TE MANATŪ WAKA
MINISTRY OF TRANSPORT

Domestic Transport Costs and Charges Annual Research

Working paper 2022/23-02: Economy-Wide Effects of Reducing Emissions from Land Transport

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Contents

Appendices

Tables

Figures

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The Research, Economics and Evaluation team operates within the System Performance and Governance Group of Te Manatū Waka Ministry of Transport. The team supports the Ministry's policy teams by providing the evidence base at each stage of the policy development.

The team is responsible for:

- Providing sector direction on the establishment and use of the Transport Evidence Base (see below) – including the collection, use, and sharing of data, research and analytics across the transport sector and fostering the development of sector research capabilities and ideas.
- Leading and undertaking economic analyses, appraisals and assessment including providing economic input on business cases and funding requests.
- Performing the evaluation function for Te Manatū Waka, including designing monitoring and evaluation frameworks and approaches, developing performance metrics and indicators, and designing, conducting and procuring evaluations.

The Transport Evidence Base

The Transport Evidence Base Strategy creates an environment to ensure data, information, research and evaluation play a key role in shaping the policy landscape. Good, evidence-based decisions also enhance the delivery of services provided by both the public and private sectors to support the delivery of transport outcomes and improve wellbeing and liveability in New Zealand.

The Domestic Transport Costs and Charges study aims to fill some of the research gaps identified in the 2016 Transport Domain Plan (Recommendation R6.2), which forms part of the Transport Evidence Base.

Citation

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For more information

For more information about this project and associated report, please contact: info@transport.govt.nz.

Executive Summary

Purpose and scope

This working paper aims to establish the national economic effects of changes in transport costs under selected intervention scenarios that address greenhouse gas emissions from land transport.

This research was undertaken for Te Manatū Waka Ministry of Transport by Infometrics Consulting. It forms part of the annual Domestic Transport Costs and Charges research programme. Its outputs will help to better understand the wider economic impacts of transport cost changes on the economy to inform activities that aim to reduce transport emissions.

Previous work completed by Te Manatū Waka has focused on changes in emissions at fine levels of disaggregation, using partial equilibrium approaches such as standard cost benefit analysis.

Tools such as cost benefit analysis of electric vehicles versus petrol vehicles would likely ignore the effect on the international current account balance and the exchange rate. In GE models such effects are fully incorporated. In fact, a key strength of general equilibrium (GE) modelling is that it can account for any secondary effects (which could be substantial) that occur beyond the industry or sector of interest.

This research uses general equilibrium modelling to assess the inter-relationships between changes in transport costs and the emissions reduction scenarios (different types and magnitudes of interventions) to gain an understanding of how behavioural changes percolate through the economy and affect significant macroeconomic measures such as GDP and national income, as well as emissions. In addition, high level effects on industries and households are also presented.

Key findings

Key findings from the research are as follows:

- Any switch from a high emission activity to a low emission activity that is also cheaper than the high emission activity, enhances aggregate economic wellbeing. An example is the switch from ICEVs to BEVs when the prices of these vehicles reach parity over time, as the latter become progressively closer substitutes for the former. The increase in economic wellbeing from an increase in BEVs is mainly driven by changes in technology. However, there are still uncertainties about the timing of such price parity and the sufficiency of BEV supply.
- Different interventions can lead to different levels of transport cost changes, which can lead to quite different wider economic impacts as some interventions may be more costly than others in terms of emissions reductions achieved. Preliminary assumptions about the cost of interventions to effect mode shift suggest that large increases in walking and cycling, and bus PT may involve higher economic costs than other policies aimed at reducing emissions, but mode shift may have other benefits which are not included in this research.
- Interventions to accelerate or induce a shift to low emission transport modes may or may not increase aggregate economic wellbeing. Changes in relative prices cause changes in consumer surplus in the relevant market and in the total market for all goods and services. For example, a PT subsidy may benefit PT patrons, but the cost falls on others. Assessing the net effect of interventions requires empirical analysis that extends beyond the market of direct interest.
- Increasing direct user changes on all travel by light vehicles (such as via distance-based charging, analogous to road user charges) can reduce emissions, but at potentially high cost. Modelling suggests that altering relative transport costs across modes might not be an efficient way of reducing emissions if substitutability between modes is low – whether because of inelastic demand or inelastic supply of alternatives. However, if the revenue from such a charge is used to improve other low-emission transport options a net benefit can eventuate.

- If most countries with vehicle manufacturers ban new light ICEVs from 2035, New Zealand's emissions would rise relative to Baseline as the ICEV fleet would no longer benefit from improvements in fuel efficiency. An accompanying enhanced shift to EVs could reverse the adverse emissions effect.

Annualised scenario costs

Although the focus of the modelling is on 2035 is appropriate given that 2035 is the last year of the government's three emissions budgets, we have also looked at some scenarios for 2030 and 2050. By 2050 the domestic emissions target is net zero, excluding biogenic methane emissions. The 2050 scenarios illustrate the extent to which lower transport emissions could contribute to the net zero objective. Longer term scenarios could also provide the opportunity to explore debt financing options for funding investment in transport infrastructure.

There are substantial uncertainties around the estimation of the level of transport cost changes that are required to produce specific emissions outcomes.

Table 1: Annualised scenario costs: ex-ante, ex-post and break-even

Scenario		Ex-ante cost (assumed) ($m)	Method	Ex-post cost as %RGNDI	Implied break-even as %RGNDI	Modelled years
Baseline		--		--	--	2030, 2035, 2050
1	EVs	--	No direct intervention cost, indirect cost due to carbon price	--	1.07	2030, 2035
2 & 2a	EVs + bus PT	900	Estimated as necessary to achieve given mode shifts. Changes in tax or property rates	0.24	0.07	2035
3 & 3a	EVs + bus PT + walking & cycling	1,000		0.12	0.04	2035
4	EVs, + PT + walking & cycling + car pooling	--	No cost assumed for car pooling	--	0.03	2035
5	Light vehicle distance charge	19,000	Implied by assumed $0.35/km	--	--	2035
6	International light ICEV ban	--	No direct intervention cost, indirect cost due to lower ICEV fuel efficiency.	0.12	--	2035, 2050
7	EVs + light VKT charge + mode shift	2,200	Implied by assumed $0.05/km	--	0.10	2030, 2035, 2050

Table 1 summarises how the various types of costs were modelled and their effects on Real Gross National Disposable Income (RGNDI), as a measure of national economic wellbeing.

- **Ex ante cost:** is an exogenous model input. In the case of mode shifts the inputs are changes in taxes or property rates paid by households. The light vehicle charge is paid directly by vehicle users.

- **Ex post cost as a percentage of RGNDI:** There is no direct correspondence between the size and/or nature of an exogenous input shock and the cost to national economic wellbeing, as measured by the change in RGNDI.
- **Implied break-even cost:** If the effect of an intervention on RGNDI is positive, and if no explicit cost is attached to that intervention, the effect on RGNDI is also its break-even cost.

Scenario 1 has no explicit intervention, other than a price on emissions that also exists in the Baseline. The interpretation of 1.07% estimate is that if the carbon price coupled with the other advantages that EVs are expected to have over ICEVs by 2035 are insufficient to induce the exogenously stipulated EV uptake, policy measures to induce take up could cost up to 1.07% of RGNDI before the net economic gain turns negative.

In **Scenario 2**, the exogenous 140% shift to bus PT (6% of light VKT) is assumed to require $900m in annual expenditure, paid for by households through income taxation. That lowers RGNDI by 0.24%, which is more than three times the value of the reduction in emissions. Either the cost of inducing the exogenous shift to bus PT would have to be much lower, or other net benefits of the mode shift would have to exceed 0.17% of RGNDI – or some combination thereof.

The exogenous shift to more walking and cycling in **Scenario 3** (a 3.7% reduction in household VKT) has a similar ex-ante cost to increasing bus patronage but has a much smaller cost in terms of RGNDI. It is assumed to be financed by higher property rates on households, which has a lower deadweight loss than raising income tax. However, the mode shift to more walking and cycling has a smaller effect on emissions than the mode shift to more bus PT, such that its breakeven cost is also about a third of the assumed cost. Therefore, other net benefits of the mode shift would need to make up the difference to break even.

For the car-pooling **Scenario 4** (a 7.7% reduction in household VKT), no ex-ante cost was modelled, but the value of its effect on emissions implies that any interventions to induce the assumed increase in car pooling should cost no more than 0.03% of RGNDI.

The 35c/km light VKT charge in **Scenario 5** has an expected ex-ante cost of about $19b before any behavioural response. No exogenous assumptions about mode shift were imposed, so only its net effect on RGNDI can be estimated. The effect is an increase in RGNDI of 0.20% (but the effects on private consumption and GDP are negative). As the 0.20% is a net change, not a pure change excluding assumed costs, it cannot be interpreted as a break-even cost.

In contrast**, Scenario 7** combines the exogenous mode shifts in Scenario 3 with the distance charge in Scenario 5 but at a lower rate per VKT. The charge has an ex-ante cost of around $2,200m. Its breakeven cost relative to the Baseline is 1.17% of RGNDI but excluding the EV effect – which is a better comparison as EVs have no explicit intervention cost – the breakeven cost is 0.10% of RGNDI.

Scenario 6 has no New Zealand intervention – it represents a global ban on new ICEVs from 2035 as a result of which the ICEV fleet in New Zealand is less fuel efficient than in the Baseline. The model shock is effectively a negative energy productivity shock. The net effect on RGNDI is a reduction (cost) of 0.12% The concept of a break-even cost does not apply as there is no New Zealand intervention associated with this scenario.

Caveats and limitations

GE models do not provide any insights into intangible or difficult to quantify impacts such as social inclusions or the value of accessibility. The research does not seek to provide policy recommendations regarding the costs and benefits of policies, nor assess the optimal combinations of scenarios. There are also substantial uncertainties with the estimation of the level of transport cost changes required to generate to specific emissions outcomes. However, the insights from this research will provide important information to support ongoing development of related interventions.

In addition, results from this research are subject to the caveats listed below:

- A general equilibrium model measures benefits and costs that can be monetised. However, it is not a CBA model and therefore does not take into account social, health and environmental (except GHG) effects, nor can it tell us much about equity impacts. On its own, it should not be used to draw policy conclusions.
- This research does not inform whether any of the combinations of interventions are optimal. A general equilibrium model cannot endogenously determine the optimal mix of policies to reduce transport emissions. It can be used only to evaluate the relative merits of policies that are decided outside the model.
- The general equilibrium model covers the impacts on New Zealand as a whole. It is, therefore, not suited to studying issues such as congestion that are time and place specific. While the model estimates the likely impacts of congestion relief interventions in very broad terms, it cannot assess the benefit of less congestion if cycling displaces journeys by private car. Equally it cannot assess the cost of more congestion if road space is converted to cycleways.

Overall, the results present a broad picture of impacts for 2035, which show how emissions from land transport differ across different scenarios. The two key elements of these scenarios are that. firstly, higher EV penetration is assumed to be induced by a price on carbon and associated technological changes. Secondly, there could be some sort of policy package consisting of measures to encourage PT and active mode shift paid for by a distance charge on light vehicles. While the emission reduction effect is proportionally larger in 2030, by 2050 such a policy will likely have no effect on emissions due to the high uptake of EVs. However, specific aspects of such a policy, especially for the next decade require more GE modelling and more detailed transport modelling.

By 2050, most of the remaining transport emissions come from air transport, road freight, fishing and construction machinery. We have not looked at opportunities for reducing emissions from these activities. The effects of policies that aim to transporting more road freight by rail or sea would warrant future research.

1 Introduction

1.1 Purpose and overview

This working paper aims to establish the national economic effects of changes in transport costs under selected intervention scenarios that address greenhouse gas emissions from land transport.

This research was undertaken for Te Manatū Waka Ministry of Transport by Infometrics Consulting. It forms part of the annual Domestic Transport Costs and Charges research programme. Its outputs will help to better understand the wider economic impacts of transport cost changes on the economy to inform activities that aim to reduce transport emissions.

1.2 Scope and report structure

Previous work completed by Te Manatū Waka has focused on changes in emissions at fine levels of disaggregation, using partial equilibrium approaches such as standard cost benefit analysis.

Tools such as cost benefit analysis of electric vehicles versus petrol vehicles would likely ignore the effect on the international current account balance and the exchange rate. In GE models such effects are fully incorporated. In fact, a key strength of general equilibrium (GE) modelling is that it can account for any secondary effects (which could be substantial) that occur beyond the industry or sector of interest.

This research uses general equilibrium modelling to assess the inter-relationships between changes in transport costs and the emissions reduction scenarios (different types and magnitudes of interventions) to gain an understanding of how behavioural changes percolate through the economy and affect significant macroeconomic measures such as GDP and national income, as well as emissions. In addition, high level effects on industries and households are also presented.

