toby Stevenson, Dr Stephen Batstone, David Reeve, Matt Poynton, Corina Comendant, 27 April 2018, Prepared for the New Zealand Productivity Commission by Sapere, page viii, available at https://www.productivity.govt.nz/sites/default/files/Transitioning%20to%20zero%20net%20emissions%20by%202050_Sapere.pdf

2.3.5. Model limitations

The CMV model provides detailed simulation of:

- changes in land use based on historical relationships between differences in land use profitability and land use change combined with detailed data on the suitability of the land for different uses
- electrification based on assumed rates of change in the price of substitute technologies and the selection of the least cost method to delivery energy needs.

As both models are partial equilibrium models, they do not allow for budget constraints and competition for resources across the economy.

For the modelling of afforestation, it is not clear how long carbon prices would need to be sustained at higher levels before they are regarded as 'reliable' and trigger the switch in land use which is large in comparison to the historical changes in land use on which the model is based.

The modelling of electrification is based on steady or falling wholesale electricity prices which appears to be questionable given the recent history of electricity prices and the forecast increase in demand leading to higher cost of electricity as higher carbon prices increase marginal back-up generation offer prices.

3. Points of comparison

3.1. Overview

The NZIER and CMV models provide top-down and bottom-up views of the adjustment of the potential adjustment paths but because of the way the models are structured the comparison points are limited to estimated carbon prices and possibly changes in land use.

A comparison of the impact on industries is not feasible because both the definitions of industries and the measure of impact are different for the two models.

3.2. Difference in carbon prices

The CMV and NZIER models produce very different estimates of average carbon prices over the period 2020 to 2050 for similar levels of forest sequestration of GHG emissions as shown in the following table.

Table 6 Forest sequestration and carbon price scenarios

CMV and NZIER scenarios sorted by 2050 forestry sequestration of carbon in ascending order

CMV			NZIER Nov 2018		
Scenario	2050 Forest Sequestration ($MtCO_2e$)	Average carbon price ($\$/tCO_2e$)	Scenario	2050 Forest Sequestration ($MtCO_2e$)	Average carbon price ($\$/tCO_2e$)
			A-Mod	19.0	1,125
			C-Wide-80%-Int-$150 [1]	24.0	567
DD25	25.2	42			
			C-Wide (30 Mt)	30.0	940
PD25	31.7	75			
PD0	31.7	105			
TO25	33.0	63			
			C-Wide (40 Mt)	40.0	406
DD0	45.9	79			
TO0	51.9	101			

Notes:

1. In this scenario domestic GHG reductions reach 80% of ZNE for 2050. The remaining 20% of emissions is offset through international purchases, at an additional cost to businesses of $2 billion between 2020 and 2050. However, the reduction in GDP by 2050 is around 1/3 of the impact when no access is considered.

Source: NZIER

The forestry sequestration in the NZIER C-Wide (30 Mt) seems to be roughly comparable to the CMV ‘25 Mt CO_2’ pathways while the forestry sequestration for the NZIER C-Wide (40 Mt) seems to sit about midway between the CMV ‘25 Mt CO_2’ and ‘ZNE in 2050’ pathways.

Afforestation makes the largest contribution to achieving the GHG emissions in both models and is also much more sensitive to changes in the carbon price than electrification – the other main adjustment mechanism. If the CMV model estimates of the carbon price sensitivity of forestry are correct, then:

- the reduction in GDP modelled by NZIER will be much lower as the carbon prices are lower
- the CMV model suggests there is an option to accelerate afforestation as a lower cost way to meet the ZNE target.

3.3. Difference in technology change

Both the NZIER and CMV models assume technology change will assist the economy to reduce GHG emission without reducing economic activity but the models include different types of technological change assumptions and where the models include the adoption of the same technology the rate of adoption is different. The main differences are shown in Table 7.

Table 7 Key technology change assumptions

Comparison of NZIER and CMV models

Technology	NZIER	CMV
Agriculture		
Methane vaccine	Reduces: • dairy emissions by 15 percent • S&B by 10 percent • 70 percent adoption; spread over 20 years (2030-2050)	Reduces: – dairy emissions by 30 percent – S&B by 20 percent – 100 percent adoption rate – available from 2030
Methane intensity reduction	Not included	Continuous improvement (year on year) in the efficiency of GHG emission per unit of product
Transport		
Electric vehicles (EVs)	80 to 95 percent of light vehicle fleet; 25% to 50 percent of heavy vehicle fleet by 2050	39 to 80 percent of total vehicle fleet by 2050
Electricity		
Renewable electricity generation	92 to 95 percent renewables from 2035-2050; remainder gas	94 to 95 percent renewables from by 2050
General		
Energy efficiency improvements	1.5 or 2 times the baseline energy efficiency trend.	Residential and commercial energy efficiency improvement of 0.25 percent per year for space heating and 0.1 percent per year for all other uses

Source: NZIER

3.4. Difference in land use change

The NZIER November 2018 model options for reduction of biogenic GHG emissions as well as the difference in assumptions about sequestration leads to different changes in land use from those forecast in the CMV model.

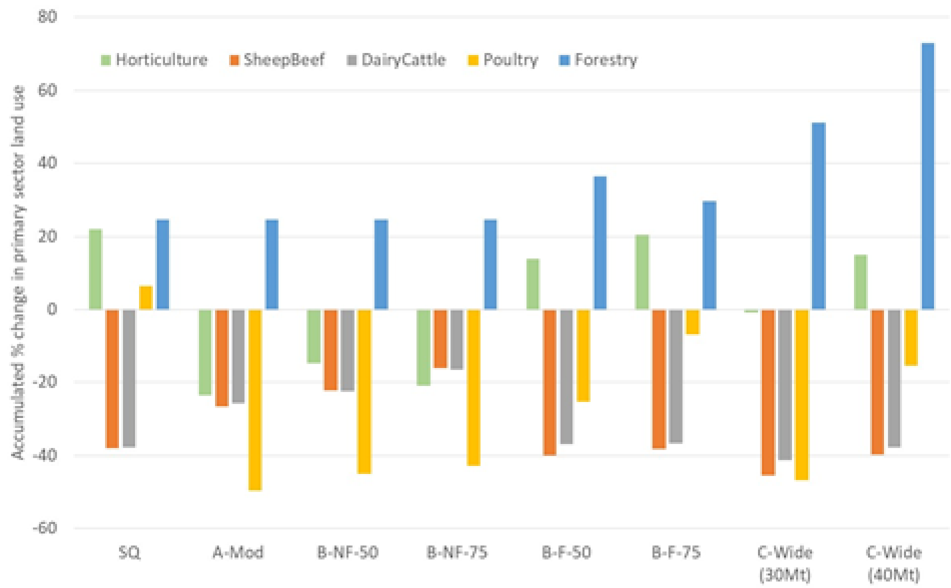
NZIER November 2018 forecasts that in 2050 compared to current levels, land use for:

