NEW ZEALAND INFRASTRUCTURE COMMISSION
Te Waihanga

Infrastructure needs analysis – Decarbonisation

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Infrastructure needs analysis – Decarbonisation

Executive Summary

The New Zealand Infrastructure Commission (Commission) is currently preparing an "Infrastructure Needs Analysis" (INA). As part of the INA, the Commission is working to understand and, where possible, quantify capital investment to meet New Zealand's infrastructure needs out to 2055. This note summarises work undertaken by Motu to understand the implications of decarbonisation for New Zealand's infrastructure needs.

In undertaking this work, the Commission and Motu have focused on infrastructure sectors that are expected to be most heavily affected by decarbonisation, specifically:

- *Electricity & gas*, including generation, transmission, and distribution; and
- *Land transport*, including road transport and non-car passenger travel.

To understand the implications of decarbonisation for capital investment in these sectors, we draw on modelling from the Climate Change Commission (CCC). The CCC's modelling considers outcomes under seven scenarios consistent with the emissions targets set by the New Zealand Government, as summarised in the table below.[1]

Scenario	Summary
EB4	Demonstration path. A credible and consistent mix of actions to reduce emissions by 50% for the fourth emissions budget. Including consideration of actions that are ambitious while also being technically and economically achievable.
HTHS	High technology, high systems change. This scenario assumes rapid technological advancements and strong government support, leading to significant emissions reductions of 60% through innovation and policy measures
HTLS	High technology, low systems change. In this scenario, technological advancements occur rapidly, but there is limited government support. The focus is on market-driven solutions to reduce emissions by 45%.
LTHS	Low technology, high systems change. This scenario assumes slower technological progress but strong government support through regulations and policies to drive emissions reductions of 40%.
LTLS	Low technology, low systems change. This scenario represents a more challenging pathway with slower technological progress and minimal government support, such that emissions reduce by only 30%.
Alternative A	This scenario explores different mixes of technological advancements and behavioural changes, aiming for a balanced approach to emissions reduction of 50%.
Alternative B	Similar to Alternative A but combines additional strategies, such as international cooperation on policy measures, to achieve emissions reductions of 55%.

We compare outcomes in these scenarios to the CCC's Reference scenario to quantify the implications of decarbonisation for capital investment needs in infrastructure. The Reference scenario describes the current trajectory of New Zealand's emissions based

[1] For detailed information on the CCC's recent work, please refer to: Commission delivers first review of the 2050 target and advice on the fourth emissions budget » Climate Change Commission

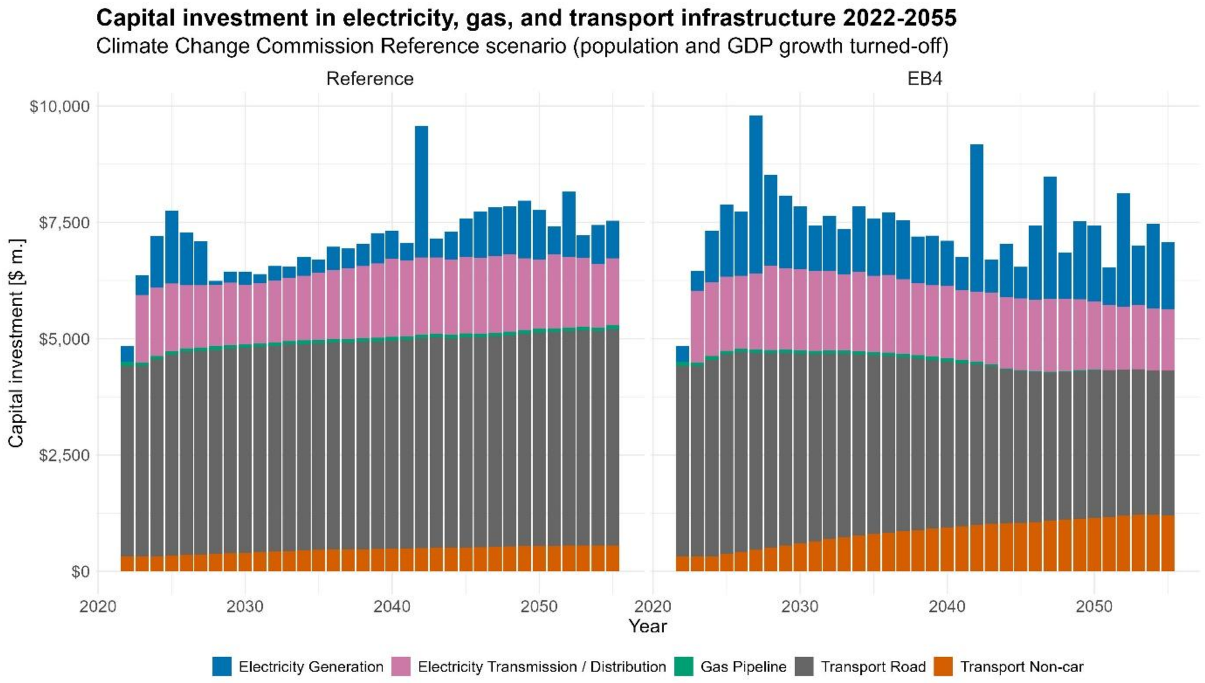
on existing policies and measures, that is, if no additional actions are taken beyond what is already planned or implemented. In the CCC's Reference scenario, New Zealand is not expected to meet its 2050 emissions reduction targets.

The Reference scenario thus provides the baseline to which we can compare capital investment under alternative scenarios that do deliver the desired emissions reductions, e.g. via a mix of further changes in technology, behaviour, and policy. For each scenario, the CCC's modelling provides information on important outcomes, for example electricity generation and transmission/distribution as well as vehicle usage and mode shift. Although this information forms the basis for our analyses, we selectively extend the CCC's modelling in some places, such as for land transport.

The following aspects of our methodology are important for interpreting our results:

- First, following engagement with a project Reference Group, we chose to adopt a "bottom-up" approach to modelling capital investment needs in the two infrastructure sectors noted above. Capital investment needs in other sectors, such as rail freight, are not considered and should be the subject of future work.
- Second, our analysis seeks to isolate the effects of changes in technologies, behaviour, and policies separately from population and economic growth. As the latter's effects are explicitly considered in other dedicated workstreams that feed into the INA, including them here would risk double-counting.
- Third, our forecasts consider only the implications of decarbonisation for capital investment in infrastructure. Specifically, we do not consider ongoing operating costs nor wider financial or economic effects. In some cases, there is a blurry line between capital and operating expenses, e.g. treatment of buses and trains.
- Fourth, as New Zealand's population and economy is projected to grow between now and 2055, we often standardise our forecasts for the change in capital investment in infrastructure as a percentage of forecast GDP per annum.

The forecast implications of decarbonisation for capital investment in several types of infrastructure is summarised in the figures below (NB: All monetary values in this technical note are denominated in 2023 New Zealand Dollar values).



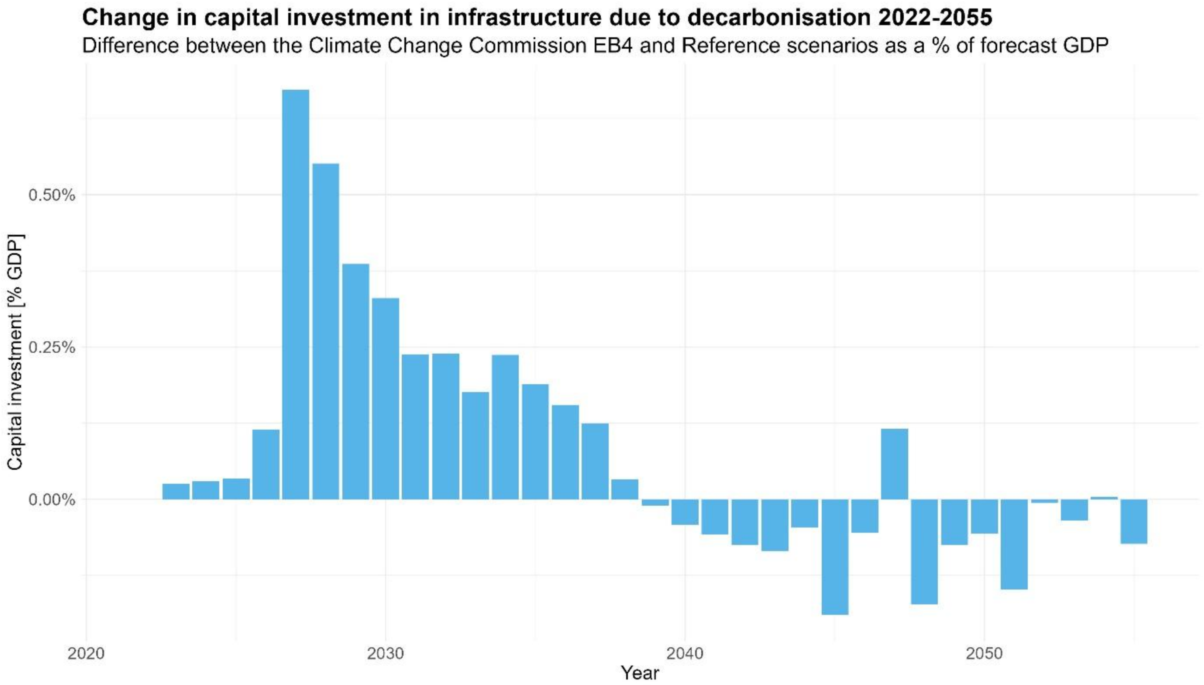
Total capital investment in each of these infrastructure sectors over this 30-year period is summarised in the table below for the Reference and EB4 scenarios.