This working paper begins with a description of the 7 scenarios developed for this research, the methodology used to model the impacts and other specifications of the scenarios. Next, we summarise the 2035 results for the 7 scenarios relative to that for baseline 2035. We then present results for 2030 and 2050 for selected scenarios. Commentary of how other mode shift interventions could be modelled will be presented next. We then conclude the working paper with a summary of the research findings.

2 Methodology and scenarios specification

2.1 Reducing Transport Emissions

There are three broad approaches to reducing transport emissions, according to the Avoid, Shift and Improve framework:

- **Avoid** unnecessary travel – including interventions that aim to improve the efficiency of the transport system by reducing the overall need to travel and shortening average trip distances.
- **Shift** to low-carbon modes – including interventions that aim to make it more attractive for people to walk, cycle, or use public transport, and make it easier for businesses to use coastal shipping and rail freight.
- **Improve** vehicles and seek fuel efficiencies – including interventions that encourage uptake of low-or-zero carbon vehicles and development and use of more efficient, lower-emissions fuels.

In the scenarios below, we consider possibilities under all three approaches. The third approach encompasses ongoing improvements in fuel/carbon efficiency including via hybrid vehicles, a change in the composition of the vehicle fleet towards smaller vehicles and switching to alternative fuels such as biofuels. Although not necessarily improving actual fuel efficiency in terms of GJ/km, such fuels do reduce GHG emissions per unit of travel (e.g., vehicle kilometre travelled).

Sense Partners have modelled biofuel blending mandates using a General Equilibrium (GE) model1. They show consistently negative changes in GDP and net national income primarily because consumers are forced to use more costly fuels. That is, biofuels require more resources per unit of energy than fossil fuels, whether they are produced domestically or imported – in which case they are paid for via resources used to produce exports. The picture is not unlike an increase in the world price of oil. There are also some secondary negative effects from the deadweight loss caused by government subsidies for biofuel production or consumption.

2.2 Methodology

Modelling the uptake of electric vehicles in general equilibrium models, while still relatively new, is reasonably straightforward; essentially using an energy elasticity of substitution between petrol/diesel powered vehicles and electricity powered vehicles. This is no different from modelling substitution between coal heating and gas heating, or between heating appliances and insulation.

The elasticity can be increased over time as ICEVs and BEVs become progressively closer substitutes with regard to features such as range and model variety, eventually becoming almost perfect substitutes. The latter will cost less to purchase and operate, even without a price on carbon. This type of fuel substitution is based on technological change that requires no significant shift in underlying consumer preferences for mobility. However, there is still a high level of uncertainty regarding the timing of when petrol/diesel powered vehicles and electricity powered vehicles become perfect substitutes.

Modelling the effects of a mode shift to bus public transport (PT), however, is rather more difficult. Firstly, the relevant model industry captures all bus transport (not just commuting) as well as taxi transport and ride sharing services. Secondly, although there is a substitution elasticity between bus PT and rail PT, the only substitutability between aggregate PT and private transport is confined to a substitution elasticity of unity.

That elasticity can be changed (see Appendix 4), but that brings up the third challenge, which is that the model knows very little about the generalised transport cost (GTC) of PT, nor of walking and cycling. For private vehicles simply knowing capital costs (net of depreciation), maintenance costs and fuel costs provides a very workable estimate of GTC. In contrast, for PT the model knows the price, but knows nothing about PT routes, frequency, reliability, comfort, hours of service, distance to bus stops and so on. Other

[1] Sense Partners (2021) Economic and emissions impacts of biofuels policy options – Phase II. An MDG6NZ dynamic CGE analysis. Report to MBIE, MoT and MPI.

types of models are better suited to including such detail, especially very fine spatial and temporal detail, than GE models.

Consequently, when modelling step-changes in PT use or walking and cycling, we need to identify other variables in the model that can act as proxies for whichever components of GTC are the targets of a particular policy or intervention. In one of the scenarios presented below we look at increasing the subsidy for bus PT to pay for more buses, more bus drivers, and other related infrastructure.

More detail on EV and mode shift modelling is provided in Appendix 1.

2.3 Scenario Specification

We look at a number of scenarios for 2035 to reflect Hīkina te Kohupara (HtK) Pathway 5 developed by Te Manatū Waka, depicted in Figure 1. Pathway 5 includes the following changes relative to 2035 baseline that is relevant to the scenario specification[2]:

- A 40% reduction in fossil fuel consumption due to increased uptake of EVs and other low emission fuels (applied in Scenario 1)
- Bus VKT increases by 140% (added in Scenario 2 and 2a)
- Light vehicle VKT reduces by 20%, with:
  - 4% shift to walking and 15% to cycling (added in Scenario 3 and 3a)
  - 39% shift to being a car passenger (e.g., car pooling) (added in Scenario 4)

Although Te Manatū Waka is interested in the effects of combinations of interventions, to help identify the various impacts, the scenarios are developed incrementally. The focus on 2035 is appropriate as that is the last year of the government's three emission budgets.[3]

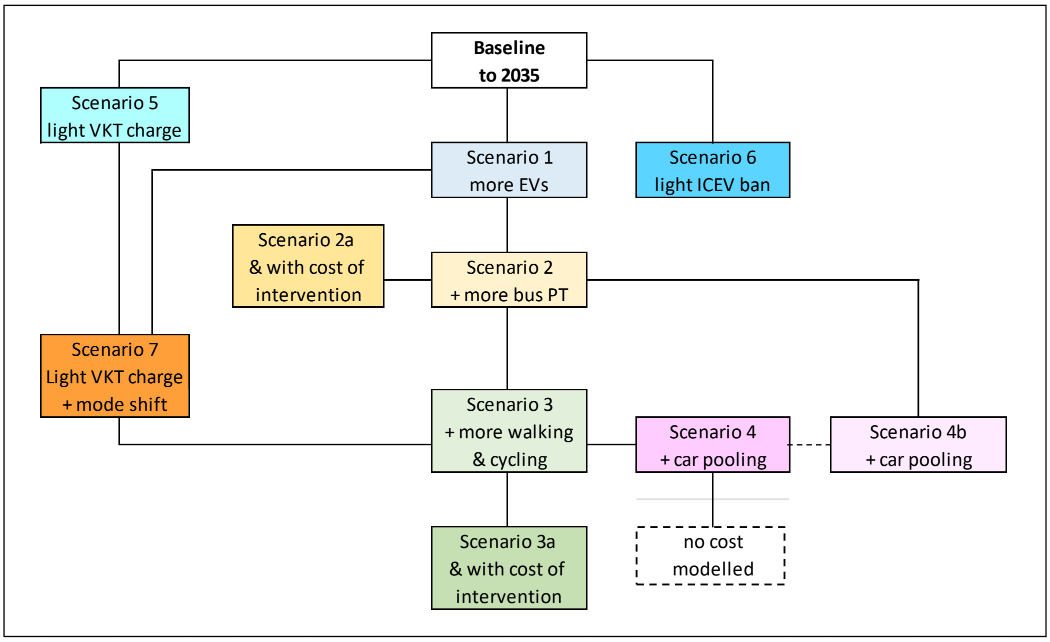

Figure 1: Scenario Outline

[2] This research does not seek to replicate Te Manatū Waka's HtK pathway 5. Instead it simply takes components of that pathway to inform the scenario specification. As such, the results cannot be used as the estimated effects for HtK pathway 5 as this research has not included all elements of the HtK pathway.

[3] https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/emissions-budgets-and-the-emissions-reduction-plan/#emissions-budgets

2.3.1 Baseline scenario

Carbon price at $160.47/tonne CO_2e and uptake of electric vehicles and bus PT is largely based on "base-high" of Te Manatū Waka's 2021 Vehicle Fleet Emissions Model. The level of EV uptake is expected to result in a 17% reduction in household consumption of petrol and diesel and 2% in industry consumption. The increase in bus PT is relatively small (a shift of only 0.2% of light vehicle VKT (which we model as household VKT), so it is assumed to result from an autonomous shift in consumer preferences – perhaps in response to publicity around IPCC reports for example. For a large shift to PT this assumption is unlikely to be valid.

Other assumptions relevant to the Baseline are set out in Appendix 2, with a general description of the model provided in Appendix 3. The Baseline scenario, while intended to represent a plausible picture of 2035 without major external shocks or large changes in policy, is not a forecast. General Equilibrium models are not forecasting models. Their strength is in scenario analysis, with the Baseline scenario acting as a frame of reference against which other scenarios can be compared.

In the scenarios below the following are kept at Baseline levels:

- Total employment measured in full time equivalent jobs; wage rates are endogenous.
- Post-tax rate of return on capital, investment and capital stock are endogenous.
- Balance of payment as a percentage of GDP, the real exchange rate is endogenous.
- Government fiscal balance, household net tax rates (by household income quintile) are endogenous.

Further discussion on these closure rules is provided in Appendix 2. Additionally, in each scenario the carbon price, forestry sequestration and the net emissions target are held constant at their Baseline values. In addition, it is assumed that the NZETS price is the same as the international price of emission units. Gross emissions are endogenous, so the equilibrating variable is the number of emission units that need to be purchased (or sold) internationally to meet New Zealand's net emissions target.

Although it would be possible to set an exogenous gross domestic emissions target and let the ETS price be the equilibrating mechanism, the difficulty with this approach is that the New Zealand carbon price could be different to the world carbon price. As long as trade in emission units is not restricted, arbitrage opportunities would soon reduce any price difference to zero. Hence, this approach collapses to the approach adopted.

2.3.2 Scenario 1, more EVs

This assumes further penetration of EVs relative to Baseline, based on Te Manatū Waka's HtK pathway 5. In this scenario, household consumption of petrol and diesel would reduce by about 47% and industry consumption by about 32%. In comparison, the Climate Change Commission's *Path to 2035* has a 48% reduction for light passenger vehicles and 42% for industry (counting all use of light commercial vehicles as industry use).

2.3.3 Scenario 2, more bus PT

As in Scenario 1 plus a large increase in bus VKT over Baseline (about 140%), again simulated as an autonomous change in preferences. Also included is major shift to electric buses.

2.3.4 Scenario 2a

As in Scenario 2, with an attempt to simulate a policy that would increase bus VKT by 140%.

In 2018/19 there were 890m bus passenger kilometres, entailing a gross cost of $865m.[4] Hence an increase of 140% would cost $1,200m – assuming the same ratio of passenger kilometres to vehicle kilometres. The cost would be less if the number of boardings per bus rises, such as might occur at peak times. However, the significant enhancement in the quality of service (greater frequency, express services, night services, more seating and so on) that is likely to be necessary to secure the envisaged mode shift would mean more largely empty buses, implying a higher cost. Hence for modelling purposes we assume a cost of $1,200m.

[4] Ministry of Transport (2023), Domestic Transport Costs and Charges Study – Working paper C12: Urban Public Transport, Prepared by Ian Wallis Associates Ltd for the Ministry of Transport, p8, Forthcoming April 2023.

Given a 73% subsidy (as in 2018/19) the cost to the government would be close to $900m, which we assume is funded by an increase in personal (household) taxation. That supports an increase in average capital and labour intensity in the industry of 11%-13% to simulate more buses, more drivers and so on.

We do not know if this is necessary or sufficient to secure the desired increase in bus PT.

2.3.5 Scenario 3, more walking & cycling

As in Scenario 2 plus an increase in walking and cycling of about 2.0 billion km, such that consumption of private (household) vehicle VKT falls by 3.7%, assuming an autonomous change in preferences.

2.3.6 Scenario 3a

As in Scenario 3, with an attempt to simulate a policy that might deliver the 3.7% mode shift. It is unknown how much of that can be accommodated with existing walking and cycling infrastructure, but as with bus PT, increases of this magnitude are likely to require incentives, in this case many new dedicated walkways and especially cycleways.

To put the increase of two billion km in perspective, in 2018/19 the walked distance was around 660m km, while the cycled distance was about 290m km. Annualised costs to government are estimated at $1,300m and $160m respectively.[5] We would expect the envisaged increase in walking and cycling to see a much greater emphasis on cycling. If the latter were to constitute (say) two-thirds of the increase (as in projections by the NZCCC[6]), the cost would be $2,100m. Based on HtK's share of 79% (being 15%/19%), the cost would be $1,750m.

However, a substantial increase in walking could probably occur without additional infrastructure. Even cycleways currently have unused capacity. On the other hand, new cycleways will get more expensive once low-cost options are implemented.

For modeling purposes, we adopt an annual cost to government of $1,000m, which means that the scenario is comparable to Scenario 2a. We assume this is paid for by higher property rates on households.

2.3.7 Scenario 4, car pooling

As in Scenario 3 plus a 7.7% (being 39% of the 20% of VKT) reduction in light (household) VKT attributable to car pooling, namely a shift from being a driver to being a passenger. Again, this is modelled as an autonomous change in consumer tastes.