- 'sheep & beef' and 'dairy' will be about 40 percent lower under both the C-Wide (30 Mt) and C-Wide (40 Mt)[25]
- forestry will be about 50 percent higher under C-Wide (30 Mt) and 70 percent higher under C-Wide (40 Mt).

[25] C-Wide (30 Mt) assumes 30 Mt of CO_2.are sequestered by forestry in 2050 and C Wide (40 Mt) assumes 40 Mt of CO_2.are sequestered by forestry in 2050

Figure 16 NZIER land use impacts on primary sector

Change from baseline primary sector land use



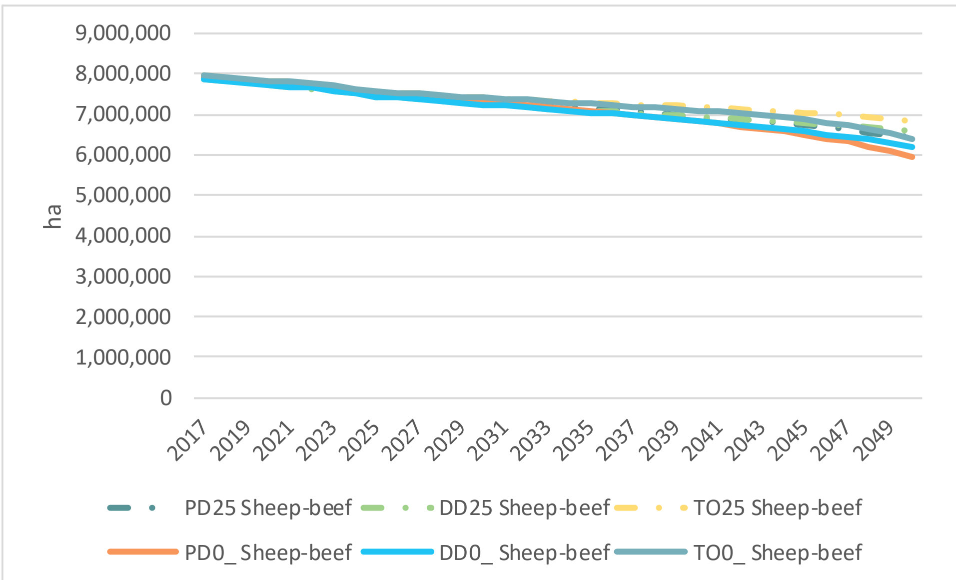
Source: NZIER

The CMV model forecasts that in 2050 compared to current levels, land use for:

- sheep & beef will be 15 to 22 percent lower
- dairy will be 23 percent lower to 6 percent higher depending on the pathway but with almost no variation between the '25 Mt CO_2e by 2050' and 'ZNE by 2050' targets for each pathway.