Sector	Type	Capital investment [2023NZD $m.]			%
		Reference	EB4	Change	
Electricity	Generation	$24,734	$47,155	$22,422	+91%
	Transmission/Distribution	$49,157	$51,627	$2,470	+5%
Gas	Pipeline	$2,707	$1,757	-$950	-35%
Transport	Road	$151,348	$124,066	-$27,282	-18%
	Non-car	$15,748	$28,617	$12,869	+82%
Totals		$243,695	$253,223	$9,528	+4%

According to these results, capital investment needs is forecast to increase by approximately $9.5b (4%) in the EB4 scenario compared to the Reference scenario.

The following figure shows the estimated combined effect on capital investment as a % of GDP in the EB4 scenario compared to the Reference scenario for these infrastructure sectors. We see decarbonisation has an initial positive effect on capital investment in the period to 2038, which thereafter turns negative. This investment profile is driven by increased capital investment in electricity generation in the short to medium term, with less transport investment in the medium to long term. Within transport, reduced capital investment in roads is partly offset by increased investment in non-car modes.

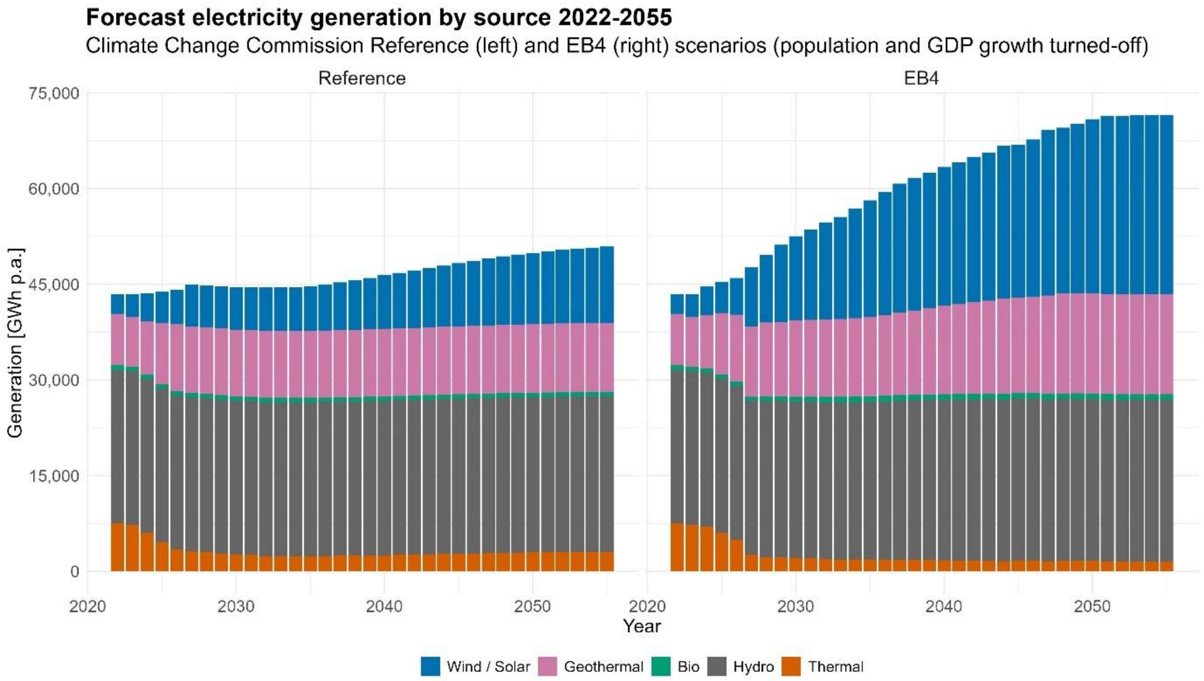
Together, these results imply that decarbonisation impacts on the timing and distribution of capital investment in infrastructure, more so than the quantum of investment required. Specifically, our results suggest decarbonisation will increase capital investment needs in the short to medium term but reduce them in the medium to long term. Similarly, we expect decarbonisation to cause a redistribution in capital investment across sectors, with shifts away from the gas and transport sectors and into electricity generation, transmission, and distribution.



Naturally, these forecasts are subject to uncertainty, which – in this technical memo – can arise from two main sources. First, uncertainty could arise due to differences between the decarbonisation scenarios that we analyse and the path that is chosen by the New Zealand Government. In this context, it is crucial to note the CCC presents the EB4 scenario as just one of many potential decarbonisation pathways that would be consistent with Government targets. Second, uncertainty could be introduced by the models used to predict the effects of decarbonisation on capital investment. Later sections of this technical memo seek to engage with the implications of both these two sources of uncertainty in more detail.

Electricity & Gas

Introduction: In this section, we quantify capital investment needs for electricity generation, transmission, and distribution as well as gas pipelines. These estimates are drawn directly from the CCC's modelling work. The figure below shows forecast electricity generation in the Reference and EB4 scenarios in GWh p.a. This figure highlights how decarbonisation causes electricity generation to grow more quickly in the EB4 scenario when compared to the Reference scenario. Even in the Reference scenario, however, electricity generation is predicted to grow.



Approach: To estimate the implications of decarbonisation on capital investment in the electricity and gas sectors, we adopted and adapted the CCC's ENZ model. Specifically, we sought to identify the capital investment attributable to decarbonisation policy and technology separately from that attributed to economic and population growth.[2]

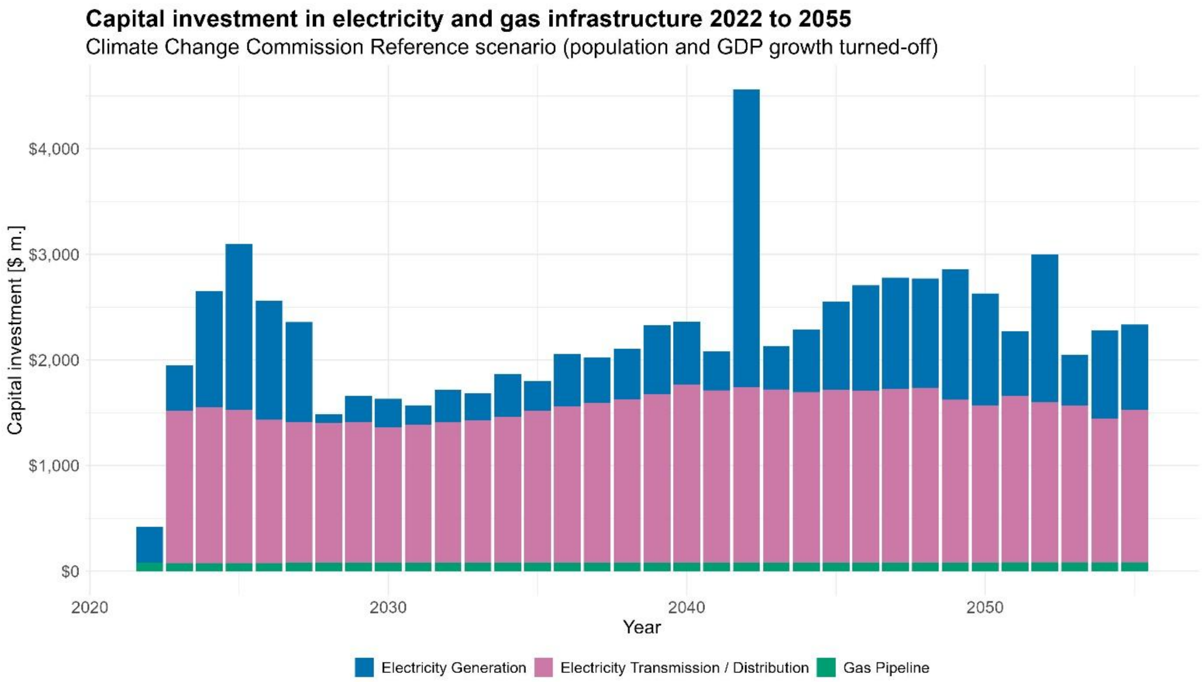
For this reason, we run the CCC's ENZ model with population and GDP held constant in the period from 2022 onwards. From the model's results file, we then extract capital investment (or, divestment) associated with the following activities:

- *Electricity*, including generation, transmission, and distribution; and
- *Gas,* specifically capital investment in pipelines.

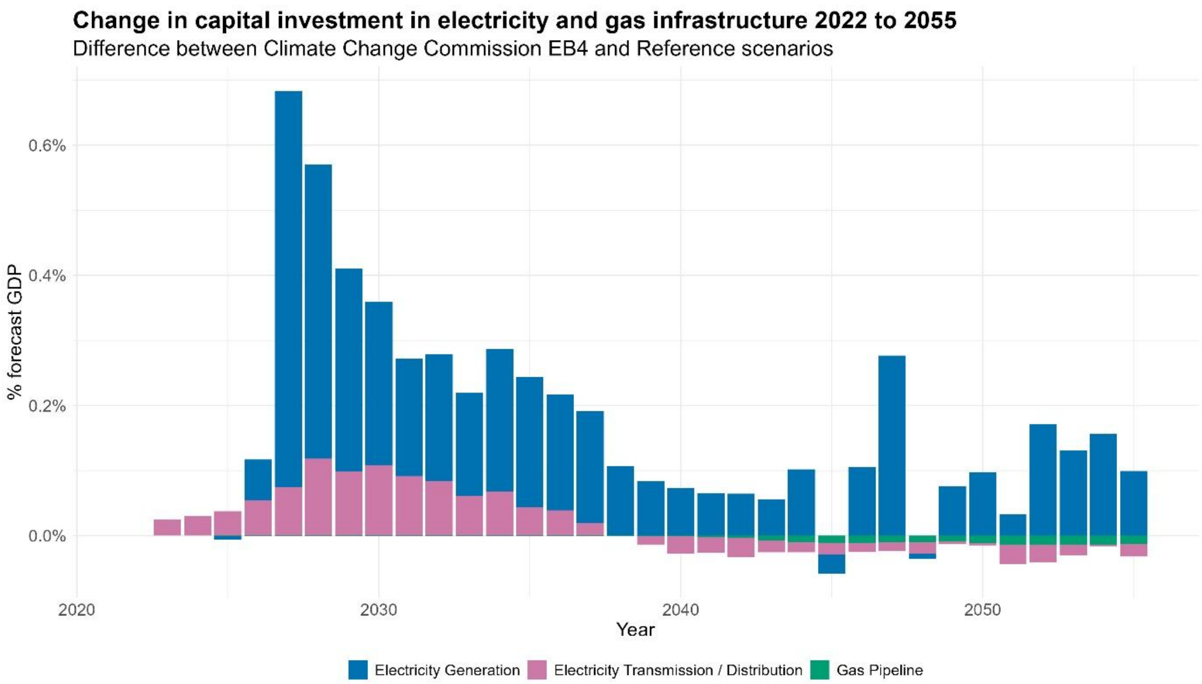
Results: Capital investment in electricity and gas infrastructure is summarised in the figure below for the CCC's Reference scenario (NB: Results for other CCC scenarios are summarised in Appendix A). We note two key findings. First, all scenarios see significant