Attaching a cost to this proposal, let alone assessing how consumer behaviour might change in response to some sort of policy is most challenging. There are T2/T3 lanes, being lanes reserved for vehicles with two/three or more people at times when congestion is high. However, they are not popular,[7] and as Brown and Paling note regarding the impact of transit lanes on mode choice; "there is very little evidence to either confirm or deny that the choice to carpool is an elastic relationship."[8] An inelastic relationship means that considerable change in relative GTC (more than just the effective difference in fuel costs and travel time) would be required to markedly increase car pooling.

The NZCCC assumes almost no change in the ratio of passengers to drivers in its pathway to 2035. Nevertheless, we present Scenario 4 for completeness, but caution against interpreting as a likely picture of 2035.

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[5] Ministry of Transport (2023), Domestic Transport Costs and Charges Study – Working Paper C8: Walking and cycling, Prepared by Veitch Lister Consulting in association with Ian Wallis Associates Limited, Forthcoming April 2023.

[6] https://www.climatecommission.govt.nz/get-involved/sharing-our-thinking/data-and-modelling/

[7] https://www.nzherald.co.nz/nz/aucklands-controversial-t3-lanes-vandals-smash-cameras-in-north-shores-onewa-rd/DGCLHMY6DD5REYF3W27A6JCWCM/

[8] https://www.nzta.govt.nz/assets/resources/research/reports/557/docs/557.pdf

2.3.8 Scenario 4b

As in Scenario 4, but without the extra walking and cycling embedded in Scenario 3. That is, Scenario 4b adds more car pooling to Scenario 2 (see Figure 1). The purpose of this variation is to test whether the order in which interventions are implemented affects the results. In this particular case, are the potential emissions benefits of car pooling undermined if there is already a significant increase in walking and cycling? We could ask similar questions about the benefits of more PT use if there is a prior shift to walking and cycling.

2.3.9 Scenario 5, VKT charge

Scenario 5 takes a different approach. It deliberately eschews any of the explicit increases in EVs, bus PT, walking and cycling, and car pooling that are simulated in Scenarios 1-4. Instead, it is a direct variation on the Baseline that incorporates a new distance charge of $0.35/km for all light vehicle travel. This incremental charge was based on the preliminary calculations by Te Manatū Waka using the price elasticity approach.

This scenario assumes existing various road user related charges including fuel excise duty and road user charges (RUC) for light vehicles would be maintained. Should a distance charge ever be implemented, we would expect these other charges to be converted to equivalent distance charges rather than having different variable charging schemes running concurrently.

2.3.10 Scenario 6, international light ICEV ban (lower ICEV efficiency)

Many countries, particularly those with vehicle manufacturing industries, have announced bans on new ICEVs from 2035. Examples include the EU, UK, Japan and South Korea, although the details are sketchy. Given vehicle development cycles, we would expect vehicle manufacturers to stop enhancing the fuel efficiency of light ICEVs from about 2030.[9] This would affect the fuel efficiency of new ICEV imports, irrespective of whether New Zealand also bans such vehicles in 2035. The fuel efficiency of used vehicle imports would continue to show some improvements until 2035.

For ease of modelling, we assume that all light ICEVs entering New Zealand in 2035 have no better than 2030 fuel efficiency. We ignore any possible change in ICEV imports just before 2035 due to any changes in world supply of and demand for ICEVs. In the Baseline scenario, the average fuel efficiency for light vehicles improves at 1.0% pa. This is intended to capture both the technical rate of improvement in ICE efficiency and changes in the composition of the light vehicle fleet.

Like Scenario 5, Scenario 6 is also a direct variation on the Baseline scenario.

2.3.11 Scenario 7: VKT Charge + EVs +Bus PT + Walking & Cycling

Scenario 7 combines the higher EV uptake and mode shifts assumed in Scenario 3 (so excluding car pooling) with the uniform VKT charge on light vehicles in Scenario 5, although the charge is reduced from $0.35/km to $0.05/km. That is more in line with existing fuel excise duty and the lowest RUC rate. It is expected to raise about $2,200m which is also comparable to the sum of the assumed policy costs in Scenarios 2a and 3a of $1,900m. As before FED and RUC are not reduced in this scenario, especially as the revenue now has a prescribed matching expenditure.

Hence, we may view Scenario 7 as showing the effects of possible intervention costs that are required to secure the exogenously specified increases in bus PT and walking & cycling (in addition to higher EV uptake). **However, a $0.05/km distance charge may not be sufficient to encourage the level of mode shift required.** For consistency, the endogenous substitutability between private and public transport in private consumption (households) is over-ridden by the exogenous bus PT shift assumed in Scenario 2.

[9] One might conjecture that less R&D expenditure on ICEV fuel efficiency could see vehicle manufacturers allocating more R&D effort to EV efficiency. At this stage such an effect is considered to be within the margin of error of the expected rate of EV development.

3 Scenarios to 2035 - results

Table 2 presents a summary of the modelling results. Note that although results are presented to two decimal places this degree of accuracy is spurious. It is intended only to assist with the estimation and presentation of break-even costs. We have no particular interest in the Baseline other than to note that the macroeconomic results are historically plausible – see Appendix 2. Industry results are also provided in Appendix 2, primarily to assess whether there are any unusual changes that could have the potential to affect the macroeconomic results in the other scenarios. It is worth reiterating that we cannot assert that any of the policy interventions suggested above will actually generate the projected increase in bus PT demand or walking and cycling. They are informed assumptions that require further testing.

3.1 Scenario 1: more EVs

As might be expected any autonomous change in technology or tastes that reduces the burden of meeting an emissions target leads to a positive macroeconomic outcome. In Scenario 1 GDP increases by 0.8% over the Baseline and RGNDI by 1.1% (about $850 per person per year or $2,270 per household per year in 2019/20 prices). The change in RGNDI is higher than the change in GDP is primarily attributable to fewer international emission units needing to be purchased as a result of lower gross emissions from transport which fall by 28%, contributing to an overall reduction in gross emissions of 4.4Mt of CO_2e. This is actually less than the 4.6Mt fall in emissions from transport, as the more prosperous economy leads to some 'take-back' effect. Such an effect could also cause more congestion, but this has not been estimated.

There are two forms of emissions take-back effect:

- More emissions from more travel by all types of vehicles including ICEVs.
- More emissions from non-transport activities – a general equilibrium effect that would not be captured in a partial equilibrium analysis.

The first of these effects is estimated to be about 600Mt CO_2e, or about 11% of the theoretical saving. However, this is not a pure take-back effect as it captures both the direct response to lower travel costs and the indirect general equilibrium effect on transport demand of more economic activity. For example, households may increase their use of private vehicles because that mode has become relatively cheaper, but they may also have more disposable income leading to a further increase in the demand for travel.

The non-transport general equilibrium take-back effect is shown in Figure 2. Industrial process emissions increase by 102Mt, mainly from additional geothermal electricity generation, needed for the higher EV uptake, with another 119Mt dominated by more activity in industries such as construction and manufacturing, plus some additional gas-fired electricity generation, but almost all industries see some increase in emissions.

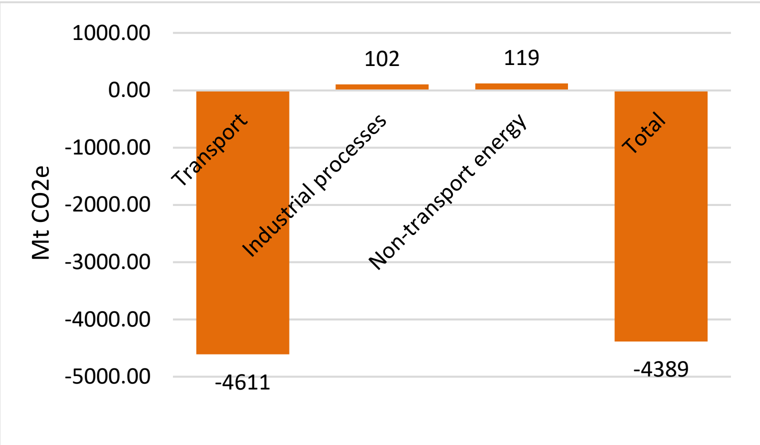

Figure 2: GE Take-back effect (Scenario 1)

Table 2: Scenarios to 2035 - Summary of results

	2019/20	Baseline 2035	Scenarios 2035 S1 More EVs	S2 + more bus PT	S2a + policy cost	S3 + more walking & cycling	S3a + policy cost	S4 + car pooling
		%Δpa	**% change relative to Baseline 2035**					
Private consumption		2.4	1.31	1.42	1.11	1.46	1.30	1.48
Gross investment		2.5	1.30	1.39	1.16	1.45	1.33	1.53
Exports		2.4	-0.84	-1.43	-1.69	-1.43	-1.45	-1.49
Imports		2.3	0.07	-0.18	-0.32	-0.17	-0.18	-0.17
GDP		2.4	0.82	0.81	0.54	0.84	0.73	0.86
RGNDI[10]		2.3	1.07	1.14	0.90	1.18	1.05	1.21
Real wage rate		1.4	0.69	0.85	0.98	0.87	0.53	0.82
			CO_2e (MT)					
Gross CO_2e	82.3	68.5	64.1	63.6	63.4	63.4	63.4	63.1
Forestry	-22.2	-14.5	-14.5	-14.5	-14.5	-14.5	-14.5	-14.5
Net CO_2e	60.2	54.0	49.6	49.1	48.9	48.9	48.9	48.7
Transport CO_2e	15.8	16.4	11.8	11.4	11.4	11.3	11.3	11.1
MoT Trans CO_2e*	16.2	14.6						9.1

	2019/20	Baseline 2035	Scenarios 2035 S5 Baseline + Light VKT charge	S6 Baseline + Int'l light ICEV ban	S7 Baseline + Light VKT charge +EVs + mode switch
		%Δpa	**% change relative to Baseline 2035**		
Private consumption		2.4	-0.17	-0.16	1.37
Gross investment		2.5	1.43	-0.12	1.66
Exports		2.4	-2.76	0.04	-1.75
Imports		2.3	-0.90	-0.05	-0.31
GDP		2.4	-0.26	-0.10	0.80
RGNDI		2.3	0.20	-0.12	1.17
Real wage rate		1.4	-2.11	-0.15	0.45
			CO_2e (MT)		
Gross CO_2e	82.3	68.5	63.0	69.0	62.7
Forestry CO_2e	-22.2	-14.5	-14.5	-14.5	-14.5
Net CO_2e	60.2	54.0	48.5	54.5	48.2
Transport CO_2e	15.8	16.4	12.3	16.9	10.8
MoT Trans CO_2e*	16.2	14.6			

Transport emissions from the model are 15.8Mt for 2019/20, while Te Manatū Waka estimates 16.2Mt for calendar year 2019. The difference is attributable to MBIE revisions of fuel consumption. For 2035, the model's Baseline projections are higher than those from Te Manatū Waka. The two main reasons for this are greater air travel and greater movement of freight. However, these differences have no material effect on the relative changes between 2035 scenarios.

[10] RGNDI is real gross national disposable income, defined as GDP plus adjustment for the terms of trade and net factor payments overseas, such as for emission units. We treat payments for emissions units like a licence, although the units could also be treated as a stock (asset) rather than a flow. This doesn't affect the essence of the argument.

Figure 3 presents the change in emissions by broad industry group and households. The largest reduction by far is in emissions from private consumption, a consequence of the relatively greater shift to EVs from light petrol ICEVs (as opposed to diesel ICEVs) and that direct use of other fossil fuels by households (such as for heating) is very small.

As noted above electricity generation sees an increase in emissions, albeit from a low base by 2035, as geothermal generation and gas-fired generation are used to boost electricity output. However, 96% of the increase in electricity generation in Scenario 1 comes from renewables.

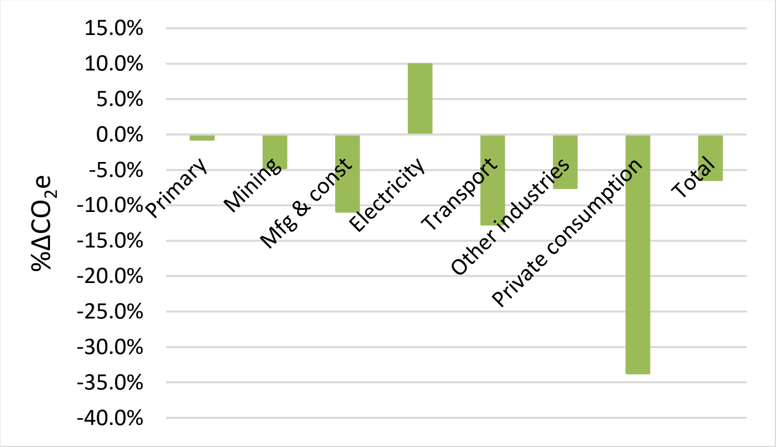

Figure 3: Changes in emissions (Scenario 1)

3.2 Scenarios 2 & 2a: more bus PT

The switch from ICEVs to BEVs in Scenario 1 (and in the Baseline) is assumed to be driven by technological change. Increasing bus PT on the other hand is not driven by technological change (albeit perhaps assisted by innovations such as real-time electronic messaging). It requires either an autonomous change in tastes (with predictable economic and emissions effects as shown in Scenario 2), or some sort of intervention which has cost implications with theoretically unpredictable net effects. A consideration of the cost-effectiveness and efficiency of related intervention is outside the scope of this report but Scenario 2a is an attempt to control for such impact by including an assumed intervention cost.