Figure 17 CMV change in sheep and beef land use

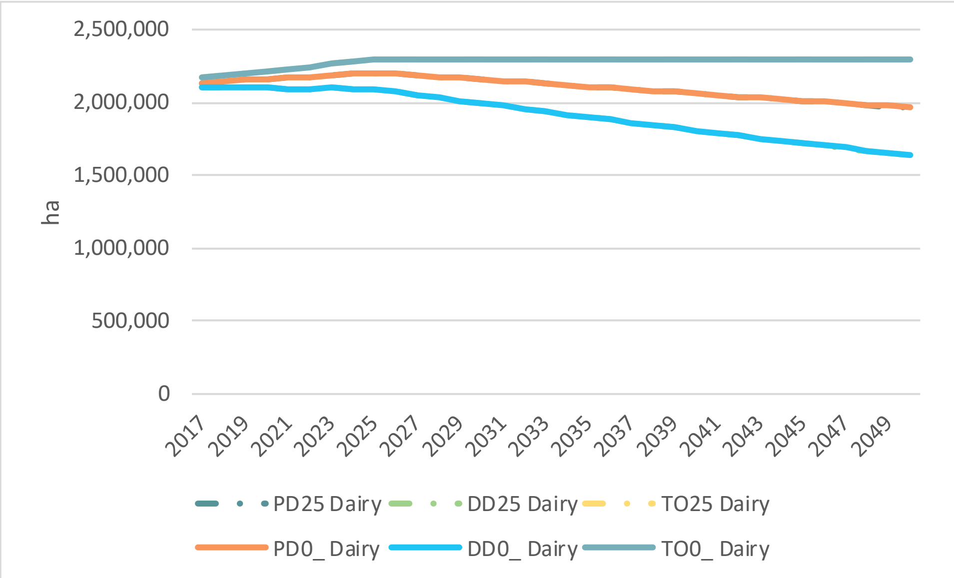
Hectares farmed



Source: NZIER

Figure 18 CMV change in dairy land use

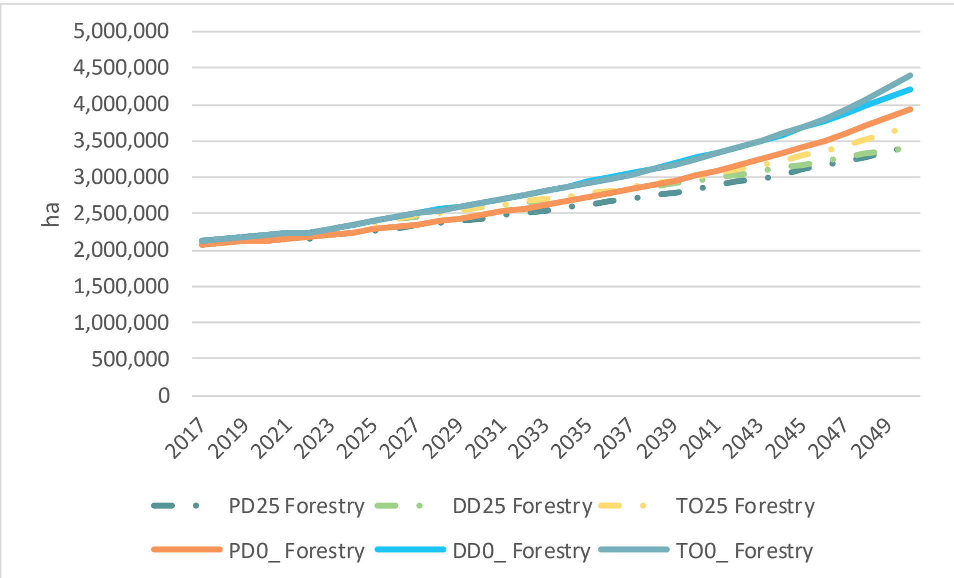
Hectares farmed



Source: NZIER

Figure 19 CMV change in forestry land use

Hectares planted in forest



Source: NZIER

Forestry in the CMV model is forecast to sequester 35 to 43 percent more carbon in 2050 than the NZIER November 2018 C-Wide (40 Mt) scenario. The area planted in forest in the CMV model is forecast to be 84 to 100 percent higher than current levels while the area planted in the NZIER November 2018 model is about 70 percent higher than current levels.

4. Short-term adjustment path

4.1. Introduction

The RIS discusses options for the setting of carbon budgets and nominates the preferred option as a sequence of three consecutive five-year budgets with the:

- government of the day able to revise the third budget subject to certain criteria and the second budget in exceptional circumstances
- banking (unlimited) and borrowing (up to 1 percent) of credits between budget periods (within limits)
- role of the CCC described as 'advising and monitoring with mechanisms to hold the government to account'.

It is unclear from the RIS what pathway assumptions or modelling will guide the setting of the initial budgets. As described in more detail in the following sections:

- the RIS comment suggests the Paris nationally determined contribution (NDC) target may not be a credible short-term milestone for the first two carbon budgets
- the CMV and NZIER models have different starting points and the pathways have quite different short-term profiles. This suggests a wide range of choices for the emission levels in the first three carbon budgets depending largely on the assumed rate of afforestation.

4.2. Paris agreement NDC

The RIS states that afforestation and innovation will not be sufficient to meet the Paris NDC target and that an adaptive approach to target setting will be required.

> *As explained above in the 2050 Target section, New Zealand has agreed under the Paris Agreement to an NDC of reducing emissions by 30 percent below 2005 levels (equivalent to 11 percent of 1990 levels) by 2030.*
>
> *New Zealand cannot rely on afforestation to deliver the necessary offsets over the next twelve years to meet its NDC, or on major innovations being market-ready and adopted (such as a methane vaccine or widespread adoption of electric or autonomous vehicles).*
>
> *Given the level of uncertainty on a cost-effective pathway for domestic emissions, this may argue for an adaptive approach to budget-setting that drives domestic abatement based on feasible opportunities available. The level of uncertainty on actual economic impacts also suggests an ability to review the target that we aim for domestically, within clear bounds and after independent advice,*

based on evolving information on technological and other developments.[26]

To place this comment in context, gross GHG emissions[27] in 1990 were 65.7 $MtCO_2$-e and in 2005 were 83.3 $MtCO_2$-e. The RIS comment implies that the Paris NDC target for GHG emissions in 2030 is around 57.7 $MtCO_2$-e. In comparison, the quickest CMV GHG reduction pathway DDO delivers gross emissions of 65.2 $MtCO_2$-e in 2030 (with net emissions of 44.8 $MtCO_2$-e after sequestration in forests). The other two reduction paths deliver net GHG emissions in 2030 of about 55 $MtCO_2$-e (after sequestration in forests) with gross emissions of 71.6 $MtCO_2$-e (PD0) and 75.5 $MtCO_2$-e (TO0).

Assuming the Paris 2030 NDC is effectively a net emissions target – the likelihood that New Zealand can meet that target is almost entirely dependent on the response of forest planting to an increase in carbon prices or access to international units (offshore mitigation).

4.3. Different starting points and pathways

The CMV model pathways PD0, DD0 and TO0 have different starting points for gross emissions and land use change but roughly similar starting points for energy, agriculture, IPPU and Waste as shown in the following table.

Table 8 CHG emissions in 2017 – CMV model

GHG by source (ktCO2-e)

Source	PDO	DD0	TO0
Energy	32,595	32,599	32,639
IPPU	5,014	5,014	5,014
Agriculture	36,774	36,407	37,130
Waste	3,813	3,813	3,813
LULUCF	-9,322	-10,338	-10,337
Net emissions	68,874	67,494	68,260
Gross emissions	78,197	77,833	78,597

Source: NZIER

For LULUCF which is primarily driven by forestry – the range in starting points is about 11 percent of the lowest starting point. The domestic carbon price is the same in 2017 for each of the pathways – $20 per tCO_2.

26 Regulatory Impact Statement: Zero Carbon Bill, page 96 available at https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/regulatory-impact-statement-zero-carbon-bill.pdf

27 These numbers are from 1990-2017 inventory report published 2019, data sourced from interactive tracker https://emissionstracker.mfe.govt.nz/#NrAMBoEYF12TwCIByBTALo2wBM4eiQDs2AHEltEA The numbers from the CMV model spreadsheet are 64.6 MtCO2-e for 1990 and 82.5 MtCO2-e for 2005. The CMV number 1990 GHG emissions is also quoted in the NZIER November 2018 report.

The NZIER starting points are not stated in the sectors but for the June 2018 model runs, gross emissions for 2017 were set at 79, 305 ktCO2-e just above the CMV model ranges.