[2] As noted in the Executive Summary, the effects of economic and population on capital investment are considered in other parts of the INA, such that including them here would give rise to "double-counting".

capital investment in electricity transmission and distribution, which is also relatively stable over this period. Second, the differences between scenarios are mostly due to capital investment in electricity generation, which is considerably more volatile.[3]



Next, we subtract capital investment in the Reference scenario above from that for the EB4 demonstration path scenario and divide the result by forecast GDP. This yields relative investment as a percentage of GDP per annum, per the figure below.



[3] The spike in 2042 appears to be associated with the planned refurbishment of hydroelectric generation. In practice, we expect generators will stage this capital investment, so its effects are smoothed over time.

The capital investment in the period 2022-2055 that is implied by the above results are summarised in the following table.

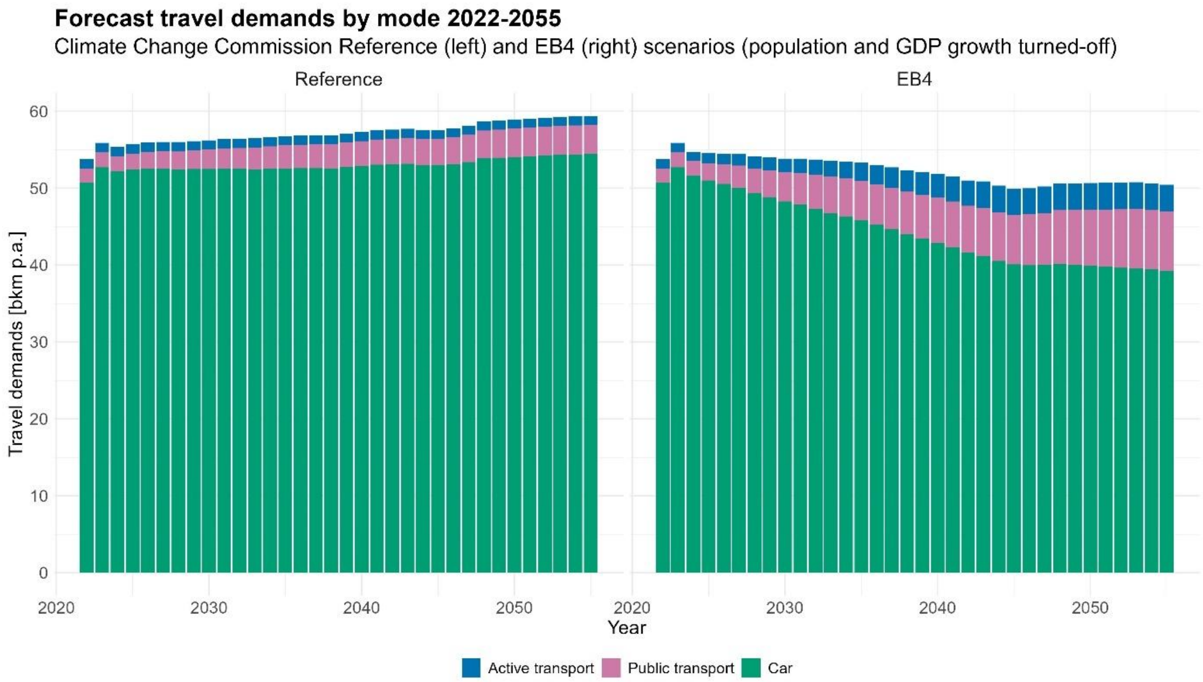
Sector	Type	Capital investment [2023 NZD $m.]		
		Reference	EB4	Difference
Electricity	Generation	$24,734	$47,155	$22,422
	Transmission / Distribution	$49,157	$51,627	$2,470
Gas	Pipeline	$2,707	$1,757	-$950
Totals		$76,598	$100,539	$23,942
% GDP		0.45	0.59	0.14

On average, decarbonisation in the EB4 scenario gives rise to a significant increase in the need for capital investment for electricity generation, with smaller effects on transmission and distribution and negative effects on investment in gas pipelines. Across the electricity and gas sectors, the net increase in capital investment needs in the period 2022-2055 due to decarbonisation is forecast to be around 0.14% of GDP.

Land transport

Introduction: In this section, we consider the implications of decarbonisation for capital investment in land transport infrastructure. Specifically, we quantify the capital investment associated with road transport as well as passenger transport. To do so, we draw on the CCC's modelling, which assumes decarbonisation will lead to reduced demand for private vehicle travel and increased demand for passenger transport.

The following figure shows estimated kilometres travelled by passenger transport modes in the Reference and EB4 scenarios. Here, "car" represents the combined kilometres travelled by drivers and their passengers as well as motorcylists. Compared to the Reference scenario, the EB4 scenario sees reduced overall demand for travel, as well as a shift in the composition of travel from car to public and active transport.



To generate forecasts for capital investment, we extend the CCC's forecast travel demands with our own analysis. For road transport, we model how changes in the CCC's forecasts for vehicle kilometres travelled might be expected to flow through to affect capital investment. For passenger transport, we multiply forecast changes in passenger kilometres travelled by estimated unit costs for public and active transport.

Road transport

Approach: We estimate regression models that predict capital investment in road transport as a function of the total demand for vehicle travel. Although we test several specifications, our preferred model specification is:

$$\ln I_t = \beta \ln V_t + s^2(t)$$
$$\ln V_t = \gamma \ln Z_t + s^1(t)$$

Where:

- $\ln I_t$ and $\ln V_t$ denote the natural log of government capital investment in road transport and vehicle travel demand in in year t, respectively
- $\ln Z_t$ denotes an exogenous instrument for $\ln V_t$ that helps to address endogeneity in the model for $\ln I_t$ that we discuss in detail below[4]
- β and γ denote model parameters that are to be estimated, where β is the elasticity of capital investment $\ln I_t$ with respect to vehicle travel demand $\ln V_t$
- $s^1(t)$ and $s^2(t)$ denote time trends[5]

The parameter, β, is of primary interest. Omitted variables pose a considerable technical challenge in trying to identify the value of β. Large shocks in capital investment can be introduced by, for example, changes in transport technologies and institutional settings. The time trend, $s^2(t)$, provides a powerful but parsimonious way to capture the effects of omitted variables and strengthen the identification of β.

Data and estimation: To estimate the above model, we use annual data for the period from 1950 to 2022 (n = 73 observations). Data on capital investment, $\ln I_t$, in the period from 1990 to the present is sourced from Stats NZ capital stocks with the Commission's estimates used prior to that point. Data on demand, $\ln V_t$, is sourced from the Infrastructure Commission and the NZ Transport Agency. Specifically, we define $\ln V_t$ by calculating the average vehicle kilometres travelled v in the previous three years, that is: $\ln V_t = \ln\big((v_{t-1} + v_{t-2} + \; v_{t-3})/3\big)$. Smoothing and lagging $\ln V_t$ in this way helps to reduce noise and strengthen causal identification. The instrument $\ln Z_t$ is then defined as long lags of $\ln V_t$. Specifically, $\ln Z_t = \ln V_{t-17}$. We adopt a lag of 17 years simply because this is the maximum available lag that enables us to start our analysis in 1950. Appendix B presents the results of some exploratory analyses of this transport data.