In Scenario 2, we assume that the level of PT service needs to be significantly enhanced. The model is limited in what it can do in this regard, given the absence of many of the components of GTC discussed above. Thus, we model the intervention as a greater government subsidy with the funds used to purchase more buses and associated infrastructure (such as electric charging stations) and to employ more drivers, per passenger kilometre. How exactly the enhancement in the level of service is manifested is beyond what a GE model can simulate.

The results show that the combined beneficial macroeconomic effects in Scenario 2, which assume an autonomous shift to PT, fall by about a third if the shift needs to be induced by (assumed) interventions that make PT more desirable – that is, to reduce its effective GTC. The beneficial effects that remain in Scenario 2a are due to the much more powerful effect on emissions produced by the move from ICEVs to BEVs.

As modelled here, real wages in Scenario 2a are higher than in Scenario 2 because the subsidy reduces the price of PT, which feeds through into the consumers price index. However, under the fiscal closure rule (Appendix 2) personal tax rates must rise to pay for the subsidy so the real after-tax wage is lower, as reflected in the relative change in private consumption of -0.3%.

If the subsidy was financed by government debt instead of by taxation, the cost would be shifted beyond 2035. However, unless that deferred cost is accounted for (such as by modelling 2040 or 2050) Scenario 2a would collapse to Scenario 2, thereby presenting the shift to more PT as costless in 2035.

Of course, these results are indicative. Other types of interventions may have different effects. As noted above we cannot assert that the interventions modelled here would actually generate the assumed mode switch to bus PT. They may be less than sufficient, or they may be more than sufficient.

If we use RGNDI as a metric of economic wellbeing, we can see that the incremental cost of the assumed bus policy is 0.24% of RGNDI (comparing Scenarios 2 and 2a), but the incremental benefit is only 0.07% (comparing Scenarios 1 and 2). Therefore, the cost of the PT intervention would need to be about 70% lower ($600m or so) than that assumed to achieve a net benefit. It must be noted that this research does not provide answers to whether this level of cost is realistic, or whether there are other benefits such as greater equity that might justify the policy.

There could also be benefits from less congestion which, if significant could be modelled as travel time savings (a productivity increase) and the associated better fuel efficiency.

Private consumption by income quintile

Figure 4 shows the changes in real private consumption by household income quintile (Q1 is lowest) relative to the Baseline. Compared to the aggregate change of -0.2% relative to Scenario 1, the variation across quintiles is quite marked. Quintile 2, which has a large proportion of superannuitant households, experiences the largest direct benefit from more bus PT, but the tax effect (to fund the PT subsidy) still causes a net loss. The net effect for Q1 is close to zero, with Q5 faring worst with a net change of -0.3%.

It is possible that the model is understating the differences across household quintiles, not so much with regard to the tax effect as the tax data is generally satisfactory, but with regard to PT demand. We know the base year incidence of PT use by quintile, but data limitations mean that the associated price elasticities of demand are calibrated using the income elasticities and the Frisch parameter, rather than being fully econometrically estimated. Hence, in reality we might see more variation in PT uptake in response to a lower GTC – notably more by low quintile households, although higher income households are also significant users of PT.

Clearly these results are particular to the specification of Scenario 2 and 2a, but the general relativities are likely to be robust to similar specifications for other PT scenarios.

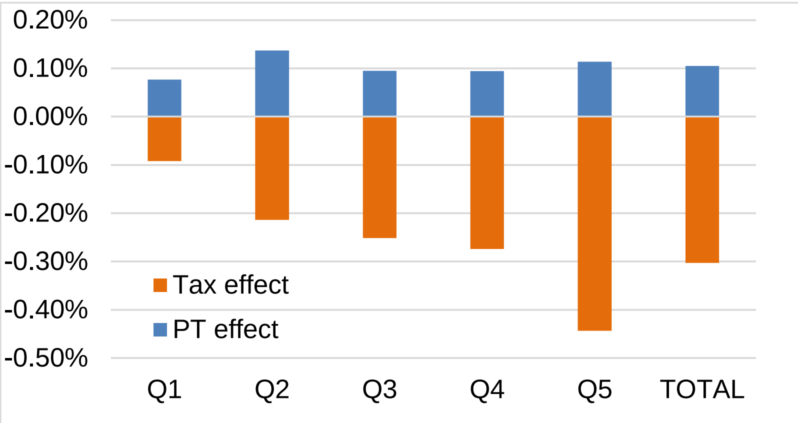

Figure 4: Scenario 2 & 2a – changes in private consumption by income quintile (relative to Scenario 1)

3.3 Scenarios 3 & 3a: more walking and cycling

Scenario 3 starts with an autonomous increase in walking and cycling, modelled as an exogenous change in consumer preferences to understand the potential wider economic impacts before including an assumed intervention cost (Scenario 3a). Unsurprisingly the various economic measures show improvements on Scenario 2, although the changes are small – 0.04% in RGNDI for example.

Incorporating a hypothetical cost to incentivise more walking and cycling in Scenario 3a naturally reduces the economic gains. For example, the change in RGNDI is lower by 0.12% relative to Scenario 3, more than negating the relative gain in Scenario 3 over Scenario 2. There is still a small reduction in emissions relative to Scenario 2.

There is a high degree of uncertainty regarding to whether the assumed $1,000m p.a. intervention cost is sufficient. Further research into the level of investment required to induce substitution of two billion VKT to walking and cycling by 2035 is warranted.

As with the PT scenarios (Scenarios 2 & 2a) we have not modelled changes in congestion; not the benefit of less congestion if cycling displaces journeys by private car, nor the cost of more congestion if existing road space (used also by buses) is converted to cycleways.

Health benefits

There is a growing literature on the health benefits of walking and cycling,[11] although many studies fail to adjust for simultaneity bias – does more cycling make people healthier or do healthier people cycle more? Nonetheless, accepting a general causative link, the main difficulty with including health benefits for any particular walking and cycling intervention is in determining what activities are substituted. For instance:

- What proportion of the extra people who might commute by bike would cycle less at the weekend or reduce other types of physical activity?
- Do the health benefits from the extra distance that someone might travel on an electric bike outweigh those from the additional exercise required on a non-electric bike used for a shorter journey?

Without understanding the activities that are substituted, we cannot determine what the value of health benefits might be from shifting 3.7% of VKT to walking and cycling. However, the break-even cost for Scenario 3 in terms of the value of emissions reduction is about $300m p.a., implying that if the $1,000m cost is correct, the annual value of other benefits (including health benefits) would need to be at least $700m to produce a net economic gain. This requires about a 40% increase in the current annual kilometres travelled by walking and cycling[12].

3.4 Scenario 4: more car pooling

More car/ride pooling leads to increases in private consumption, GDP and RGNDI. At only 0.03%, however, the increase in RGNDI compared to Scenario 3 implies that the incremental wellbeing effect of car pooling is very small. And that is ignoring any intervention costs that might be required to effect such a significant change in consumer behaviour. However, as discussed below, the order in which these changes in behaviour are introduced into the modelling affects the results.

At this stage we have no associated intervention to incentivise car pooling that is readily amenable to GE modelling, so Scenario 4 should be seen as optimistic[13].

3.5 Scenario 5: light vehicle distance charge

The assumed charge of $0.35/km is almost five times the current lowest RUC rate. Fuel excise duty is $0.70/litre, which for an average petrol-powered light vehicle using, say, seven litres per 100km, implies

[11] For example, a 2014 report claims very high benefit-cost ratios from an increase in commuter cycling. However, the estimates are not discounted or annualised, the System Dynamics model used in the research does not seem stable, contains numerous arbitrary assumptions about parameter values, and it is unclear how some important variables (such as the potential trip length that cycling could displace) are used in the model. Nevertheless the approach itself is promising and merits further research. See Macmillan, A., Connor, J., Witten, K., Kearns, R., Rees, D., & Woodward, A. (2014). The societal costs and benefits of commuter bicycling: simulating the effects of specific policies using system dynamics modelling. *Environmental health perspectives*, 122(4), 335-344.

[12] In 2018/19, walking and cycling accounted for approximately 945 million passenger kilometres of travel. According to the draft results of a DTCC working paper (D3), the net economic benefit to society amounts to $2.885 per kilometre walked and $1.598 per kilometre cycled, relative to no travel or to travel by car or other modes which do not involve significant physical activity. The weighted average net benefit per kilometre walked (20%) and cycled (80%) would be around $1.86 per km.
Source: Ministry of Transport (2023), Domestic Transport Costs and Charges Study – Working Paper D3: Health impacts of active transport, Prepared by Anja Mizdrak and Ed Randal, University of Otago in association with Ian Wallis Associates Limited for the Ministry of Transport, Forthcoming April 2023.

[13] A recent trial in Wellington found that carpooling lured people away from bus PT rather than self-driving. See https://www.stuff.co.nz/dominion-post/news/wellington/129676496/wellingtonians-arent-ready-to-carpool-despite-startups-best-efforts

about $0.05/km. Light vehicle VKT in the Baseline is around 54 billion km so the potential revenue before any response to the charge is almost $19b (or $15b if a 20% reduction in VKT is achieved). With this level of cost increase, we might expect to see significant macroeconomic effects, especially as the existing fuel excise duty, road user charges and motor vehicle registration fees are assumed to be maintained.

This incremental charge is modelled as a tax on petrol and diesel used by light vehicles, as well as on electricity used by EVs, although in the Baseline scenario (which is the reference point for Scenario 5) the EV component is small.

As shown in Table 2 private consumption and GDP both decline relative to Baseline, but RGNDI still shows a small increase – as with the other scenarios this is because less of the nation's income is needed to purchase international emission units.

Real wages fall by 2.1%, a direct consequence of the increase in the CPI caused by the distance charge. That this decline is much larger than the drop in private consumption is because the model assumes the revenue from the VKT charge is used to reduce income taxes on households – in line with the fiscal closure rule (refer Appendix 2). Arguably of course some of the revenue could be used to invest in infrastructure for bus PT or walking and cycling, as in Scenarios 2 and 3. We explore this further in Scenario 7.

As it stands, however, Scenario 5 has no exogenous assumptions about how households and industries react to the higher cost of travel by light vehicle. As might be expected the model projects major declines in spending on petrol and diesel, vehicle repairs and maintenance, and vehicle purchases. Spending on road and rail public transport increases, but overall demand for transport declines – a consequence of the nested nature of the demand functions. The much higher cost of travel by private vehicle raises the relative price of transport as whole, so demand for all transport declines.

Industries that benefit from the switch in consumer demand include public transport, communications, ownership of dwellings and personal services (consistent with more working from home). There is also a rise in demand for imported food items.

Total gross emissions fall by 8.0% and transport emissions fall by 25.3%. Given a broad alignment between VKT and emissions for the light vehicle fleet (in the Baseline) we may infer that light vehicle VKT declines by slightly more than the 20% provisionally estimated by Te Manatū Waka for this level of distance charge.

Two sensitivity tests on Scenario 5 are presented in Appendix 4, one with a higher carbon price and one with a higher private-public transport substitution elasticity in household consumption.

3.6 Scenario 6: international light ICEV ban (lower ICEV efficiency)

This scenario is in effect a study of the effects of lower fuel efficiency (relative to the Baseline) in the light vehicle fleet, although the causal policy is an international ban on new ICEVS (no domestic ban is assumed).

The macroeconomic effects are clearly negative with RGNDI being 0.12% lower than in the Baseline and emissions higher by about 0.5Mt. Although these effects could theoretically easily be offset by an increase in EV penetration as Scenario 1 demonstrates, the pure effect of the ban is to lessen the carbon efficiency of ICEVs in the vehicle fleet in 2035, generating a cost to economic wellbeing in the process. Holland et al (2021)[14] using a partial equilibrium model, demonstrate that an ICEV ban cannot improve welfare (even without general equilibrium considerations) if ICEVs and EVs are not close substitutes – as is the case in the 2035 Baseline but not in Scenario 1. Welfare is reduced further if there is a spike in ICEV purchases just before the ban.

A welfare loss could continue for many years due to reduced availability and choice of ICEVs, so we extrapolate this scenario to 2050 in Section 5 below. On the other hand, an ICEV ban might lead to greater support for BEVs.