The main difference between the CMV pathways over the first 15 years is the difference in carbon sequestered in forests followed by the change in GHG emissions from energy as shown in the following table. (‘Energy’ includes transport. Electrification of the vehicle fleet is the main driver of the reduction in energy related emissions.)

Table 9 CMV GHG emissions at 5-year intervals

GHG emissions by selected source (ktCO2-e). Forecast carbon price $ per tCO_2

Pathway	2017	2020	2025	2030	2035
PD0					
Energy	32,595	33,163	31,028	28,447	25,300
Agriculture	36,774	36,671	36,564	35,934	35,353
LULUCF	-9,322	-7,238	-9,826	-16,043	-22,130
Net emissions	**68,874**	**71,182**	**65,685**	**55,511**	**45,186**
Gross emissions	78,197	78,420	75,511	71,554	67,316
Carbon price	20.00	30.35	49.27	80.00	100.59
DD0					
Energy	32,599	32,787	28,538	25,779	22,379
Agriculture	36,407	36,083	35,545	34,463	33,457
LULUCF	-10,338	-8,864	-12,967	-20,464	-26,587
Net emissions	**67,494**	**68,606**	**56,748**	**44,782**	**33,765**
Gross emissions	77,833	77,470	69,715	65,246	60,352
Carbon price	20.00	28.51	39.60	55.00	71.44
TO0					
Energy	32,639	33,494	32,096	30,803	29,691
Agriculture	37,130	37,249	37,534	37,323	30,202
LULUCF	-10,337	-8,862	-12,932	-20,241	-26,029
Net emissions	**68,260**	**70,482**	**64,692**	**55,253**	**40,678**
Gross emissions	78,597	79,344	77,624	75,494	66,707
Carbon price	20.00	28.51	39.60	55.00	80.31

Source: NZIER

The variation in the pathways highlights the difficulty of setting five-year carbon budgets and the need for policy makers to have more detailed information on the model drivers than has been published.

For example:

- change in the carbon price should be the main driver of GHG emission reduction from forestry – however PDO has lower GHG emission reduction from forestry than the other two pathways despite having the highest carbon price profile
- net emissions for PDO in 2035 (at the end of the third carbon budget) are 33 percent above those for DD0 and 11 percent above those for TO0 suggesting that the effect of the cost improvement and technology cost change assumptions affect the model results more than the carbon price.

5. Other issues

5.1. New energy models to enter debate

At least two models of energy emissions will be publicly available for the carbon budget setting process that were not available at the time this report was written – the ICCC modelling for achievement of 100 percent renewable electricity generation and the TIMES energy scenario modelling.

5.1.1. ICCC – 'renewable' electricity target

To assess the feasibility and cost of achieving 100 percent renewable electricity generation the ICCC developed detailed models of electricity generation options and consulted extensively with key stakeholders about both the structure of the models and the indicative costs and benefits of the options.

This modelling provides additional insight into the likely range of electricity prices under various scenarios for reduction emissions from generation which will materially affect the incentives for electrification of transport and industrial processes.

5.1.2. TIMES energy scenario modelling

Business New Zealand Energy Council and public and private partners have commissioned a TIMES energy scenario modelling project. TIMES energy models estimate the least-cost energy system that meets end user demand while:

- meeting constraints for GHG emissions, generation mix etc.
- allowing for technology and demand change over time.

The outputs from the model include: energy flows and prices, GHG emissions and marginal abatement costs.

5.2. International credits

The RIS indicates a strong preference for the GHG emission reductions to be achieved through domestic initiatives and afforestation. However, the:

- 'Paris Agreement National Interest Analysis'[28] clearly contemplated the purchase of international units as part of the achievement of the 2030 target

  > *64. New Zealand's first nationally determined contribution was developed on the basis that New Zealand will achieve the 2030 target through a combination of domestic emission reductions, forestry growth and participation in international carbon markets. New Zealand needs to transition to a low-emissions economy and forestry is critical for carbon sequestration. However as climate change is a problem which must be solved by collective global*

[28] Available at https://www.parliament.nz/resource/en-NZ/51DBHOH_PAP69732_1/b3d874584455ca4c02251f71995b03d6f0aeee42

action, environmentally it makes no difference where emissions reductions come from (as long as emissions are reduced overall). The Agreement allows a market approach to emissions reductions which allows New Zealand to reduce emissions at least cost. New Zealand will need to be progressively more ambitious in its contributions over time.

- NZIER November 2018 modelling of GDP growth illustrates that even on restrictive assumptions the purchase of international units is a lower cost way of meeting the ZNE 2050 target than relying on domestic initiatives if forests sequester 30 $MtCO_2$-e by rather than 40 $MtCO_2$-e by 2050. Average real GDP growth over the period 2020 to 2050 under the wide innovation scenario is:
  - 1.71 percent per year (0.35 percentage points below the 'Status quo') with 30 $MtCO_2$-e sequestered in forests and an average carbon price of $NZ 1,056 /tCO₂.This annual rate of GDP growth is:
  - 1.95 percent per year (0.11 percentage points below the 'Status quo') with 20 percent of the target met by the purchase of international units and an average carbon price of $NZ 567 /$tCO_2$
  - 2.03 percent per year (0.03 percentage points below the 'Status quo') with 40 $MtCO_2$-e sequestered in forests and an average carbon price of $NZ 406 /$tCO_2$.
- The CMV 'uncertainty analysis'[29] included a 'Low' international carbon price scenario with carbon prices of:
  - $NZ 38 /$tCO_2$ in 2030 compared with domestic carbon prices for the 'ZNE in 2050' scenarios of $NZ 55 /$tCO_2$ to $NZ 80 /$tCO_2$
  - $NZ 70 /$tCO_2$in 2050 compared with domestic carbon prices for the 'ZNE in 2050' scenarios of $NZ 157 /$tCO_2$ to $NZ 250 /$tCO_2$

Overall the modelling provides limited guidance on the potential costs and benefits of using international credits to bridge the gap between domestic emission reductions that are *'ambitious but technically and economically feasible'*[30]

[29] 'Modelling the transition to a lower net emissions New Zealand, Uncertainty analysis, July 2018', Table 3, p12