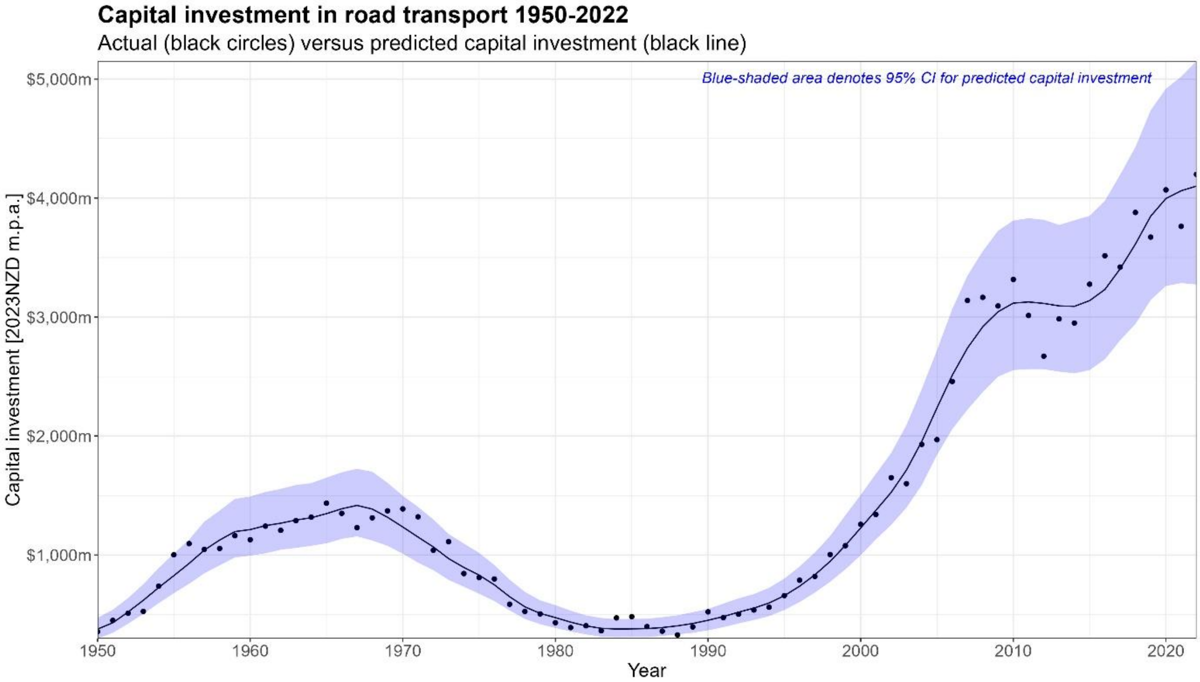
We estimate the above model using Bayesian methods, which allows us to formally incorporate prior information for the parameter, β. Specifically, we expect vehicle travel demands to have a positive effect on capital investment in roads, such that $\beta > 0$. In a hypothecated transport system where revenue is approximately proportional to distance travelled and is – at least in recent decades – reinvested in the transport sector, we might expect the value of β to be around 1.0. For this reason, our priors assume the parameter β is normally distributed with a mean of 1.0 and a standard deviation of 0.5. This prior implies that, prior to seeing any data, we would expect β to lie

[4] Endogeneity in the model for $\ln I_t$ could arise, for example, due to omitted variables and/or reverse causality whereby capital investment $\ln I_t$ affects vehicle travel demand $ln\ V_t$.

[5] Specifically, $s(t)$ denotes a non-linear, non-parametric "generalized additive model", or GAM. The latter provide a flexible way to model trends that – when estimated in a Bayesian setting – reduce, or "penalise", over-fitting. For a background to GAMs, see BaayenLinke2020.pdf.

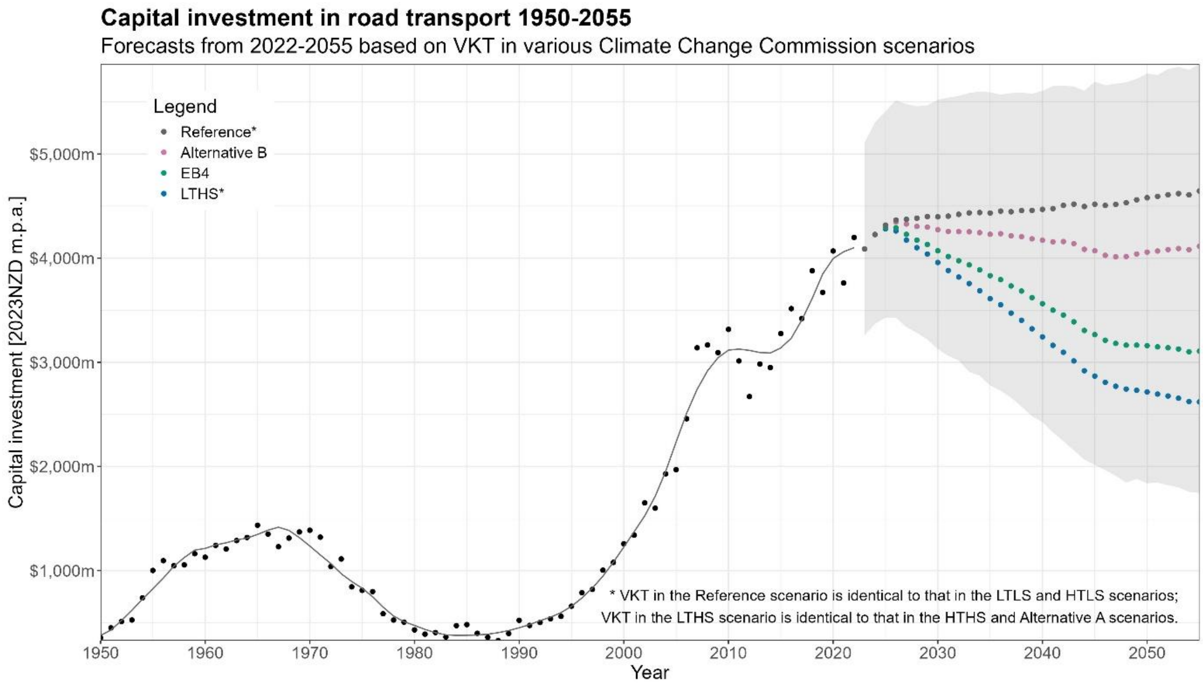
in the range 0-2 approximately 95% of the time. In Appendix C, we discuss the effects of alternative priors, including those that are more and less informative than we assume.

Results: Using these data and assumptions, our preferred model yields an estimate for β of 1.32 (95% CI 0.41-2.19). Appendix C presents more detailed regression results, including for alternative model specifications. As $\beta > 1$ we find some evidence that capital investment in roads has historically responded elastically to demand, although we note the credibility interval for the parameter easily includes 1. The figure below shows actual (black circles) versus predicted capital investment (blue line) using the preferred model, where we transform results from the log scale back to levels.

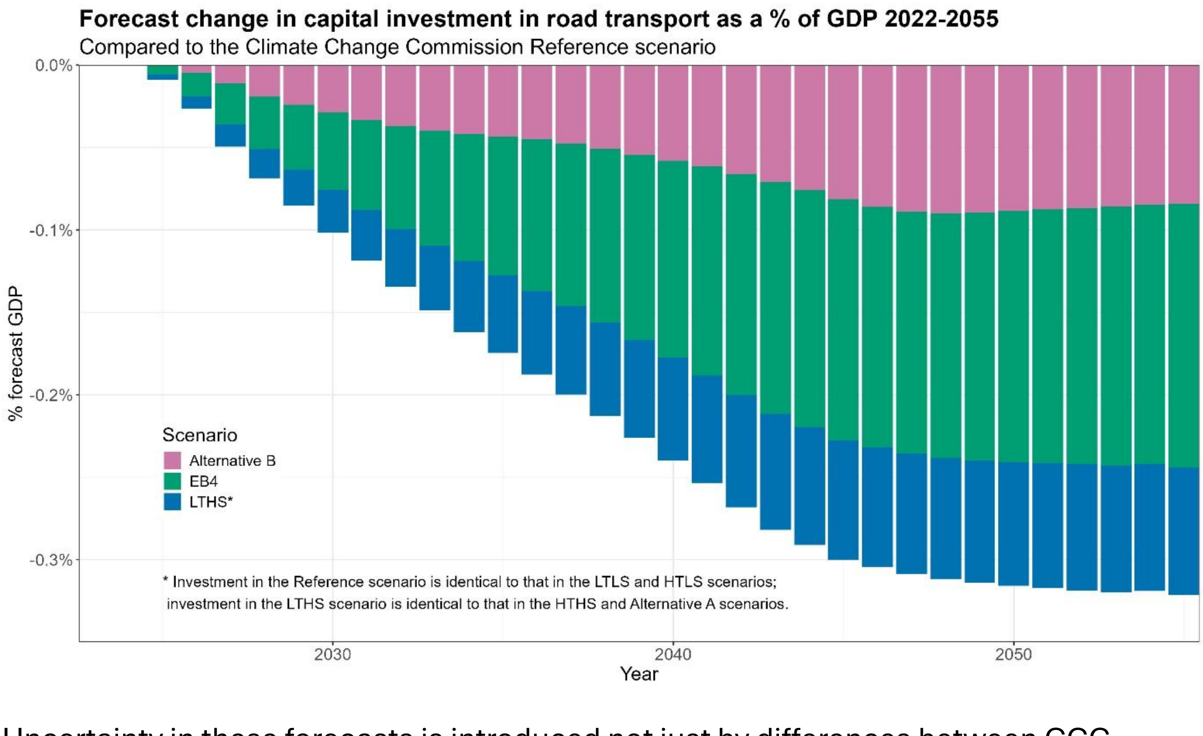


Despite its parsimonious nature, our preferred model captures much of the variation in levels of capital investment in roads during this period 1950-2022. As well as the effect that operates via β and $\ln V_t$, our results suggest the time trend, $s^2(t)$, is also significant. To finish, we note the parameters in the IV equation – that is, γ and $s^1(t)$ – are precisely estimated, which confirms the strength of our chosen instrument.