[14] Holland, S.P., Mansur, E.T. and Yates, A.J., 2021. The electric vehicle transition and the economics of banning gasoline vehicles. *American Economic Journal: Economic Policy*, 13(3), pp.316-44.

If vehicle manufacturers cease improving the fuel efficiency of light ICEVs – as assumed here, any actions by New Zealand are largely irrelevant. However, the details of a ban could be important. For example, would it apply to ICEVs that run on biofuels? What about PHEVs?

Appendix 4 has a sensitivity test on Scenario 6 that extends the ban (modelled by lowering fuel efficiency) to heavy vehicles.

3.7 Scenario 7: light VKT charge + EVs + bus PT + walking & cycling

Scenario 7 (combining scenarios 2, 3 and 4 but with a lower distance charge of $0.05/km) presents a generally positive picture. The increases in private consumption and RGNDI are both greater than in Scenario 1, but for GDP the reverse applies. Total gross emissions and transport emissions are lower than in any of the other scenarios.

It seemingly makes better economic sense to charge motorists for improvements to PT and walking & cycling facilities than to pay for such improvements through general taxation and property rates. One might conjecture that this is simply the theory of the second best at work, namely that if private vehicle use is underpriced it may make sense to underprice public transport, but public transport should face the full marginal social cost if appropriate road pricing exists.

However, although the model knows about emissions, that is addressed by the carbon charge. The model knows nothing about other under-priced aspects of vehicle use, notably congestion. Hence the fact that the VKT charge produces better outcomes than the alternatives of income taxes and property rates suggests that emissions at $160/tonne are still under-priced and, as a VKT charge is 'closer' to emissions than are income taxes and property rates, it provides an additional incentive to reduce emissions.

And of course, it is still an open question as to whether the revenue raised from the VKT charge is sufficient to enhance bus PT and upgrade walking and cycling facilities to the extent required to induce the assumed mode shifts.

Note also that although this mix of policies is preferred to those in the other scenarios, we cannot infer that it is optimal. This research does not answer two questions:

- Could other policies be more efficient?
- What is the best use (e.g., PT vs heavy vehicles vs alternative fuel technologies) of the revenue from a distance charge?

3.8 Overall picture

Scenario 4 combines large shifts to EVs and bus PT, much more walking and cycling, and a substantial increase in car pooling – assuming all could be achieved without any intervention costs. It is therefore very much a best-case scenario in which total gross emissions fall by 7.8% (5.3Mt), transport emissions fall by 32.6%, while RGNDI increases by 1.2% – all relative to the Baseline.

As modelled, the costs of the interventions in Scenario 4 (if broadly correct) add up to about 0.4% of RGNDI, so there is a net benefit– excluding any intervention costs for more car pooling. However, the benefit is largely attributable to the shift to EVs which requires no policy intervention except a carbon price – at least by 2035.

Scenario 5 takes a different approach by not specifying any particular mode adjustment to the imposition of a distance charge on light vehicle VKT. The effect on total emissions is greater than in Scenario 4, but transport emissions are higher. More importantly the macroeconomic benefits are not only less than in Scenarios 3 and 4 – the case with RGNDI; for private consumption and GDP they are negative.

Hence, we infer that substantially raising the GTC (generalised travel cost) of light vehicle travel without accompanying changes in access to alternative modes may well reduce transport emissions, but at a relatively high economic cost. Scenario 7 shows that a lower charge on light vehicle VKT, comparable to current rates of FED and RUC, with the revenue directed at raising bus PT and walking and cycling (as in Scenario 3), generates a much more favourable picture.

Scenario 6 examines the pure effect of an international ban on new light ICEVs from 2035, or more accurately, the effects of no increase in light ICEV fuel efficiency after 2030. It suggests that there would be no gain in economic wellbeing, nor a reduction in emissions.

3.9 Comparing between scenarios and the incremental effects

Table 3 presents the ratio of the change in RGNDI (in $m) to the change in the value of emissions reduction (in $m at the assumed carbon price of at $160.47/tonne CO_2e) for each scenario, relative to the Baseline scenario.

The ratios are negative because the numerator is positive while the denominator is negative (the higher the negative number, the higher the increase in RGNDI relative to a unit reduction in CO_2e). This means all scenarios are preferable to the Baseline.

In no scenario is there an overall cost in terms of RGNDI, but if the ratio falls in absolute terms between scenarios, there is certainly a marginal cost to RGNDI.

For example, moving from Scenario 1 to Scenario 2a does involve a cost to RGNDI. That is, economic wellbeing is higher in Scenario 1 than in Scenario 2a, but Scenario 2a is still preferable to the Baseline.

Table 3: Change in RGNDI/CO_2e relative to baseline 2035

Scenario		ΔRGNDI/ΔCO_2e
1	EVs	-6.88
2	EVs and bus PT	-6.53
2a	2 with intervention cost	-5.02
3	EVs, bus PT and walking & cycling	-6.57
3a	3 with intervention costs	-5.87
4	EVs, bus PT, walking & cycling and car pooling	-6.40
4b	EVs, bus PT and car pooling	-6.54
5	Light vehicle distance charge	-1.04
7	Light VKT charge, EVs and mode shift	-5.76

As the model assumes the increase in EVs in Scenario 1 would occur without an explicit intervention cost other than a carbon price, it delivers the greatest gain per unit value of emissions saved. Adding more bus PT (Scenario 2) is less efficient even without the costs of intervention. Further adding more walking and cycling (Scenario 3) is more efficient than raising bus PT, but still less so than shifting from ICEVs to EVs (Scenario 1). With the assumed intervention costs for bus PT, Scenario 2a has a larger adverse effect than intervention costs for walking and cycling (Scenario 3a), but we reiterate that the assumed intervention costs are exploratory.

Further adding car pooling in Scenario 4 reduces the ratio to below that in Scenario 3. That might seem strange, but it merely reflects the familiar concept of diminishing returns. In partial equilibrium models the unit cost of reducing emissions usually rises as the reductions increase – the well-known marginal abatement cost (MAC) curve. The same forces are at play in a general equilibrium model, but instead of a progressively increasing cost, we see a progressively decreasing benefit, even without considering any intervention costs.

In Scenario 4b (not shown in Table 4 as the results are almost identical to those in Scenario 4), which excludes walking and cycling, the efficiency ratio is higher than in Scenario 4 and close to that in Scenario 2, as one would expect. However, without knowing the cost of interventions to encourage more carpooling we cannot say much about the net economic merits of such a shift.

For Scenario 5 (relative to baseline), the ratio is close to zero (in absolute terms) and would depict a net cost if private consumption or GDP was used in the numerator instead of RGNDI, reinforcing the inference that a substantial blanket increase in the GTC of one mode is inefficient without considering the availability, accessibility and relative cost of other modes. This is exemplified by Scenario 7 which assumes a substantially lower light VKT charge and uses the revenue to enhance bus PT and walking and cycling facilities.

The ratio of the change in RGNDI to the change in CO_2e in Scenario 7 is -5.76, much better than the -1.05 in Scenario 5, but still not as good as the -6.88 in Scenario 1. This is because a switch to EVs requires fewer interventions than does mode shift. However, it is uncertain whether the revenue raised from the VKT charge is sufficient to enhance bus PT and upgrade walking and cycling facilities to the extent required to induce the assumed mode shifts modelled in this scenario.

Scenario 6 (international ban on light ICEV) is not included in Table 3 as its ratio of ΔRGNDI to ΔCO_2e has a negative numerator and a positive denominator, the reverse of the ratios for Scenarios 1-5. This is illustrated in Figure 5. Any scenario in the top left-hand quadrant delivers both higher RGNDI and lower emissions. Scenario 5 is in the correct quadrant, but clearly inferior to the others. In contrast, Scenario 6 is in the least desirable quadrant, delivering neither lower emissions nor higher RGNDI.

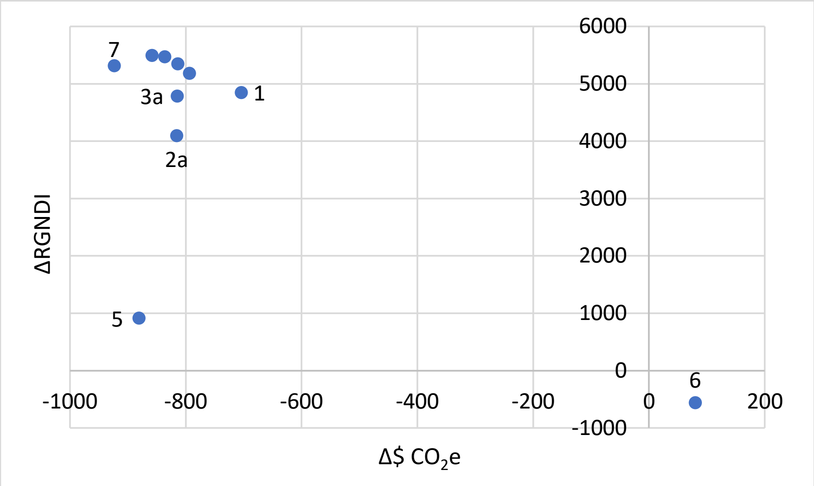

Figure 5: Changes in RGNDI versus changes in CO_2e

4 Scenarios to 2030 – results

An issue that arises from the preceding scenarios is that the results for 2035 in relation to EV uptake may be too optimistic, in the sense that they could be unachievable if well before 2035 there are no other interventions (other than the carbon price that is) to encourage EV adoption.

Currently there are in fact other interventions, namely the Clean Car Discount (CCD) and the imminent Clean Car Standard (CCS), together known as the Clean Car Package (CCP). We explore these interventions below.

The main assumptions for the 2030 Baseline are noted in Appendix 2. Apart from the carbon price which is set at $150/tonne there are no other explicit policy interventions aimed at reducing transport emissions. So as for 2035 the Baseline has a deliberately low uptake of EVs. About 3% of petrol and diesel used by light vehicles is replaced with electricity. Across industries, including heavy vehicles, the percentage substitution average is 1%. A 20% penalty for range and variety applies. This scenario is not intended as a likely picture of 2030.

4.1 Scenario 1-30: more EVs (clean car package)

In Scenario 1-30 all penalties for model range and variety are assumed to be zero, with equivalent total costs of ownership between EVs and ICEVs brought about by the CCP. There is a correspondingly higher penetration of EVs, displacing 15% of household use of petrol and diesel and 13.5% of industry use of petrol and diesel. Those figures are similar to the Climate Change Commission's projections of approximately 17% and 16% respectively. Scenario 1-30 is intended to be a more plausible projection of 2030 and is comparable to Scenario 1 for 2035.

Table 4 presents the two scenarios for 2030. As for the 2035 results, the greater uptake of EV's leads to an increase in economic wellbeing. RGNDI is up by 0.6% ($430/capita) relative to Baseline.

In the Baseline, the uptake of EVs is so low that it does not even offset the rise in emissions from the growth in travel and transport between 2019/20 and 2030, but in Scenario 1-30 transport emissions are 1.4Mt (8.9%) lower than in 2019/20. By 2035, in Scenario 1 they decline by a further 18.1% to 11.8Mt (Table 2). Another way of looking at this is that of the total decline in transport emissions between 2019/20 and 2035, 65% occurs in the last five years.

Average annual emissions in the government's emission budgets are 16% lower in the second budget period (to 2030) than in the first period (to 2025), and 21% lower in the third period (to 2035) compared to the second period.

This makes the 8.9% reduction by 2030 for transport emissions in Scenario 1-30 look unimpressive. However, there is no theoretical case for every industry or sector to reduce its emissions by the same proportions – indeed the opposite is true. Other interventions may bring forward the uptake of EVs, but that would not, given a total emissions cap, lead to a reduction in total emissions. Instances of market failure, however, could justify other interventions, although that still would not reduce total emissions (unless the affected emissions are outside the ETS which is not the case for transport emissions).

Table 4: Results for Scenarios 1 and 7 relative to baseline 2030

	2019/20	2030 Baseline	2030 Scen 1-30	2030 Scen 7-30
		%Δpa	% change on Baseline	
Private consumption		2.4	0.67	0.76
Gross investment		2.6	0.97	1.03
Exports		2.6	-0.86	-1.99
Imports		2.4	-0.28	0.73
GDP		2.4	0.46	0.48
RGNDI		2.3	0.61	0.80
Real wage rate		1.6	0.09	-0.40
			CO_2e (MT)	
Gross CO_2e	82.3	72.4	70.8	69.4
Forestry	-22.2	-10.8	-10.8	-10.8
Net CO_2e	60.2	61.6	60.0	58.6
Transport CO_2e	15.8	16.0	14.4	13.4

This brings us back to the Clean Car Package. In October 2022, Te Manatū Waka estimates that EVs were 1.1% of the (light) vehicle fleet, which is about 0.3 percentage points above forecasts, including the effect of the CCD (the CCS was yet to implement in January 2023). Although small in absolute terms, the proportionate difference could indicate that the policy is accelerating EV uptake at a faster rate than expected.