[30] This is one of the matters the CCC and the Minister must have regard to in setting carbon budget. See 'Climate Change Response (Zero Carbon) Amendment Bill, page 15, section 5Z (2)(b)(iv)

Appendix A CMV model

A.1 Scope

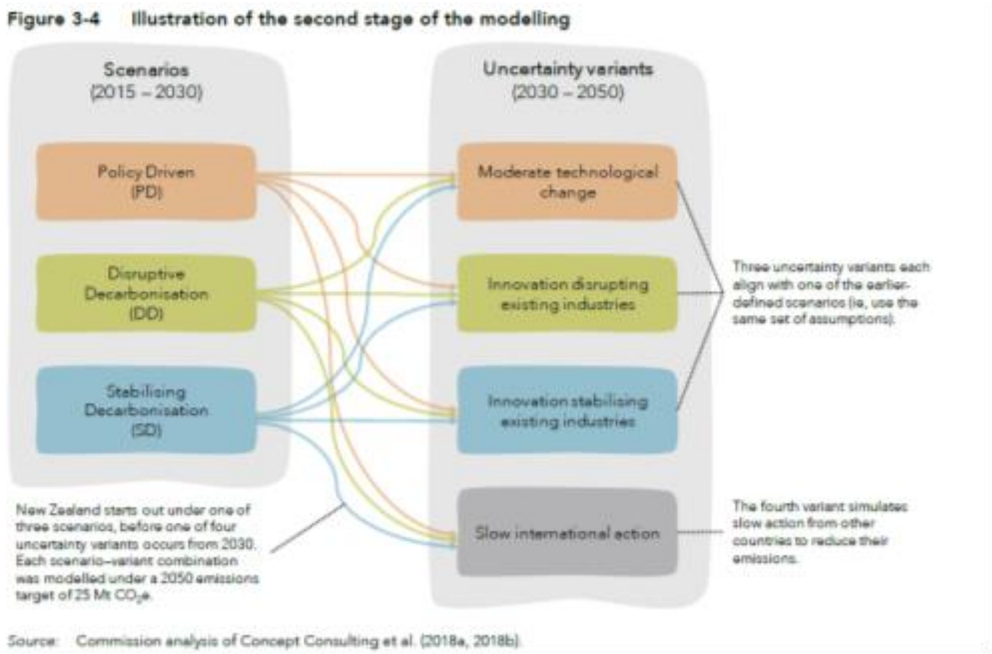
The CMV model results reviewed in the body of the report are for the core PD, DD and TO pathways for the 25 Mt CO_2 in 2050 and ZNE in 2050 targets. CMV also modelled uncertainty scenarios over the period 2030 to 2050. This part of the modelling has not been reviewed in this report because the CMV model spreadsheet provided by the Productivity Commission only included uncertainty scenarios for the 25 Mt CO_2 in 2050 target and not the ZNE in 2050 target.

A.2 Uncertainty modelling

The uncertainty path modelling approach used in the CMV model is summarised in the following diagram.

Figure 20 Uncertainty path modelling

Four technology scenarios for each of the core policy pathways



Source: Productivity Commission

Appendix B NZIER June 2018

B.1 Introduction

The NZIER June 2018 and November 2018 models are not directly comparable despite using a top-down CGE approach. Some of the changes were due to attempts to improve the model's relevance (change in agricultural land use and approach to biogenic methane) while others reflected changes in assumptions (lower GDP baseline and correction of error in calculation of status quo reduction target.

Table 10 Comparison of June 2018 and November 2018 models

Differences in key assumptions

Attribute	June 2018	November 2018
Model specification	Increase in forestry did reduce land available for agriculture or recognise increase in forestry output	Land is reallocated between forestry, agriculture and horticulture based on changes in land returns.
Baseline emissions	NZIER estimate based on expected economic growth and industry emission intensity in the absence of official emission projections to 2050	Emissions projections to 2050 prepared by government agencies based on the same assumptions used in both New Zealand's Seventh National Communication and Third Biennial Report
GHG targets	Three potential emissions targets: • Zero Net Emissions (100% reduction) • Split gas target (75% reduction) • Zero Net Carbon (50% reduction)	More granular scenarios: • A Net Zero Carbon target • Non-fungible stabilisation - net zero emissions of long-lived gases and short-lived gases capped at 50% or 75% of 2016 levels. • Fungible stabilisation - equivalent reduction in emissions, but short-lived gas emissions can be offset by forestry. • Net Zero all gases with access to international units at $150 per unit.
Innovation assumptions	Two sector specific scenarios 'Energy' and 'Agriculture' to test whether targets could be met through innovation in parts of the economy. These two scenarios were combined to form a third scenario – Wide innovation	Wide innovation scenario that is the same as June 2018 but with a less effective methane vaccine. Moderate innovation scenario that has no methane vaccine and slower rates of innovation than the Wide innovation
Rest of world action	Assume all other countries take comparable action to New Zealand in reducing their emissions	Assume all other countries take comparable action to New Zealand in reducing their emissions