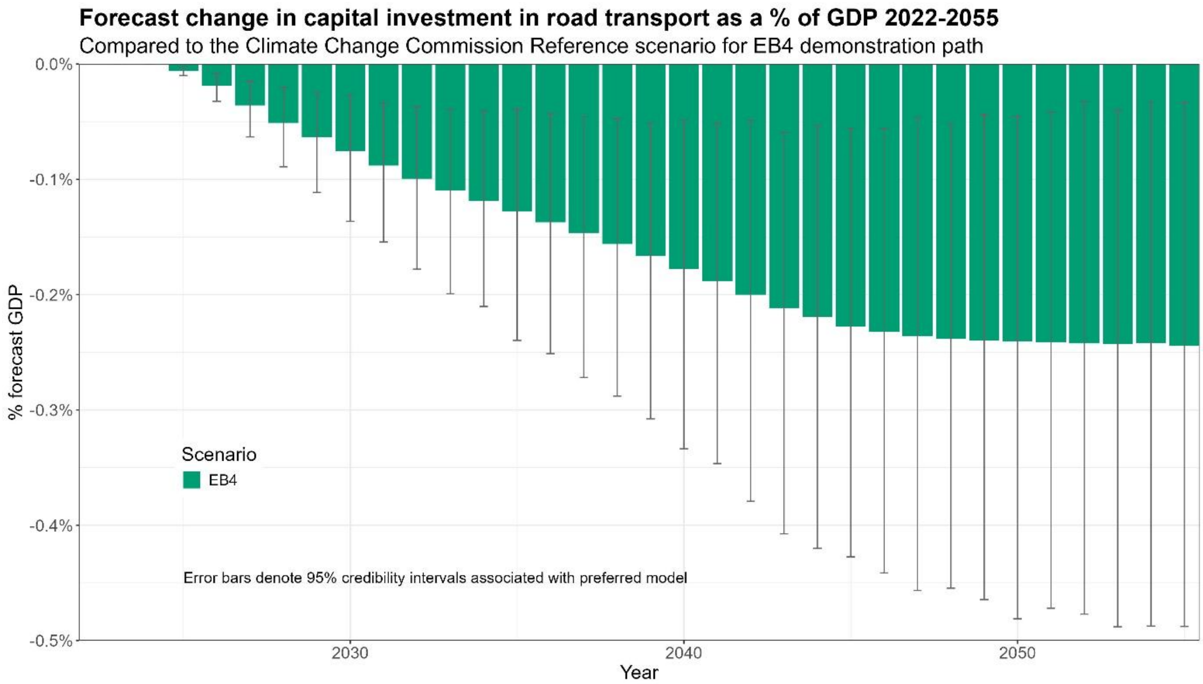
Forecasts: To forecast future capital investment in road transport, we draw on VKT forecasts produced by the Climate Change Commission's (CCC) "ENZ" model, as shown in the figure below. In producing these forecasts, we turn-off the time trend, $s^2(t)$, such that differences in capital investment over time are driven solely by the effects of differences in VKT between scenarios as determined by the parameter β estimated above. As such, the forecasts shown below seek to hold constant all other (non VKT) factors, such as population growth and income effects.



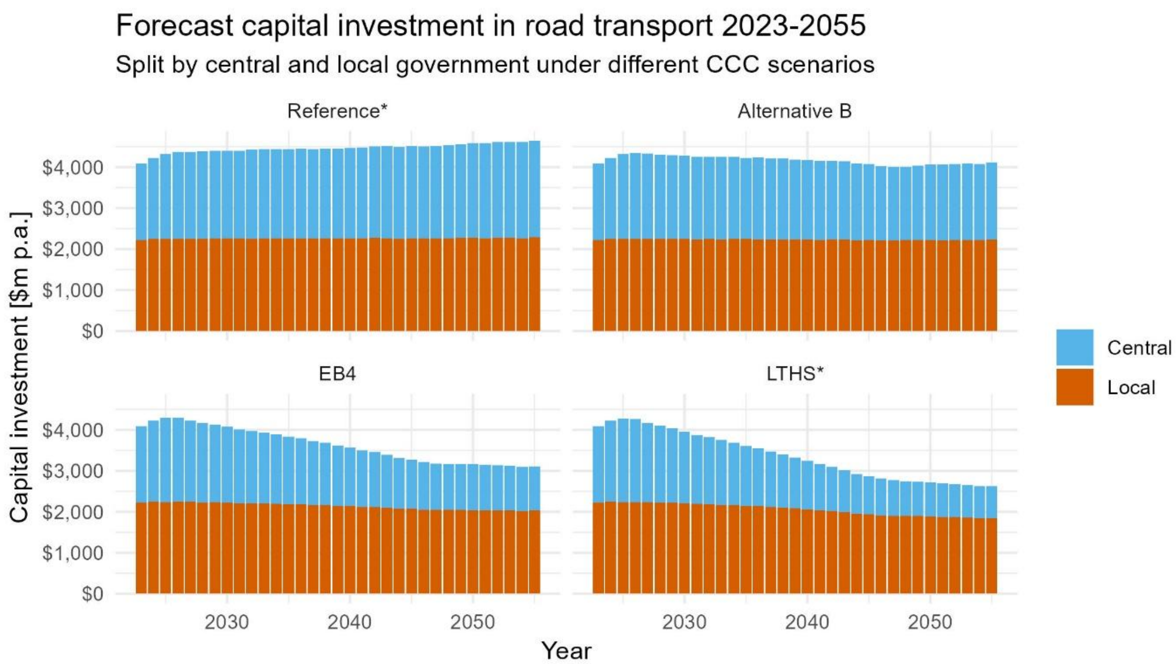
We convert the average difference in capital investment in road transport between the Reference and other CCC scenarios into a percentage of forecast GDP in future years, as shown in the figure below. In the EB4 scenario (green), for example, capital investment is forecast to fall by just under -0.25% of GDP by 2055.



Uncertainty in these forecasts is introduced not just by differences between CCC scenarios ("future uncertainty") but also uncertainty in the value of the estimated parameter, β ("model uncertainty"). In the figure below, we have added error bars to the forecast effects for the EB4 scenario to show the magnitude of uncertainty in β.



To finish, we estimate a model of central government's share of capital investment in road transport. Details of this model are discussed in Appendix D. The model suggests the historic response to increased road travel demand has been for central government to increase its share of investment relative to local government. For each CCC scenario, we combine the forecast capital investment with the forecast for central government share in each year to yield the following capital investment profiles.



** Investment in the Reference scenario is identical to that in the LTLS and HTLS scenarios; investment in the LTHS scenario is identical to that in the HTHS and Alternative A scenarios.*

Public and active transport

The CCC's modelling predicts decarbonisation will lead to a relative reduction in car travel demands but an increase in demand for public and active transport – that is, "mode shift". As such, the Commission considered it important to attempt to quantify the implications of this mode shift for capital investment in non-car modes.

To do so, we draw on several the following aspects of the CCC's modelling:

- Estimates of kilometres travelled by light passenger vehicles, which are *outputs from* the CCC's ENZ model
- Assumptions for vehicle occupancy and public and active transport mode shares, which are *inputs into* the CCC's ENZ model

Using this information, we infer the kilometres travelled by car vis-à-vis public and active transport in the CCC's scenarios.

We then estimate unit capital costs per kilometre travelled by public and active transport. To do so, we draw on the Ministry of Transport's Domestic Transport Costs and Charges (DTCC) study, as summarised in the following table.[6]

Mode	Capital cost	Passenger-kms	Unit capital cost
Rail	$35.283m[7]	339.5m[8]	$0.1039
Bus	$16.95m[9]	162.355m[10]	$0.1044

For public transport, we take the average of these values ($0.10415 per passenger kilometre) and apply an inflation factor of 23% to account for consumer price inflation in the period since the DTCC study was undertaken (2018) and the present to yield a final unit capital cost of $0.1281 per passenger kilometre. For active transport we have less information to go on, so for simplicity we assume the unit capital cost for active transport that is half that for public transport ($0.0641 per passenger kilometre).[11]

Using these unit capital cost estimates, we can forecast the capital investment in public and active transport that is implied by differences in travel demands between CCC scenarios. The following figure illustrates capital investment in the Reference scenario (left) and EB4 scenario (right). As one might expect, capital investment in public and active transport is forecast to increase under both scenarios, although decarbonisation causes the growth to approximately double compared to the Reference scenario.