Figure 6 shows the shares of petrol/diesel displaced by electricity under different uptake scenarios:

- For 2030: Baseline with low EV uptake and Scenario 1-30 with more EVs
- For 2035: Baseline with low EV uptake and Scenario 1 with more EVs
- For 2050: High EV uptake, no low Baseline (see next section).

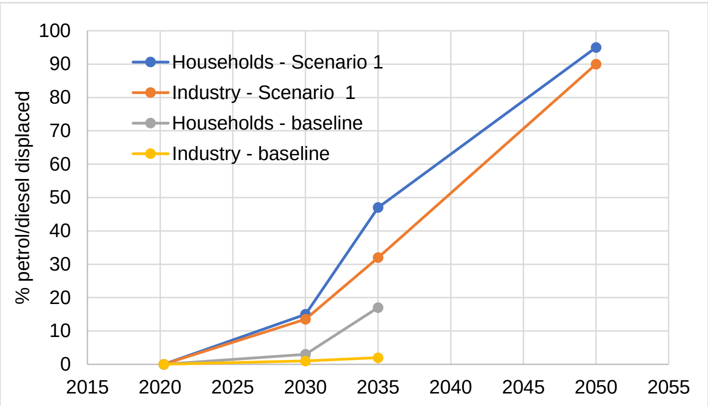

Figure 6: Proportion of petrol/diesel displaced by electricity

A rapid uptake of EVs between 2030 and 2035 does not seem implausible, but the 2030 projections could nevertheless be too low (although there might be supply constraints). If so either our estimates of the effects of the CCP over the period to 2030 are too small, suggesting that the EV-ICEV elasticity of substitution is too low, or the projected carbon price in 2030 (at $150/tonne) could be too low.

Alternative scenarios of EV uptake by 2030 could be explored with the model but would seem to be of limited usefulness unless they are more securely anchored on detailed (not GE) modelling of EV uptake.[15]

4.2 Scenario 7-30: Light VKT Charge + Bus PT + Walking & Cycling

Scenario 7-30 repeats the Scenario 7 (and 7-50) approach of combining more bus PT, and more walking and cycling, paid for by a distance charge of $0.05/km on light vehicles. The uptake of EVs is as in Scenario 1-30. The results are summarised above in Table 4.

Consistent with the 2035 results there is an increase in RGNDI relative to Scenario 1-30, but it is proportionally larger because EV penetration is less. Total emissions fall by a further 1.4Mt meaning that less foreign exchange is required to purchase international emission units so more of the nation's income is available for domestic consumption.

Reiterating the earlier caveat, it is unclear whether the level of the VKT charge is sufficient to support the level of mode shift implied in the scenario. It is also unclear whether the $0.05/km charge would generate enough revenue to pay for the ongoing investment and operating costs of enhanced bus PT services and walking and cycling facilities. However, we may infer that an additional cost of up to 0.19% of RGNDI could be incurred before the net RGNDI benefit is zero. The corresponding figures for 2035 and 2050 are 0.10% and 0.04% respectively, again reflecting the relatively greater impact of more bus PT and more walking and cycling on emissions when EV penetration is lower.

[15] See for example Resource Economics and Infometrics (2018) Projection of Electric Vehicles Uptake: Model Update, Report to Ministry of Transport, December 2018.

5 Scenarios to 2050 – results

The key assumptions for the 2050 Baseline are noted in Appendix 2. Apart from the carbon price there are no other explicit policy interventions aimed at reducing transport emissions. We extend two 2035 scenarios to 2050.

5.1 Scenario 6-50: International light ICEV ban

Scenario 6 looked at an international ban on new light ICEVs from 2035, effectively a scenario in which manufacturers stop improving the fuel efficiency of light ICEVs after 2030.

Scenario 6-50 extends Scenario 6 to 2050. By then EVs are projected to displace 90-95% of fossil fuel use in road transport, suggesting that a smaller effect of the ICEV ban might be expected. On the other hand, the ICEVs that remain in 2050 would have extremely poor fuel economy compared to what they would have without the ban.

As shown in Table 5, the former effect dominates. By 2050, the incremental effect on transport emissions is much smaller than in 2035. Negative macroeconomic effects persist, but they are very small and probably within the error margin on EV penetration in the Baseline.

Note that there is no allowance in the model for people keeping their ICEVs for longer than they would without a ban.

Table 5: Results for scenario 6 relative to baseline 2035 and 2050

	2035 Baseline	2035 Scen 6	2050 Baseline	2050 Scen 6-50
		% change on Baseline		% change on Baseline
Private consumption		-0.16		-0.04
Gross investment		-0.12		-0.04
Exports		0.04		0.07
Imports		-0.05		-0.01
GDP		-0.10		-0.01
RGNDI		-0.12		-0.03
Real wage rates		-0.15		-0.03
		CO_2e (MT)		
Gross CO_2e	68.5	69.4	47.8	48.2
Forestry	-14.5	-14.5	-19.5	-19.5
Net CO_2e	54.0	54.9	28.3	28.7
Net excl Biogenic CH_4			4.0	5.1
Transport CO_2e	16.4	17.1	3.9	4.1

5.2 Scenario 7-50: Light VKT Charge + Bus PT + Walking & Cycling

Scenario 7 for 2035 combined the exogenous mode shifts in Scenario 3 with a uniform distance charge on light vehicles of $0.05/km – analogous to Scenario 5, but at a lower rate. Here we run the same scenario, with the same input shocks for 2050. Table 6 presents the results.

Table 6: Results for Scenarion 7 relative to baseline 2035 and 2050

	2035 Baseline	2035 Scen 7	2050 Baseline	2050 Scen 7-50
		% change on Baseline		% change on Baseline
Private consumption		1.37		0.04
Gross investment		1.66		0.08
Exports		-1.75		-0.64
Imports		-0.31		-0.30
GDP		0.80		-0.05
RGNDI		1.17		0.04
Real wage rates		0.45		0.17
		CO_2e (MT)		
Gross CO_2e	68.5	62.7	47.8	47.2
Forestry	-14.5	-14.5	-19.5	-19.5
Net CO_2e	54.0	48.2	28.3	27.7
Net excl Biogenic CH_4			4.0	3.6
Transport CO_2e	16.4	10.8	3.9	3.7

With the very high uptake of EVs by 2050 already in the Baseline (displacing 90-95% of fossil fuel use in road transport) the reduction in VKT comes mostly from less use of EVs. Unsurprisingly therefore the reduction in transport emissions is negligible; less than 0.2Mt.

Higher transport costs have a negative effect on exports (such as international tourism) leading to a small decline in GDP, although the resources displaced from exports do permit a corresponding rise in private consumption.

As for the 2035 scenarios, we cannot be certain that the revenue from the VKT charge will be sufficient (or more than sufficient) to enhance PT services and expand cycleways to the extent necessary to secure the assumed mode shift. By 2050 though, these results suggest that the mode shift is largely irrelevant, at least from an emissions perspective. As discussed above there may other reasons to encourage mode shift.

Although not directly relevant to transport emissions, total net emissions excluding biogenic methane are 4Mt short of the 2050 net zero target in the 2050 Baseline. At $250/tonne the cost of international emission units is a billion dollars. The more transport emissions decline and approach zero (even if they never attain zero), the more important it is to carefully analyse the next emissions-reduction initiative. Most of the remaining emissions in 2050 are from fishing, construction machinery (arguably not actually transport), road freight and non-road transport. Although in the model these industries benefit from ongoing fuel efficiency improvements, by 2050 there may well be other energy technologies that generate step-changes in emissions intensity. We have made no assumptions in that regard.[16]

[16] For example, Sense Partners op cit look at Sustainable Aviation Fuels.

6 Other mode shift interventions not modelled

Thera are other policies that could encourage mode shift which we have not examined. We comment briefly on these below.

6.1 Congestion and parking costs

Parking surcharges and congestion pricing are likely to be time and space specific at gradations that are much too fine for GE models to simulate. Probably the best that could be done with a GE model is to exogenously impose a quantum of mode shift that would be estimated from other modelling, accompanied by some form of tax on private VKT. This could possibly be linked to Scenario 5 or Scenario 7.

6.2 Car sharing

Another possibility is car sharing, where a fleet of vehicles is available for use by many people, as opposed to car pooling (as modelled in Scenario 4) in which people share rides in a privately owned vehicle.

In a study of a car sharing scheme in San Francisco Cervero et al (2007)[17] found that 30% of trips would otherwise not have occurred and 29% displaced public transport. Only 11% of car share trips would otherwise have been by private vehicle (whether as driver or passenger). That seems to be largely because most car share users lived in non-car owning households. The main reason for a car share trip was shopping, not commuting.

Based on these findings, as a means of reducing transport emissions car sharing might have the opposite effect. Its main benefit is probably enhancing mobility for households without access to their own vehicle. Car sharing is not amenable to GE modelling.

6.3 Subscription-based modes

Horcher and Graham (2020)[18] also consider subscription-based car sharing, described under the modern parlance of ‘mobility as a service’ (MaaS). Subscription-based PT is included as well. They find that such schemes lead to welfare losses. Those with subscriptions face a marginal travel price close to zero and so overconsume PT and car sharing. The associated overcrowding and high marginal cost of use for non-subscribers induces more private car use, which causes an additional welfare loss as private car use does not reflect the cost of congestion (in the model). Differentiated pricing is recommended to reduce the welfare loss.

Like Cervero et al their focus in not on transport emissions, but it seems that the net effect could go either way depending on the relative sizes of the shift to PT (if the shift is from more carbon-intensive modes) and the higher congestion.

Thus, MaaS does not seem particularly promising as a way to reduce transport emissions but could improve accessibility for those with limited transport options.

[17] Cervero, R., Golub, A., & Nee, B. (2007). City CarShare: longer-term travel demand and car ownership impacts. Transportation Research Record, 1992(1), 70-80.

[18] Hörcher, D., & Graham, D. J. (2020). MaaS economics: Should we fight car ownership with subscriptions to alternative modes? Economics of Transportation, 22, 100167.

7 Summary and key findings

7.1 Scenarios to 2035

The overall conclusion from the modelling is that if ICEVs can easily be switched to EVs without the need for government intervention (Scenario 1), it is the most efficient way to reduce emissions from land transport. Based on current EV technology development, EV and ICEV will become close substitutes by around 2035, therefore reducing the need for policy interventions, apart from a carbon price. However, there are still uncertainties around the timing of when these vehicles would become close substitutes and in the interim and to accelerate the level of EV uptake by 2035, there may be a role for government to support EV infrastructure (where there is a coordination problem).

Mode shift can assist, but mode choice depends on many attributes other than price, such as reliability, comfort, expected travel time and journey purpose. Decisions are complex, suggesting that mode shift probably needs to be targeted to specific areas, times, or types of travel (such as commuting) to avoid unnecessary economic costs. Scenarios 2 to 4 illustrate that substantial mode shift to walking and cycling, and bus PT could be less efficient ways to reduce emissions compared to an autonomous increase in EVs (Scenario 1). In addition, mode shifts may not act independently of one another, even though we have modelled them that way. A recent report on New Zealand's experiment with half price bus fares found that of the 7% increase in patronage (implying an ex-post elasticity of 0.14), 1% was new travel, 3% switched from private cars and taxis, and 3% switched from walking and cycling[19].

After a detailed analysis of trip distances and duration by different modes, Concept (2017) conclude that mode shifting from road to bus, cycling or walking is unlikely to lead to large reductions in emissions without very substantial changes in relative mode prices.[20] That finding is consistent with the results from our modelling, but mode shift may still be worthwhile at the margin if it is implemented efficiently, and of course may be justified on other criteria such as health or equity of accessibility.

7.2 Selected scenarios to 2030

To test if the results for scenarios 2035 in relation to EV uptake may be too optimistic, Scenario 1 was re-estimated for 2030. Results show that most of the effects of EV uptake appears to take place between 2030 and 2035. While this does not seem implausible, the 2030 projections could be too low. If this were the case, the estimated effects of the Clean Car Package over the period to 2030 could be too small or the projected carbon price in 2030 (at $150/tonne) could be too low.

7.3 Selected scenarios to 2050

By 2050, it is expected that over 90% of the light vehicle fleet would be electric. Two scenarios that are of interest for this period are Scenarios 6 and 7.

For Scenario 6 with an international ICEV ban, by 2050 the incremental effect on transport emissions is much smaller than in 2035. While negative macroeconomic effects persist, they are very small and probably within the error margin on EV penetration in the Baseline.

For Scenario 7 with a small VKT charge for light vehicles and more bus PT and walking and cycling, by 2050 the incremental effects of VKT charging on transport emissions would be negligible (less than 0.2Mt) as the majority of the VKT would be carried out by electric vehicles at that time.