Source: NZIER

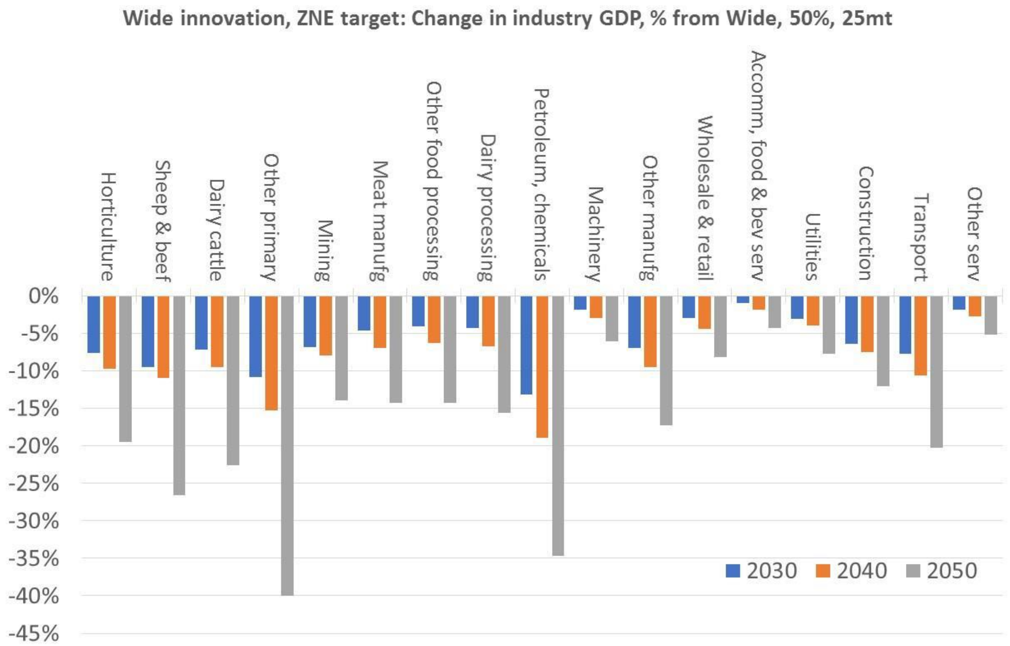
A brief description of the model results is included in this section to illustrate the variation between the two rounds.

B.2 Forecast GDP and GNI change

- 'Baseline' – continuation of current trends:
  - CO2 $20/t, 65%EV take-up by 2050, no international permits
  - Illustrates size of change required from today
- 'Status quo' – 'wide innovation 50%':
  - Agreed with officials to reflect commitment to reduce GHG
  - Methane vaccine by 2030 reduces biological emissions by 30%
  - EV uptake 95% light and 50% heavy vehicle fleets by 2050
  - Forestry sequesters 25 Mt CO2 by 2050
- 'Wide innovation 75%':
  - 'Wide innovation 50%' & Forestry sequesters 35 Mt CO2 by 2050
- 'Wide innovation 100%':
  - 'Wide innovation 50%' & Forestry sequesters 50 Mt CO2 by 2050.

B.3 Change in industry structure

Figure 21 Value added by industry



Source: NZIER

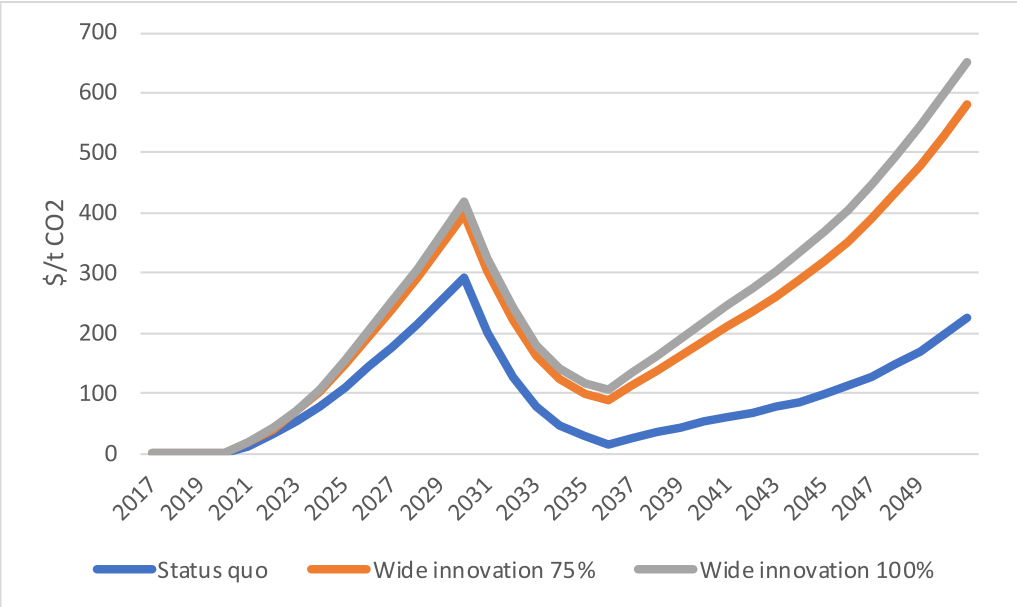
B.4 Carbon prices

The NZIER model computes carbon prices that are expected to be necessary to deliver the rate of change in economic activity necessary to lower GHG emissions after the assumed reduction afforestation as shown in the following chart.

The carbon prices required to achieve the 50% target and ZNE do not diverge significantly until after about 2035. As forestry sequestration is imposed on the model it is not clear how the potential impact of volatility in the carbon price on forestry has been modelled.

Figure 22 Comparison of NZIER forecast carbon price

Main GHG reduction scenarios

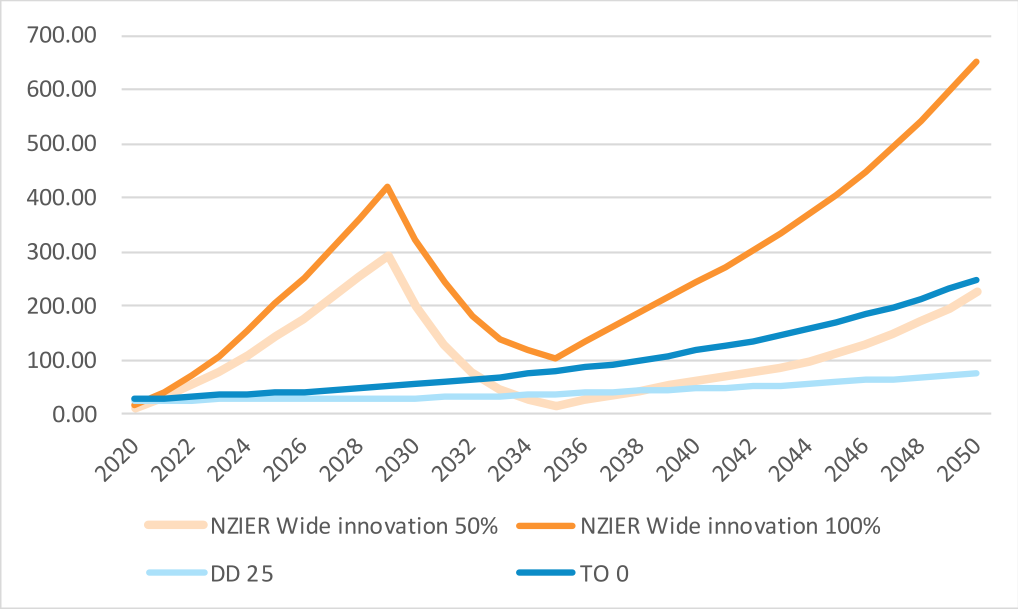


Source: NZIER

The following chart compares the modelling of carbon prices by NZIER and selected CMV pathways with similar emission reductions.