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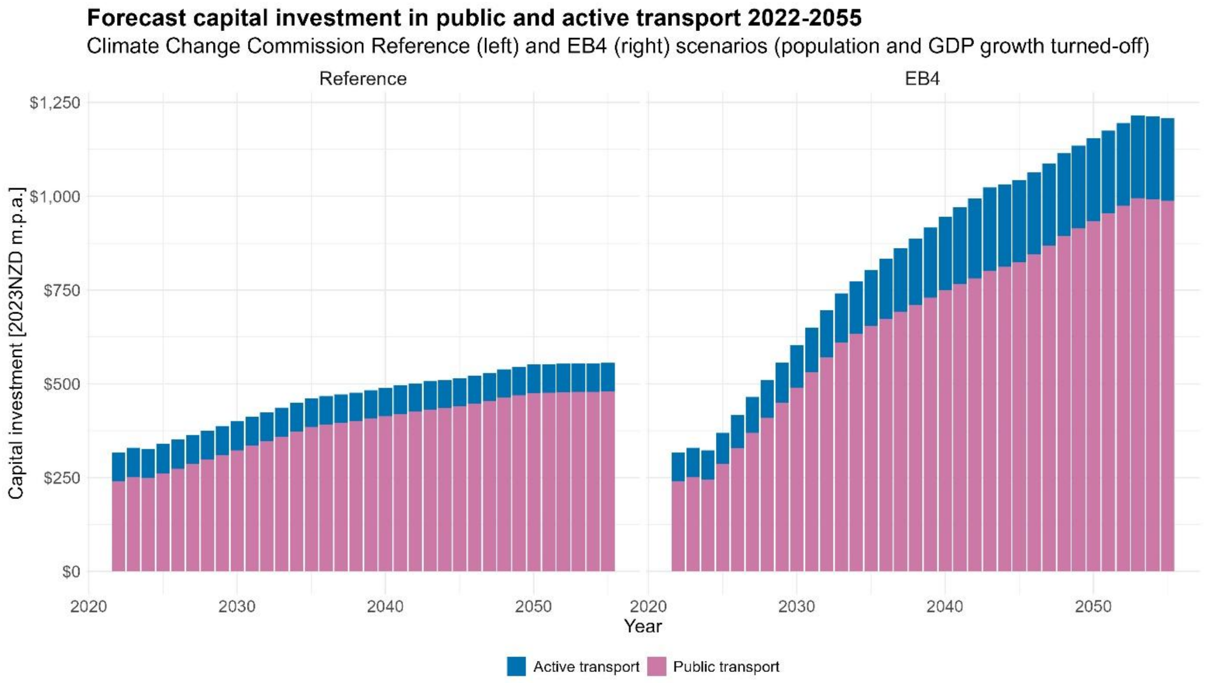
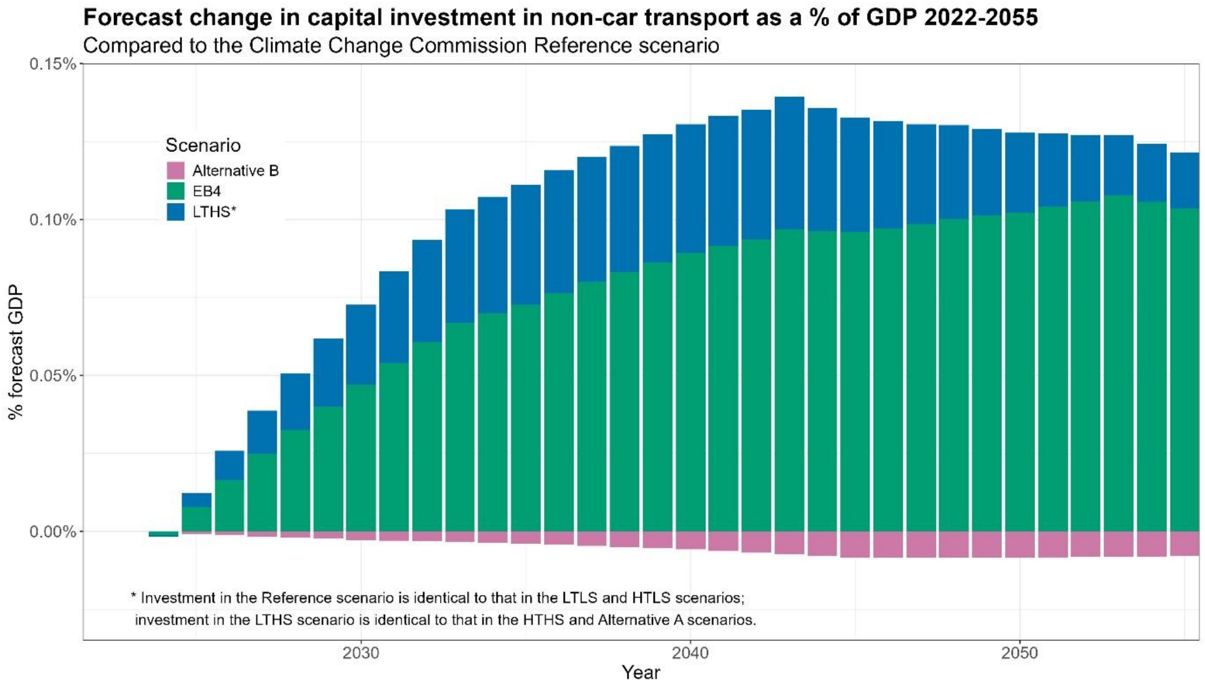
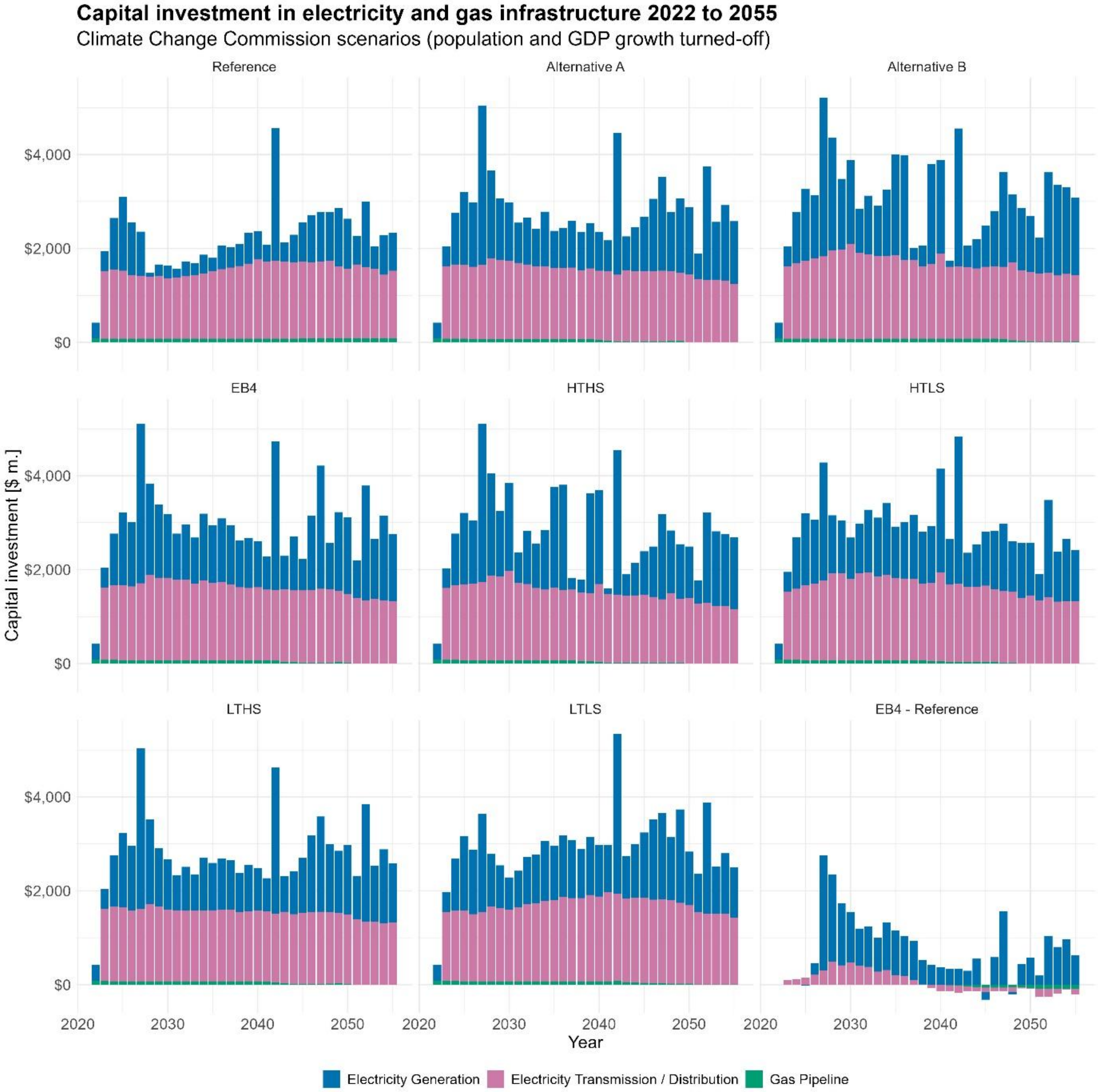
[6] Specifically, WP C12 "Urban Public Transport", DTCC-WP-C12-UPT_June-2023.pdf
[7] Sourced from Table 3.3.3.
[8] Sourced from Table 3.4.1.
[9] This is estimated by multiplying the cost per bus ($39,510 pa, cf Table 4.2.1, row F) with total fleet (390 buses, cf Table 4.2.1) and then adding a spares factor of 10%.
[10] Sourced from Table 4.3.1.
[11] Future research could improve on this approach to estimating the unit capital costs for active transport.



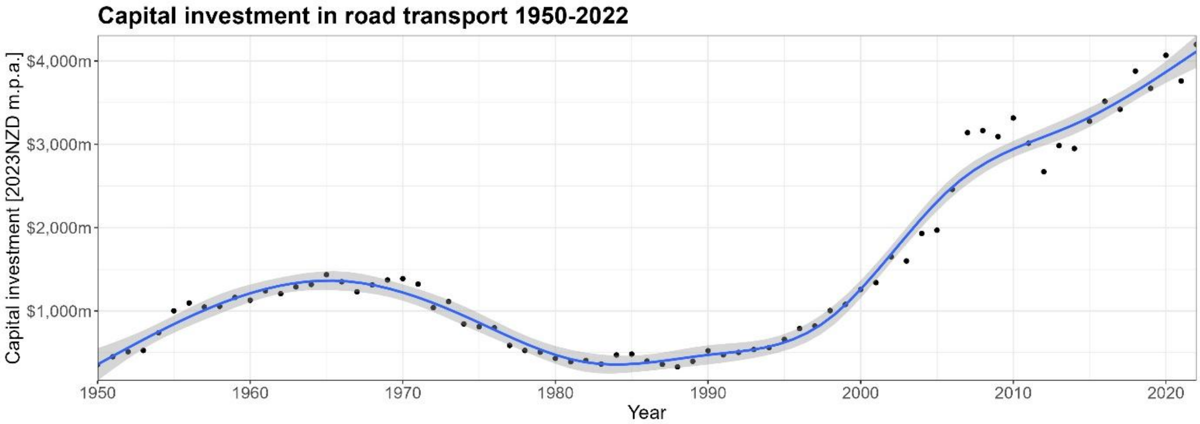
The figure below illustrates the implied total difference in capital investment in public and active transport under different scenarios as a % of forecast GDP. In the EB4 scenario, the effects of decarbonisation peak at just over 0.10% of GDP, which is approximately half the size of the estimated reduction in capital investment for road transport, as discussed in the previous sub-section.