[19] Magill (2022) Impact of half price public transport fares – a research note. NZTA RN 009.

[20] Concept Consulting (2017) *Cost-effective energy options for transitioning New Zealand to a low carbon economy*. Report to the Parliamentary Commissioner for the Environment, September 2017, p45.

7.4 Key findings

Key findings from the research are as follows:

- Any switch from a high emission activity to a low emission activity that is also cheaper than the high emission activity, enhances aggregate economic wellbeing. An example is the switch from ICEVs to BEVs when the prices of these vehicles reach parity over time, as the latter become progressively closer substitutes for the former. The increase in economic wellbeing from an increase in BEVs is mainly driven by changes in technology. However, there are still uncertainties about the timing of such price parity and the sufficiency of BEV supply.
- Different interventions can lead to different levels of transport cost changes, which can lead to quite different wider economic impacts as some interventions may be more costly than others in terms of emissions reductions achieved. Preliminary assumptions about the cost of interventions to effect mode shift suggest that large increases in walking and cycling, and bus PT may involve higher economic costs than other policies aimed at reducing emissions, but mode shift may have other benefits which are not included in this research.
- Interventions to accelerate or induce a shift to low emission transport modes may or may not increase aggregate economic wellbeing. Changes in relative prices cause changes in consumer surplus in the relevant market and in the total market for all goods and services. For example, a PT subsidy may benefit PT patrons, but the cost falls on others. Assessing the net effect of interventions requires empirical analysis that extends beyond the market of direct interest.
- Increasing direct user changes on all travel by light vehicles (such as via distance-based charging, analogous to road user charges) can reduce emissions, but at potentially high cost. Modelling suggests that altering relative transport costs across modes might not an efficient way of reducing emissions if substitutability between modes is low – whether because of inelastic demand or inelastic supply of alternatives. However, if the revenue from such a charge is used to improve other low-emission transport options a net benefit can eventuate.
- If most countries with vehicle manufacturers ban new light ICEVs from 2035, New Zealand's emissions would rise relative to Baseline as the ICEV fleet would no longer benefit from improvements in fuel efficiency. An accompanying enhanced shift to EVs could reverse the adverse emissions effect.

Appendix 1 Modelling EV Uptake & Mode Shift

EV Uptake

The standard industry production structure in the model is a two-level translog specification. The top level has four factors: capital, labour, energy and materials (other intermediate inputs) and the second level splits energy into coal, oil-based fuels, gas and electricity. Some industries such as primary metal processing and electricity generation have more restrictive specifications.

Private consumption is split into eight commodity groups using an AIDS (Almost Ideal Demand System) specification. There is also fuel substitutability in household operation, and between energy and other inputs into household operation.

Until recently, however, other than industries and households being able to substitute between road and rail inputs, the model had no mechanism to substitute between fossil fuels and electricity in road transport. That is, the Allen elasticity of substitution between oil and electricity in road transport was zero – for industries and households. As it is currently impossible to econometrically estimate new production functions that allow for oil-electricity substitution in motive power, we calibrate a value for the Allen elasticity as described below. To satisfy the usual demand conditions (homogeneity etc), the own price elasticities are endogenous.

From previous experience with developing an EV projection model,[21] a useful way to model EV uptake is to include artificial cost penalties on EVs that decline over time as the variety of EV models, battery range, charging options etc improve. The penalties are components in the total price of owning and operating an EV. To this is applied a constant elasticity of substitution that determines the split between EVs and ICEVs. The elasticity is set at a high value of 10 (although it is user-changeable) to recognise that the two types of vehicles will eventually be functionally almost perfect substitutes, at least for light vehicles.

As estimated in 2018, the penalties were about 55% of average EV total cost in 2020, falling to about 30% in 2035 and to less than 5% by 2050. Based on newer information the NZCCC projects that by 2030 the whole of life cost for EVs will be 20% lower than for equivalent ICEVs.[22] We assume that by 2035 the difference in whole of life costs will more or less offset any remaining penalties.

General equilibrium models are not readily amenable to including cost penalties. Instead, we treat improvements in battery range (and accompanying concerns about obsolescence) and greater model variety as electricity-biased technological advancement, simulated as an outward shift of the demand curve for electrical motive power. In Te Manatū Waka's Baseline projections for 2035 about 17% of household demand and about 2% of industry demand for petrol and diesel (for transport) shifts to electricity. The oil-electricity Allen substitution elasticities required to produce these shifts, given the simulated technological change, are 0.71 for households and 0.60 for industries.

In other scenarios for 2035 these elasticities may be raised to achieve a faster uptake of EVs. Similarly for different time periods. Adopting this approach means that the effect of changes in relative energy prices, which are endogenous in the model, can be fully captured in the oil-electricity (ICEV-EV) decision.

With competitive pricing and a range of EV models wide enough to meet the requirements of most users, the price of used imported ICEVs could fall dramatically, pulling back some of the envisaged ICEV-EV substitution. In Scenario 1 we do not model this explicitly as the exogenously imposed increase in EV penetration is net of such effects by definition. However, it would be possible to run a variation on Scenario 1 with the ICEV price lowered by some specified amount and then applying the calibrated elasticities of substitution discussed above.

[21] Resource Economics and Infometrics op cit..

[22] New Zealand Climate Change Commission (2021) Ināia tonu nei: a low emissions future for Aotearoa, p108.

Mode Shift

Vehicle kilometres travelled

Vehicle kilometres travelled (VKT) is not a model variable. Thus, in scenarios such as Scenario 3 fuel consumption for transport is used a proxy. For example, a 5% reduction in household private car VKT is simulated as a 5% reduction in household demand for motive fuels, including electricity for EVs. Arguably maintenance costs could also be reduced and even vehicle purchase costs. However, even though some of the shifts to PT and walking & cycling are large in relation to their respective base levels, as proportions of total household VKT they are small. Thus, although a household will see lower fuel costs with mode shift, the changes in overall vehicle use are unlikely to have a significant effect on maintenance costs and even less on the decision to buy a vehicle.

Public transport

The model has five transport industries – Road Transport, Rail Transport, Water Transport, Air Transport and Transport Support Services. There is no differentiation between transporting people and transporting goods. The household sector has eight broad commodity groups, one of which is Transport. Each has its own income elasticity of demand and there is a full matrix of cross price elasticities.

If a household uses public transport, it purchases that service from one or more of the five transport industries. Private transport comprises expenditure on vehicles, fuel, maintenance and so on. Substitution between these components and public transport (whether road, rail, etc.) is possible with an elasticity of unity. However, in the PT scenario (Scenario 2) this elasticity is effectively over-ridden by shifting the baseline mix of public-private transport.

Direct expenditure on freight transport (such as on couriers) by households is not part of the Transport commodity. It is part of expenditure on the Other Services commodity.

Appendix 2 Baseline Scenarios

Assumptions

In the Baseline scenario for 2035 EV uptake and bus PT usage is as specified by Te Manatū Waka, as is the carbon price at $160.47/tonne CO_2e. It is assumed that international emission units can also be bought at that price. In other respects, the Baseline is broadly in line with NZCCC pathway projections. In particular:

- Methanex and NZAS have ceased operation by 2035 and there is no domestic oil refining.
- Biogenic CH_4 is in the ETS with 95% free allocation, declining linearly at 1% pa.
- Oil price: US$80/bbl.
- Forestry sequestration: 14,500 Kt.
- An emissions target of 42.5Mt. The government does not have annual targets, but 42.5Mt is consistent with its carbon budgets and a trending decline towards net zero for long lived gases by 2050.
- Population, labour force etc, Stats NZ 50th percentile projections.
- Energy efficiency: Coal: 2% pa; Gas: 1% pa; Oil: 1.5% pa; Electricity: 1.0% pa.

For the Baseline to 2050, the changes from 2035 are as follows:

- The carbon price is $250/tonne CO_2e.
- Forestry sequestration is 19,500 Kt.
- The emissions target is net zero for non-biogenic methane emissions.

For the Baseline to 2030, the changes from 2035 are as follows:

- The carbon price is $150/tonne CO_2e.
- Forestry sequestration is 10,800 Kt.

The emissions target is a 50% reduction in net emissions on 2005 gross emissions.

Model closure

The following macroeconomic closure rules are adopted for the alternative scenarios, consistent with generally accepted modelling practice:

1. The current account balance is fixed as a percentage of GDP. This means for example that if New Zealand needs to purchase international emissions units to meet an emissions reduction target, that liability cannot be met simply by borrowing more from offshore with indefinitely 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 total employment. This prevents the long run level of total employment being driven more by emissions policy than by the forces of labour supply and demand, and the skills of the workforce. Over time education and training programmes respond to a different set of market demands so that those entering the labour force acquire the necessary skills.
4. The fiscal balance is fixed across scenarios. This means for example that if the government needs to purchase overseas emission units it must ensure that it has matching income. If it earns insufficient income from the sale of domestic emission units (because of free allocation for example) it would have to adjust tax rates. Personal income taxation as represented by household effective income tax rates, including social welfare benefits, are the default equilibrating mechanism.

With regard to the first rule, if the current account balance is endogenous, purchasing emission units could lead to an increase in overseas debt. Without a matching inflow of foreign exchange repayment of the debt is effectively deferred to some future date and onto future generations, simultaneously understating the present cost of not meeting an emissions target. We consider this an undesirable situation, so we exogenously set the current account balance to be a fixed proportion of GDP. This means that if New Zealand needs to buy more international emission units, the cost has to be covered by a combination of more exports and fewer imports of good and services. Analogously, being able to sell more emission units means exports can be lower and imports higher.

The real exchange rate adjusts to generate the required changes in exports and imports. Nominal prices are not modelled. All prices are relative to a numeraire such that the model is homogenous of degree one in prices and degree zero in quantities. The numeraire could be almost anything, but in our case, it is the price of a basket of imports excluding oil.

The real exchange is one of the most important prices in the model and is one of the features that distinguishes a GE model from a PE model. Along with the wage rate, the cost of capital and the terms of trade, it plays an important part in determining how the economy adjusts to a ‘shock’ such as a change in tax rates or the cost of electric vehicles.

Results

As a GE model is not a forecasting model, we have no particular interest in the results other than to check for anything that seems implausible or unusual enough to potentially affect the differences (not levels) in results between scenarios.

Table 7 and Table 8 present the percent per annum changes between the base year 2019/20 and 2030, between 2030 and 2035, and between 2035 and 2050, in the main macroeconomic variables. For industry gross output the changes shown are between 2019/20 and 2035.

Table 7: Changes in macroeconomic variables

	%∆pa 2019/20 to 2030	%∆pa 2030 to 2035	%∆pa 2035 to 2050
Private consumption	2.4	2.5	1.9
Gross investment	2.6	2.4	2.0
Exports	2.6	2.0	1.7
Imports	2.4	2.2	1.8
GDP	2.4	2.3	1.9
RGNDI[23]	2.3	2.4	2.0
Real wage rate	1.6	1.2	1.2
Gross CO_2e	-1.3	-0.9	-2.5
Transport CO_2e	0.3	0.5	-9.5

Table 8: Changes in Industry Gross Output 2020 to 2035

	Industry	%∆pa from 2019/20		Industry	%∆pa from 2019/20		Industry	%∆pa from 2019/20
1	HFRG	4.2%	21	FERT	2.8%	41	COMM	2.3%
2	SBLC	1.1%	22	RBPL	3.0%	42	FIIN	2.6%
3	DAIF	1.6%	23	NMMP	2.6%	43	HIRE	2.7%
4	OTHF	1.0%	24	BASM	-3.4%	44	REES	2.9%
5	SAHF	2.3%	25	FABM	2.4%	45	OWND	2.7%
6	FOLO	2.3%	26	MAEQ	2.0%	46	SPBS	2.3%
7	FISH	1.1%	27	OMFG	2.6%	47	OBUS	2.5%
8	COAL	-2.8%	28	EGEN	0.7%	48	GOVC	1.8%
9	OIGA	-1.4%	29	EDIS	1.5%	49	GOVL	2.0%
10	OMIN	1.5%	30	WATS	1.4%	50	SCHL	2.1%
11	MEAT	0.7%	31	WAST	2.6%	51	OEDU	2.1%
12	DAIR	1.5%	32	CONS	2.7%	52	MEDC	2.4%
13	OFOD	2.3%	33	TRDE	2.6%	53	CULT	2.4%
14	BEVT	2.5%	34	ACCR	2.9%	54	REPM	2.5%
15	TCFL	2.7%	35	ROAD	2.7%	55	PERS	2.7%
16	WOOD	2.3%	36	RAIL	2.6%			
17	PAPR	2.4%	37	WATR	2.5%			
18	PRNT	2.7%	38	AIRS	3.7%			
19	PETR	1.8%	39	TRNS	2.5%			
20	CHEM	3.0%	40	PUBI	3.0%			
							Total	**2.3%**

[23] RGNDI is real gross national disposable income, defined as GDP plus adjustment for the terms of trade and net factor payments overseas, such as for emission units.