Figure 23 Comparison of NZIER and CMV carbon price scenarios

Comparison of forecast carbon prices for similar GHG reduction targets



Source: NZIER

Appendix C RIS quality assessment

C.1 Introduction

The RIS process includes a quality assurance assessment. In this case the assessment was completed by the by the Regulatory Quality Team at Treasury and the Regulatory Impact Analysis Panel at the Ministry for the Environment.

The quality assurance assessment comments[31] suggest that the RIS:

- under-emphasises downside risks:

  > *The extent and nature of uncertainty, on both the upside and the downside, of the economic costs and benefits of differing levels of ambition, is clear. The downside risks that assumptions about achievable levels of afforestation and technological innovations will be met are, however, given less prominence than the upsides.*

- notes that further policy measures will be needed to achieve the targets:

  > *The case is made that a clear institutional and policy framework around emissions reductions is required to guide investment decisions, although it is acknowledged that the arrangements discussed in the RIS are not in themselves sufficient for that purpose. Further policy measures will be needed to achieve the targets and it will be important for these to undergo similarly careful analysis and evaluation of their impacts.*

- states the RIS provides little evidence to support the assumed benefits on ambitious GHG reduction target:

  > *The assumption is also made that a high level of ambition in New Zealand will bring reputational benefits and have a positive influence on other countries' mitigation efforts; and that this in turn will mitigate climate change to the point that New Zealand will experience further benefits, in terms of avoided adaptation costs.*
  >
  > *However, little evidence or argument is available to support that assumption. For example, it is emphasised that New Zealand's challenge in meeting its climate change obligations is different from that of other countries. This must reduce the likelihood that those other countries will want or need to follow New Zealand's example or to take advantage of any New Zealand technological innovations. This in turn weakens the logic that mitigation action by New Zealand will reduce the impacts of climate change experienced here. This creates significant uncertainty as to the benefits of the proposed action and it will be important to monitor progress.*

[31] 'Regulatory Impact Statement: Zero Carbon Bill', 'Section C: Evidence certainty and quality assurance' page 15, available at https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/regulatory-impact-statement-zero-carbon-bill.pdf

Appendix D Impact analysis

D.1 Assessing the Zero Carbon Bill RIS

The models reviewed in this report are quantitative inputs to the Zero Carbon Bill RIS. The review of the models raises the question of how well the models meet the requirements of the RIS and how well the results and limitations of the models are reflected in the RIS.

The purpose of this section is to summarise the role and requirements for regulatory impact assessment (RIA) and in particular the requirements for modelling in the impact assessment. The RIA guidelines do not specify the modelling techniques that must be used and do not require cost benefit analysis. However, the guidelines and best practice documents do list several criteria that the analysis is supposed to meet.

In considering the following it is important to note that the Treasury best practice documents quoted below are watermarked 'INTERIM VERSION - UNDER REVISION'.

D.2 RIA objective

RIA is expected to support and inform the government's decisions on proposals for regulatory change by providing a process and an analytical framework. The impact analysis requirements are intended to ensure:

> *9.1 the underlying problem or opportunity is properly identified, and is supported by available evidence;*
>
> *9.2 all practical options to address the problem or opportunity have been considered;*
>
> *9.3 all material impacts and risks of proposed actions have been identified and assessed in a consistent way, including possible unintended consequences; and*
>
> *9.4 it is clear why a particular option has been recommended over others.*[32]

D.3 Impact analysis best practice

The best practice guidelines for impact analysis include the following[33] elements:

- *Describe the status quo (or counter-factual) - assessing one or more policy options against the situation expected to occur in the absence of any further government action or decisions (the status quo).*

32 Cabinet Office Circular (17/3) Impact Analysis Requirements 30 Jun3 2017, page 2-3 available at https://dpmc.govt.nz/publications/co-17-3-impact-analysis-requirements.

33 Guidance Note, Best Practice Impact Analysis, June 2017, The Treasury available at https://treasury.govt.nz/sites/default/files/2018-03/ia-bestprac-guidance-note.pdf.

- *Define the problem and assess its magnitude - - the nature and size of the problem associated with the expected outcomes in the absence of any further government action.*
- *Define the objectives - summarise the Government's policy intentions, but also inform how any potential regulatory solution will be evaluated for effectiveness*
- *Identify the full range of feasible options - Impact Analysis should identify and describe:*
  - *the status quo scenario projected forward—where no further regulatory changes occur (behaviour may still be expected to change over time)*
  - *one or more non-regulatory options (eg, education, industry self-regulation)*
  - *one or more regulatory options, and*
  - *what would happen without regulation or government intervention (if different from the status quo).*

  Levels of analysis; Generally speaking, the level of analysis undertaken (detail and depth) should be commensurate with the magnitude of the problem and the size of the potential impacts of the options being considered
- *Having identified the full range of feasible options, the next step is to analyse the costs, benefits and risks of each option. The analysis needs to show how each option would alter the status quo, which option is likely to be the most effective for solving the problem, and which option has the highest net-benefit. …*

  All options analysis must aim to answer:
  - *How does the option broadly measure up against the objectives? Answering this question may require a full impact analysis of each option.*
  - *What is the net impact (or net benefit or cost) of taking any of the available options?*
  - *What are the distributional implications of the options being considered? Options analysis requires evidence and analysis of who wins and who loses—and by how much.*
- *Consultation; to provide confidence about the workability of proposals and that options have been properly considered … It is crucial for Impact Analysis, and particularly for the summary of the analysis in the Regulatory Impact Assessment, to clearly explain what decisions are required, what choices are available, and what stage of the policy process the Impact Analysis reflects.*