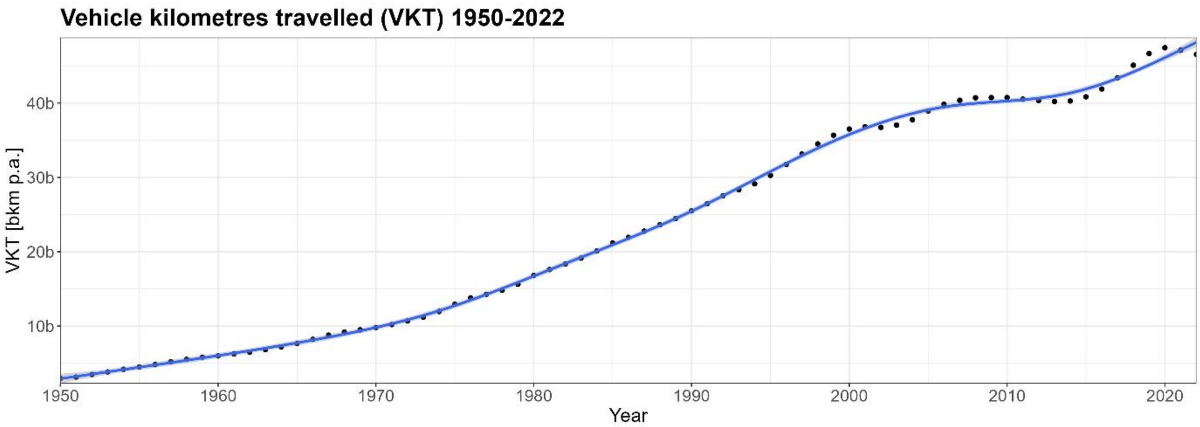


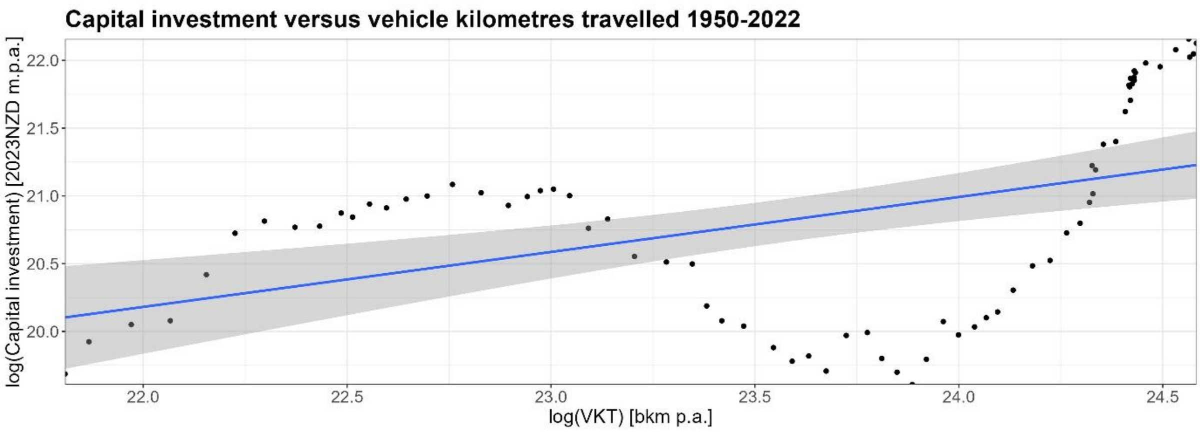
Appendix A – Additional information for electricity and gas

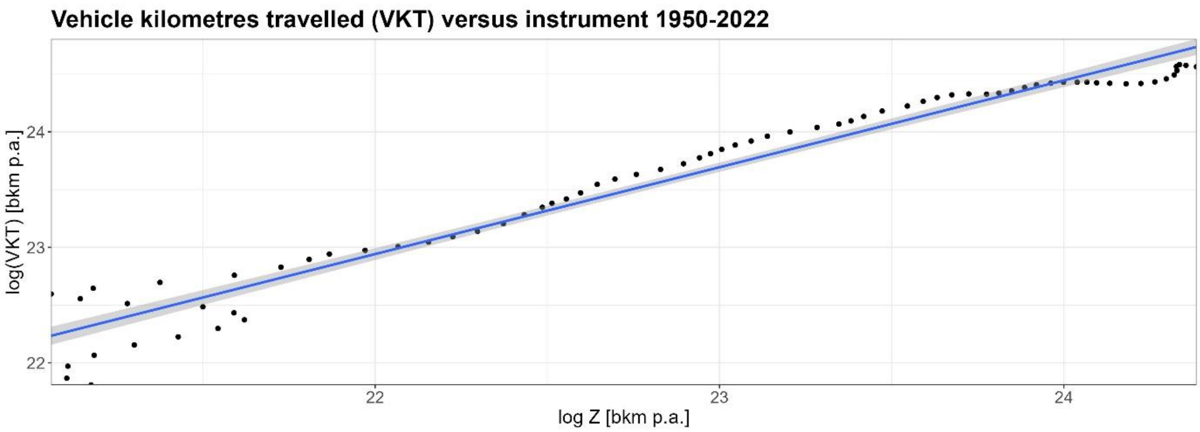


Appendix B – Exploratory analysis of transport data









Appendix C – Summarising regression models and results

Models

For the road transport analysis, we estimate five simple regression models as summarised below (NB: Intercepts are included in all models but omitted for clarity).

Model	Specification	Notes
1	$\ln I_t = \beta \ln V_t$	Basic model
2	$\ln I_t = \beta \ln V_t + s^2(t)$	Add GAM time trend
3	$\ln I_t = \beta \ln V_t + s^2(t)$ $\ln V_t = \gamma \ln Z_t$	Add instrumental variables (IV)
4	$\ln I_t = \beta \ln V_t + s^2(t)$ $\ln V_t = \gamma \ln Z_t + s^1(t)$	Add GAM time trend to IV first stage
5	$\ln I_t \sim t(\beta \ln V_t + s^2(t), \sigma_i, \nu_i)$ $\ln V_t \sim t(\beta \ln Z_t + s^1(t), \sigma_z, \nu_z)$	Add Student's-t distributions

Results

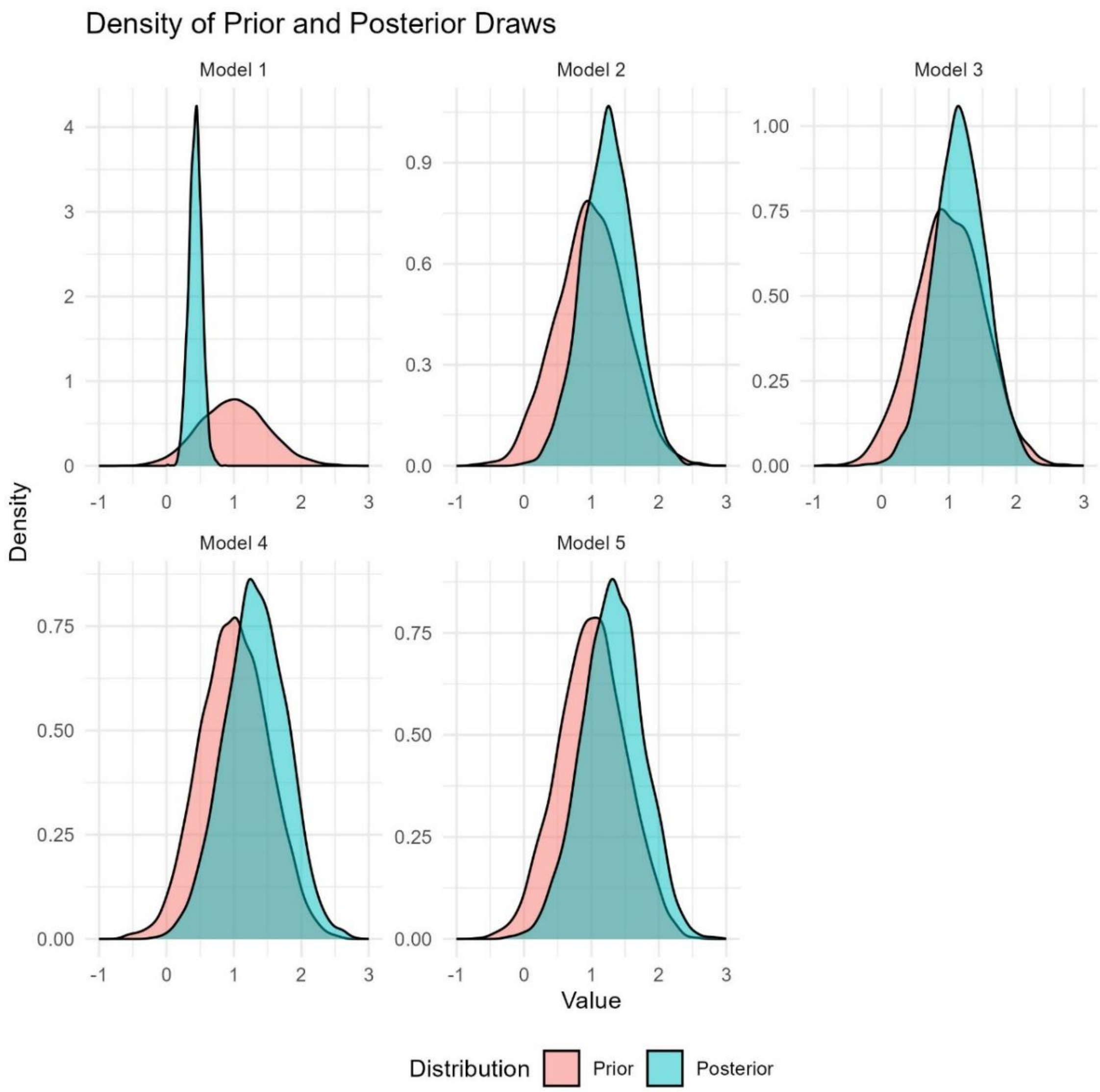
The estimated value of β in each of these five model specifications are summarised in the table below. In Model 1, the estimated value of β is 0.429 (95% CI 0.239-0.617). When we include a GAM in Model 2, β increases to 1.250 (95% CI 0.489-2.00), which then remains quite stable even when instrumenting $\ln V_t$ in Models 3, 4, and 5. Model 4 has the best out-of-sample performance and is therefore used to generate forecasts.