Appendix 3 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
- Public investment in new technology
- Funding regimes for roading and wider economic benefits
- Biofuels from purpose grown forestry

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, 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 standard 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 the year ended March 2020.

Greenhouse Gas Emissions

Greenhouse gas (GHG) emissions from energy are directly linked to the use of fossil fuels, split into coal, oil products, and natural gas. In addition, there are process emissions such as from the calcification of lime in the production of cement. GHG emissions from livestock are also treated as process emissions. Methane emissions are linked to the volume of output, and nitrous oxide emissions are partly linked to output and partly to the use of fertiliser. Major sources of fluorinated gases are also captured, again treated as process emissions.

All emissions are also cross tabulated by industry and households. Emissions related to the use of private ICEV transport by households are treated as household emissions, analogous to emissions from energy used to heat homes, run appliances and so on. As with electrical appliances, if a household has a BEV, emissions from thermal electricity generation are treated as emissions from the Electricity Generation industry.

Table 9: List of industries

	Abbrev	Description
1	HFRG	Horticulture and fruit growing
2	SBLC	Sheep, beef, livestock and cropping
3	DAIF	Dairy and cattle farming
4	OTHF	Other farming
5	SAHF	Services to agriculture, hunting and trapping
6	FOLO	Forestry and logging
7	FISH	Fishing
8	COAL	Coal mining
9	OIGA	Oil and gas extraction, production & distribution
10	OMIN	Other Mining and quarrying
11	MEAT	Meat manufacturing
12	DAIR	Dairy manufacturing
13	OFOD	Other food manufacturing
14	BEVT	Beverage, malt and tobacco manufacturing
15	TCFL	Textiles and apparel manufacturing
16	WOOD	Wood product manufacturing
17	PAPR	Paper and paper product manufacturing
18	PRNT	Printing, publishing and recorded media
19	PETR	Petroleum refining, product manufacturing
20	CHEM	Other industrial chemical manufacturing
21	FERT	Fertiliser
22	RBPL	Rubber, plastic and other chemical product manufacturing
23	NMMP	Non-metallic mineral product manufacturing
24	BASM	Basic metal manufacturing
25	FABM	Structural, sheet and fabricated metal product manufacturing
26	MAEQ	Machinery and other equipment manufacturing
27	OMFG	Furniture and other manufacturing
28	EGEN	Electricity generation
29	EDIS	Electricity transmission and distribution
30	WATS	Water supply
31	WAST	Sewerage, drainage and waste disposal services
32	CONS	Construction
33	TRDE	Wholesale and retail trade
34	ACCR	Accommodation, restaurants and bars
35	ROAD	Road transport
36	RAIL	Rail transport
37	WATR	Water transport
38	AIRS	Air Transport
39	TRNS	Transport services
40	PUBI	Publication and broadcasting
41	COMM	Communication services
42	FIIN	Finance and insurance
43	HIRE	Hiring and rental services
44	REES	Real estate services
45	OWND	Ownership of owner-occupied dwellings
46	SPBS	Scientific research and computer services
47	OBUS	Other business services
48	GOVC	Central government administration and defence
49	GOVL	Local government administration
50	SCHL	Pre-school, primary and secondary education
51	OEDU	Other education
52	MEDC	Medical and care services
53	CULT	Cultural and recreational services
54	REPM	Repairs and maintenance
55	PERS	Personal services

Appendix 4 Sensitivity Analysis

Feedback from reviewers and members of the steering group has led to three sensitivity tests for some 2035 scenarios:

- Scenario 5p: Scenario 5 with a higher price on carbon emissions; $250/tonne CO_2e compared to $160.47/tonne CO_2e.
- Scenario 5s: Scenario 5 with a higher elasticity of substitution between private transport and public transport in household consumption.
- Scenario 6h: Scenario 6 with the 2035 international ban on light ICEVs extended to include heavy vehicles.

Scenario 5p: higher emissions price

It should be recognised and accepted that all modelling results contain margins of error. Relative numbers are more reliable than absolute numbers.

Sensitivity analysis can provide additional confidence in the results. Obvious tests include changing elasticities and altering the values of exogenous variables, but the number of potential tests that could be run is much larger than the resources available to this project.

In Scenario 5p we re-run Scenario 5 with the emissions price raised from $160/tonne to $250/tonne. This is a useful scenario for testing sensitivity with respect to the carbon price as it has no exogenously imposed uptake of EVs, bus PT or walking & cycling.

There are two ways to run this type of sensitivity test:

1. Simply re-run Scenario 5 with the higher emissions price. This essentially expands the specification of Scenario 5 to include not only its original input assumptions, but also a different emissions price. Hence the policy mix is fundamentally different, and we would expect the results to be different.
2. Re-run both Scenario 5 and the Baseline with the higher emissions price. The policy mix is unchanged. Comparing the two scenarios will show to what extent the effects of the policy mix are influenced by the emissions price.

These are two very different tests. The second option is a true sensitivity test. It answers the question: How sensitive are the estimated effects of a particular mix of policies to a different underlying emissions price? The first option answers a different question: What is the effect of a change in the emissions price, given some assumption about other policies?

We adopt the second approach. The results are shown in Table 10 along with the original results for Scenario 5.

The numbers are reasonably close, but the changes in private consumption and RGNDI are more favourable, reflecting the now higher value ($250/tonne v $160/tonne) of the reduction in emissions consequent to the VKT charge. More resources can flow into consumption rather than exports or import substitution to pay for overseas emission units. Overall though, while the differences are small the results do demonstrate what should be obvious: the higher the carbon price, the greater the relative foreign exchange benefit from reducing domestic emissions, whatever other policies might prevail.

Table 10: Scenario 5 sensitivity testing

	Scen 5	Scen 5p	Scen 5s
	% change on Baseline		
Private consumption	-0.17	0.07	-0.05
Gross investment	1.43	1.59	1.21
Exports	-2.76	-2.83	-2.87
Imports	-0.90	-0.62	-0.90
GDP	-0.26	-0.17	-0.28
RGNDI	0.20	0.38	0.22
Real wage rates	-2.11	-1.90	-1.68
Gross CO_2e	-8.0	-7.6	-8.6
Transport CO_2e	-25.3	-25.1	-27.3

Scenario 5s: higher substitution elasticity

The elasticity of substitution between private transport and public transport in private consumption has a default value of 1.0, implying constant expenditure shares. Here we re-run Scenario 5 with the elasticity raised to 1.3. As for Scenario 5p a new Baseline is required.

The results are shown in Table 10. As might be expected, with more flexibility to switch from private transport to public transport the negative impact on households of the light VKT charge is lower. There is a very small additional increment to RGNDI, reflecting the larger drop in emissions (8.6% v 7.6%) and thus less need to buy international emission units. Overall, though the results indicate insensitivity of macroeconomic effects to the elasticity of substitution between private transport and public transport consumed by households.

The model has no specific supply constraints on goods and services. Supply will meet demand at the equilibrium price point. In Scenario 5s the supply of PT expands to meet the demand, with no change in the capital-output ratio (other than what might occur from a change in relative factor prices), so there is no enhancement of service quality as modelled in Scenario 2a.

We can think of the elasticity of substitution as how readily consumers switch transport modes in response to a change in relative mode prices. Hence the results in Scenario 5s may be seen as reinforcing the argument that changing relative mode prices has better results if people can indeed change modes.

Scenario 6a: international light & heavy ICEV ban

Scenario 6a extends the global light ICEV ban modelled in Scenario 6 to include heavy vehicles, with vehicle manufacturers assumed to not improve the fuel efficiency of any ICEVs from 2030. This is probably not a realistic scenario, but it does provide a picture of how welfare-reducing such an initiative could potentially be if there are few substitutes.

Table 11 summarises the results.

Unsurprisingly the outcome is much worse, with RGNDI in Scenario 6h being 0.6% below Baseline compared to only 0.1% in Scenario 6. What is perhaps surprising is the extent of the difference, given the relative shares of light versus heavy vehicles in the fleet.

However, relative fuel consumption is more important than the relative number of vehicles, as is the nature of the user. Less fuel efficiency for heavy vehicles essentially means less efficiency for diesel vehicles which are used by a range of large industries – agriculture, mining, forestry and construction for example. There are fewer alternatives to diesel use by these industries compared to the options available to households.

With a consequent increase in transport emissions (relative to Baseline) driving the increase in total emissions, the usual story applies. More of the nation’s income must go to purchasing international emission units, leaving less available for domestic consumption.

Table 11: Scenario 6 sensitivity testing

	Scen 6	Scen 6h
	% change on Baseline	
Private consumption	-0.16	-0.77
Gross investment	-0.12	-0.60
Exports	0.04	0.09
Imports	-0.05	-0.08
GDP	-0.10	-0.55
RGNDI	-0.12	-0.59
Real wage rates	-0.15	-0.69
Gross CO_2e	0.73	1.26
Transport CO_2e	2.66	4.31

Appendix 5 Reviews by Sense Partners and Principal Economics

In June/July the draft report was reviewed by Sense Partners and Principal Economics. They contain a number of recommendations which can be classified as either general improvements to the report or additional modelling. These are summarised below with comments in response in *Italics*.

General enhancements to the report

1. Add explanation of how emissions are included in the model's database.

Added in Appendix 3.

2. More discussion of consumer preferences in connection with PT (Scenario 2), and in general on how PT links with the model's transport industry with regard to production and consumption. Note that possible travel time savings are not captured in the PT scenario.

Added in the body of the report and in Appendix 1.

3. Clarify the role of emissions targets and the carbon price.

Added in the section on Scenario Specification.

4. Clarify why the current account balance and the exchange rate matter.

Explained in Appendix 2.

5. Clarify how fuel use can be a proxy for VKT.

Discussed in Appendix 1.

6. Amend the costs of the Auckland cycling programme (as supplied by Sense Partners) and note that diminishing marginal returns to investment are relevant.

Corrected.

7. Expand discussion on BEV-ICEV substitution, noting higher costs of EVs and potentially falling cost of used imported ICEVs with adverse emissions outcomes.

Discussed in Appendix 1 and in Conclusion.

8. Add quintile analysis of changes in private consumption.

Done for Scenario 2.

9. Re-iterate the caveat about the health benefit of walking and cycling being excluded and estimate what value these benefits would have to be to offset the net cost of the walking and cycling intervention. Similarly for PT.

Estimated and noted in various place where the scenarios are discussed.

10. Include a graph to illustrate the emissions 'take back' effect for Scenario 1. Use this as an illustration of the additional insights provided by GE analysis over PE analysis.

Included with accompanying text.

11. Mention that support for improving EV infrastructure is probably a sensible policy to support the shift to EVs.

Mentioned in the Conclusion.

12. More output data on emissions by industries or selected industries for some scenarios.

Presented only for the 2035 Baseline, but more could be made available.

13. Elaborate or delete the quote by Concept.

Amended the associated discussion.

14. More discussion on ride hailing and car pooling/sharing.

Included in Section 3.

Possible additional scenarios

1. Perhaps re-run Scenario 3a with higher costs, as a consequence of pt 6 above.

Corrected.

2. Sensitivity tests with different elasticities. Sense Partners suggest changing the elasticity of substitution between private transport and public transport in household consumption from a default value of 1.0 to 0.8 and/or 1.2.

Investigated as a sensitivity test on Scenario 5 rather than on Scenario 2 as in the latter the elasticity is over-ridden by the exogenously specified change in PT.

3. In relation to the fiscal closure rule, consider financing some of the transport interventions by government debt instead of by taxation.

This is discussed, but not pursued as it was considered low priority. It would need to be assessed with respect to say 2050; otherwise, the 2035 picture could look like a free lunch.

4. Test combinations of scenarios.

Investigated in Scenario 7, 7-50 and 7-30. More combinations could be pursued.

5. Some standard sensitivity testing with regard to assumptions about the carbon price, the oil price and the electricity price.

Some sensitivity tests, including on the carbon price are presented in Appendix 4. Different oil and electricity prices were not explored as were considered lower priority.

Future possibilities

In most research projects, it is technically possible to do more. Some issues that were deemed lower priority could not be accommodated within the budget. Nonetheless they may be worthwhile exploring as part of any follow-up research.

- As suggested by the reviewers, payment for PT and active mode infrastructure via a short-term increase in government debt could be considered, by running scenarios over a longer time period so as to capture the debt repayment profile.
- Further sensitivity testing such as with regard to oil and electricity prices (especially if the aluminum smelter at Bluff remains open) could also be useful.
- We have looked at scenarios that raise bus PT and walking & cycling, with the associated infrastructure upgrades financed by a uniform distance charge on light vehicles. This mix yielded some interesting insights, suggesting that other policy combinations may also be worth exploring.

We have not looked at emissions from freight transport, so moving more road freight by rail or sea is a possible area for research.

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