  There are various ways of summarising and presenting the outcomes of options analysis. Summary information to convey includes:
  - *For each option, a summary of the main costs, benefits and risks and overall (net) impacts, in relation to the status quo. This should include aggregates (eg, economy-wide totals).*
  - *Key assumptions underlying estimates of net benefits. For example, the assumptions around expected compliance rates.*

The usual methods of presenting convincing options analysis in a Regulatory Impact Assessment to meet Cabinet's Impact Analysis Requirements include:

- *cost-benefit analysis (CBA) if feasible—an assessment of net-benefits including quantitatively, and if necessary qualitatively, estimated impacts (see Treasury's Cost-Benefit Analysis Primer)*
- *cost-effectiveness analysis, if feasible—to determine the least cost method of achieving a policy objective or standard, and*
- *incentive analysis—if an option's design is intended to change the behaviour of certain groups.*

… In each case, the aim is to compare the likely situation under the status quo with each option and conclude which option is preferred according to the objectives and a judgement about net-benefits.

- *Implementation; Impact Analysis requires consideration of how the preferred option would be implemented if agreed.*

Appendix E Zero Carbon Bill requirements

E.1 New modelling is needed to set carbon budgets

This section compares the matters that must be considered in the Zero Carbon Bill[34] with the coverage of the available quantitative modelling.

Table 11 Matters Climate Change Commission must consider

Zero Carbon Bill Section 5L

Matter	Quantitative model coverage
(a) current available scientific knowledge; and	NZIER and CMV models use this as the basis for assumptions about technical change but do not provide an independent assessment of the current available scientific knowledge
(b) technology that could be efficiently adopted and the likelihood of any advantages arising from early adoption of the technology; and	The NZIER and CMV technology adoption scenarios are an indication of the possible contribution of technology to reducing emissions but there is uncertainty about the timing and effect of key elements such as the methane vaccine and the impact of electricity price increases on the take-up of electrification.
(c) the likely economic effects; and	Only the NZIER modelling assesses the macroeconomic impacts of reduction in GHG emissions.
(d) social, cultural, environmental, and ecological circumstances, including differences between sectors and regions; and	Not covered by the models. The models could provide economic and land use changes at a regional level which could inform assessment of the social and environmental impacts
(e) the distribution of benefits, costs, and risks between generations; and	Not covered by the models.
(f) responses to climate change taken or planned by parties to the Paris Agreement or to the Convention.	Not covered by the models (except to assume that all other countries will comply with their emission reduction obligations).

Source: NZIER

[34] The opening clause of section 5L is "In performing its functions and duties and exercising its powers under this Act, the Commission must consider, where relevant,—".

Appendix F Timeline

F.1 Little time to set the first carbon budgets?

This section outlines what needs to be done to implement carbon budgeting as proposed under the Zero Carbon Bill.

The Zero Carbon Bill requires the CCC to provide its first advice[35] on emission reductions plans to the Minister by 1 February 2021 – approximately 19 months from the date of this report. In preparing this advice the CCC must[36] consult widely with New Zealanders and consider all the following matters[37]:

> *(i) the emission and removal of greenhouse gases projected for the emissions budget period:*
>
> *(ii) a broad range of domestic and international scientific advice:*
>
> *(iii) existing technology and anticipated technological developments, including the costs and benefits of early adoption of these in New Zealand:*
>
> *(iv) the need for emissions budgets that are ambitious but technically and economically feasible:*
>
> *(v) the results of public consultation on an emissions budget:*
>
> *(vi) the impact of the actions taken to achieve the 2050 target:*
>
> *(vii) the distribution of those impacts across the regions and communities of New Zealand, and from generation to generation:*
>
> *(viii) the implications of that distribution for mitigating, and adapting to, climate change:*
>
> *(ix) economic circumstances and the likely impact of the Minister's decision on taxation, public spending, and public borrowing:*
>
> *(x) the responses to the threat of climate change by all parties to the Paris Agreement or to the Convention:*
>
> *(xi) New Zealand's relevant obligations under international agreements.*

F.2 New issues to cover

As noted in both the Executive summary and Appendix E, the modelling completed to date does not cover the distribution of GHG emission reduction impacts across regions or over generations and assumes all parties to the Paris agreement will honour their obligations. Modelling of the regional distribution of impacts of GHG emission reductions can use the NZIER and CMV modelling already completed but will need an

35 Zero Carbon Bill, page 18, section 5ZE (2)

36 Zero Carbon Bill, page 18, section 5ZE (3)

37 Zero Carbon Bill, page 15, section 5Z (2)(b)

additional round to allocate the national impacts to regions. Modelling of inter-generational impacts is arguably harder than the macroeconomic modelling because of the difficulty of agreeing on an approach to valuing future states[38] in present value terms let alone defining alternative futures.

To successfully meet the requirements of the section 5ZE of Zero Carbon Bill the CCC has to:

- update and verify the modelling already completed on economic impacts and feasible GHG emission reduction pathways
- develop new modelling for regional impacts and frameworks for discussing allocation of impacts between generations
- co-ordinate this work with advice from government agencies on the fiscal impacts of proposed emission reduction emission reductions
- present these issues in a form that the public can understand and comment on meaningfully so that a durable commitment to GHG reduction initiatives is formed.

F.3 How long did it take to get to his point?

To put the timeframe for the carbon budget tasks in perspective:

- the Productivity Commission inquiry into a low emissions economy (which included CMV modelling), the two stages of the NZIER modelling and the ICCC work all took roughly 12 months to complete to a stage ready for public consultation. These processes did overlap – but as yet the outputs of these models have not been systematically compared
- the first round of public consultation on the Zero Carbon Bill in June 2018 ran for about 7 weeks followed by another two months during which the submissions were analysed and summarised.

[38] The approaches need to balance between the ‘dictatorship of the future by the present’ which tends to arise from the application compounding models to discount future costs and benefits to the present and ‘dictatorship of the present by the future’ which tend to arise from zero-time preference models where people are assumed to value current and future costs and benefits equally.