Model	β	se	95% Interval		Notes
1	0.429	0.0968	0.239	0.617	Basic model
2	1.250	0.3820	0.489	2.000	Add GAM time trend
3	1.160	0.3810	0.428	1.910	Add instrumental variables (IV)
4	1.320	0.4570	0.412	2.190	Add GAM time trend to IV first stage
5	1.310	0.4520	0.403	2.170	Allow Student's-t distributions

In all model specifications, we assumed the prior $\beta \sim N(1,0.5)$ and otherwise used defaults. We tested alternative prior distributions for β, both less informative uniform priors as well as more informative priors $N(1,0.25)$. Models estimated using these alternative priors were, however, found to have worse out-of-sample performance – as measured by the loo-ic – compared to those estimated with $\beta \sim N(1,0.5)$ priors.

In general, these results provide strong evidence the parameter β is positive. That is, capital investment in road transport in New Zealand has historically on average responded positively to demand, as we expect. There is also some evidence $\beta > 1$, that is, the relationship capital investment and the demand for vehicle travel is elastic.

The following charts compare the density of the prior and posterior distributions for the parameter β from each of the five models. We see how confronting the prior distribution for β with the data shifts the posterior distribution compared to the prior. Specifically, the posterior distribution for β shifts down in Model 1 but up in Models 2, 3, 4, and 5.



Although endogeneity is a concern, our approach mitigates this risk in two ways: First, we model capital investment as a function of lagged VKT and, second, we instrument lagged VKT – which is the only endogenous variable in the model – with long lags of VKT.

Robustness tests

We undertook several robustness tests to address key concerns that can arise when working with time-series data, specifically heteroskedasticity, time-varying effects, autocorrelation, non-stationarity / cointegration, and endogeneity / serial correlation. The nature of these tests and the associated results are summarised in the table below, where we focus on implications for model performance and parameter estimates of β.

Empirical problem	Robustness test
Heteroskedasticity	We estimated a model where the variance in both equations was a non-linear, non-parametric function of time, specifically, $\sigma = 1 + s(Year)$. This led to a small improvement in performance, although parameter estimates were consistent with the baseline model ($\beta = 1.26$, s.e. 0.44).
Time varying effects	To test whether the effect of VKT on capital investment has varied with time, we estimated a variant that included an interaction between VKT and the time trend, $s^2(t)$. Parameters for the latter term were statistically significant, although model performance and estimates of the elasticity were consistent with the baseline model ($\beta = 1.34$, s.e. 0.44). We also tested a variant that included a linear interaction term between VKT and time, for which results were also consistent with the baseline model ($\beta = 1.28$, s.e. 0.51).
Autoregressive errors	Graphical and statistical diagnostics – including the ACF and Box-Ljung test – revealed autoregressive (AR) behaviour in model residuals. We estimated several model variants incorporating AR and MA terms. AR terms were statistically significant, although model performance and parameter estimates remained consistent with the baseline model ($\beta = 1.05$, s.e. 0.47).
Stationarity and cointegration	Unit root tests – namely, Dickey-Fuller, Phillips-Perron, and KPSS – indicated both capital investment and VKT are non-stationary. Similarly, the Johansen test confirmed the series are integrated and cointegrated. An Engle-Granger ADF test further supported the existence of a long-run cointegrating relationship where capital investment converged to a long-run equilibrium.
Endogeneity and serial correlation	We estimated a dynamic OLS ("DOLS") variant of the model that included lead and lag differences in VKT to correct for endogeneity and serial correlation, respectively.[12] DOLS is designed to yield unbiased and efficient estimates of long-run parameters in cointegrated systems, such as ours. The results showed that both model performance and parameter estimates ($\beta = 1.17$, s.e. 0.48) were consistent with the baseline model.

Estimates of the long-run elasticity parameter β — which governs the effect of VKT on capital investment — are statistically consistent across these robustness tests. Taken together, these results suggest the model we use to estimate the elasticity, β, is relatively robust to misspecification. This finding is particularly reassuring given the challenging empirical context in which we estimate these models, specifically we use a relatively short time series spanning an era with large shifts in technology and policy.

Further research

In terms of opportunities for further research, we note there may be value in testing alternative instruments for $\ln V_t$. While we find long lags of $\ln V_t$ are a reasonably strong instrument, alternative instruments may be available that help to strengthen the first stage and contribute to more precise estimates of β. Similarly, our results make use of only 73 observations. As time passes and more data becomes available, there may be value in re-estimating these models to generate updated parameters and forecasts.

[12] To include lead and lag differences in VKT, $\Delta \ln V_{t+1}$ and $\Delta \ln V_{t-1}$, we re-specified $\ln V_t = \ln(v_{t-4} + v_{t-5} + v_{t-6})$, such that $\Delta \ln V_{t+1} = \ln(v_{t-1} + v_{t-2} + v_{t-3}) - \ln(v_{t-4} + v_{t-5} + v_{t-6})$ and $\Delta \ln V_{t-1} = \ln(v_{t-4} + v_{t-5} + v_{t-6}) - \ln(v_{t-7} + v_{t-8} + v_{t-9})$. Given these changes, the consistency in the estimated elasticity between the DOLS model ($\beta = 1.17$) and the baseline model ($\beta = 1.32$) is reassuring.

Appendix D – Estimating Central Government's share of capital investment in road transport

To estimate central government's share of capital investment in road transport, we estimated the following Beta distribution model with logit link:

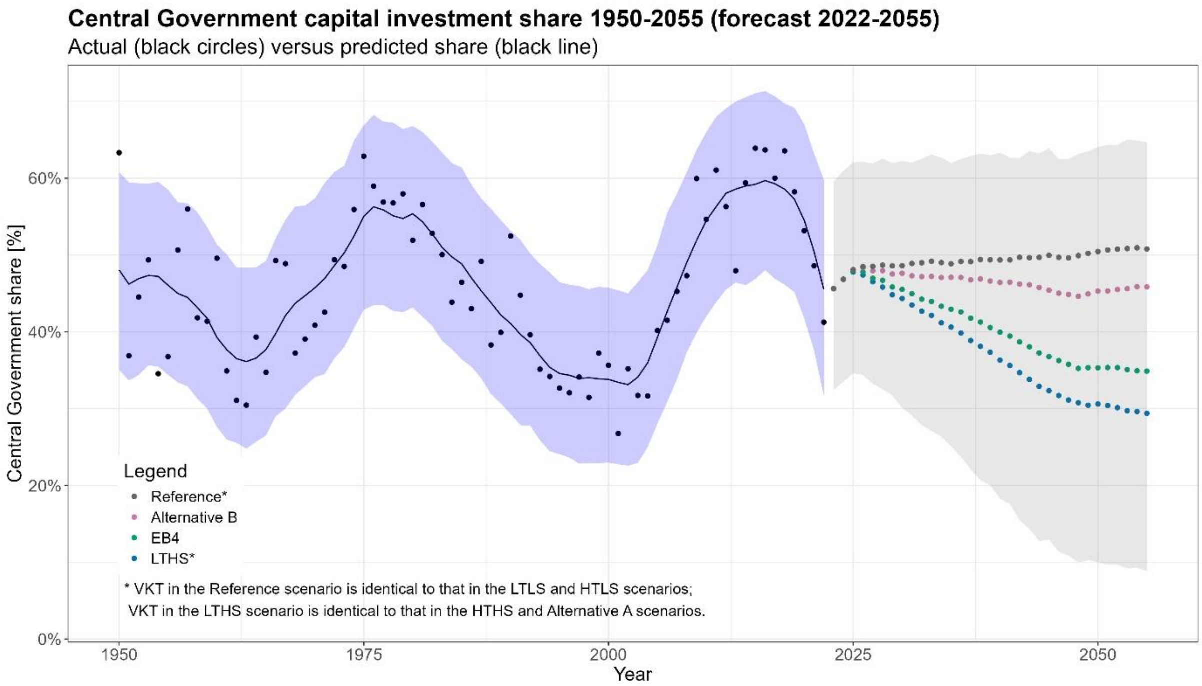
$$x \sim Beta(\mu, \phi)$$

Where x denotes a random variable that is bounded to lie between 0 and 1, e.g. the share of CG capital investment, and the parameters μ and ϕ define the mean and spread of the distribution. We then model the mean, μ, as follows:

$$\mu_t = \alpha \ln V_t + s(t)$$

Where $\ln V_t$ is defined as above, α is a parameter to be estimated; and $s(t)$ is a non-linear, non-parametric GAM to control for time trends. We use Stats NZ data on capital stocks to calculate the share of capital investment in road transport made by central government, x, in the period 1950-2022. Estimating this model returns an estimate for α of 2.27 (95% CI -0.79—5.28). That is, central government's share of capital investment appears to increase with VKT, although this effect is not precisely estimated.

We use this model to forecast the central government share of capital investment in the period 2022-2055 under various CCC scenarios, as shown in the figure below. In generating these forecasts, we again turn-off the time trend, $s(t)$, such that differences between scenarios are solely driven by differences in forecast VKT.



Compared to the Reference scenario, we forecast a lower central government share of investment in forward years, which reflects lower VKT in these scenarios.