House View 01

October 2016

Electric Vehicles

Making a positive contribution to New Zealand

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Z House View

In summary the current Z house view on EVs is:

1. **Global mass adoption of EVs is inevitable**
2. **New Zealand is well placed to be part of an EV revolution given its relatively high renewable electricity base**
3. **EVs present a future disruptive threat to the use of fossil fuels in transportation**
4. **Timing for mass adoption of EVs is difficult to predict given the critical uncertainty associated with technology breakthroughs and regulatory intervention**
5. **The most transformational scenario for New Zealand sees exponential update of electric powertrains in the light duty vehicle fleet from 2020 – EVs, PHEVs, HEVs**
6. **Industry fossil fuel volumes for transportation could be impacted to the extent below under plausible boundary scenarios for EV uptake in New Zealand; based on existing trajectory and insights Z predicts the impact to be within this range:**

	MOGAS 3050 mlpa			GAS OIL 2290[1] mlpa		
	Waka Scenario	mid-range	Kayak Scenario	Waka Scenario	mid-range	Kayak Scenario
2020	(200)	(10)	180	(140)	(100)	(50)
2025	(600)	(260)	90	(170)	(90)	(10)
2030	(1,000)	(570)	(70)	(180)	(50)	70

7. **Two main signposts to watch for as tipping points for exponential EV uptake – regulatory intervention / price of carbon and battery development (cost of energy storage and improving energy density)**
8. **There is a need to maintain a watching brief on speculative technology that could see a more aggressive reduction in demand for fossil fuels over the longer term horizon – autonomous vehicles and electric powertrain adoption in the heavy vehicle task**
9. **With no upstream interest in fossil fuels, Z will continue to look for opportunities to meet the needs of customers as the transport energy landscape changes**

1 Actual diesel consumption for 2015 was ~40ml above the range bounded by the scenarios, meaning Z predicts an impact closer to the Kayak scenario for 2020.

Context and Background

Growing uncertainty exists around the future supply and demand for transportation energy. This uncertainty stems from a dichotomy of plausible future environmental and social contexts, and the uptake of breakthroughs in technology.

Amongst the growing external commentary and speculation around electric vehicles (EVs), Z is subject to increasing levels of investor enquiry. While Z is actively supportive of technology uptake to address the risks of climate change, the prevailing view has been that mass adoption of EV's is 10+ years away. This presumption may no longer hold and consequently Z needs a more definitive view on the emergence of EVs, which can be used to respond to investor enquiry in an informed manner.

Forecasting New Zealand market demand for petroleum transportation fuel has typically been made from a representation of the past. This traditional approach loses relevance when potentially disruptive technologies are on the horizon, as is the case currently with energy systems globally – and not limited to the transport context.

As Clayton Christensen in the Harvard Business Review writes: "Data is only available about the past. When we teach people that they should be data driven, and fact based, and analytical as they look into the future, in many ways we condemn them to take action only when the game is over. The only way you can look into the future – where there's no data – is to have a good theory."[2]

Distributed energy generation, energy storage and energy management technology development have the potential to fundamentally change the way energy is produced, distributed and consumed.

> **"The only way you can look into the future – where there's no data – is to have a good theory."**

2 Clayton Christensen, Harvard Business Review

Key issues

1. Transport fuel demand scenarios

The primary drivers for petroleum transportation fuel demand in New Zealand have traditionally been population growth, economic growth (GDP) and ongoing fuel efficiency gains. Forecasting future demand becomes more complex when considering the possible technology developments that may emerge over time such as EVs.

Five primary factors have been identified as key drivers of future demand:

Primary Drivers	Dependencies
Population growth	Immigration policy
Economic growth (GDP)	Status of global economy; correlation factor with GDP given recent trend to services-based economy (and lower energy intensity)
Energy efficiency gains	Regulatory governance and decision making (incentives); Internal Combustion Engine (ICE) ongoing efficiency gains; technology development and adoption of dual powertrain hybrids; vehicle fleet composition and turnover
Alternate power train substitution	Disruptive technology developments, breakthroughs and adoption transforming the vehicle fleet to non-petroleum e.g. improving relative merits of EV's; hydrogen fuel cells; biofuels and natural gas
Social change impact	Changing attitudes towards travel through climate change responses; carbon pricing; price elasticity of demand; urbanisation; digital connectivity; public transport alternatives; ride-sharing; technology development in autonomous vehicles

Sufficient insight exists to forecast New Zealand transportation fuel demand over the short term horizon, however it becomes more difficult predicting longer term demand. The most comprehensive and credible scenarios for considering the longer term horizon are those published by the Business NZ Energy Council in October 2015. These scenarios were developed through a network of energy sector expertise from across New Zealand, and through leveraging the World Energy Council's global modelling framework and capability.

Z sponsored and participated in the development work around the two boundary scenarios, 'Kayak' and 'Waka'. The boundary scenarios were based on an understanding of what could actually occur in the rest of the world, combined with a range of critical uncertainties that have meaning to New Zealand. The benefit of each boundary scenario is that it embodies a unique and coherent mix of economic, environmental, social and behavioural contexts – an integrated storyline of what could plausibly occur. In a Kayak future, markets drive supply chain decisions and innovation, with consumers making informed decisions based on price and quality. In a Waka future, heightened environmental awareness drives business, consumers and government to make decisions in the national interest.

2. EV uptake

Through access to the BEC2050 modelling data Z has been able to extract plausible EV uptake numbers from both scenarios, effectively showing the range of potential impact over time – refer to the appended charts.

The Ministry of Transport define EVs as vehicles that are capable of being powered by an external electricity source. Included under this definition are Plug-in-Hybrid Electric Vehicles (PHEVs), which have both an electrically driven powertrain and an ICE driven powertrain. Hybrid Electric Vehicles (HEVs) are not included under this definition given they are not capable of being powered by an external electricity source; however they are a material technology disruptor in both scenarios given their relative energy efficiency improvement over ICE vehicles.

The table below shows the uptake of electric powertrain vehicles based on the Waka scenario, noting this scenario sees the most disruptive potential impact to Z's existing business. The table shows the number of vehicles in the light duty fleet increasing materially over the period to 2050 (12.1 per cent CAGR), driven by wide availability at economic prices on the back of global technology developments, which, combined with New Zealand's commitment to a lower carbon emission economy and high renewable electricity base, promotes exponential uptake.

Actual electric powertrain vehicle fleet numbers for 2015 are tracking below the Waka scenario, however this is insignificant given that potential exponential uptake commences from 2020.

The Government recently announced "an ambitious and wide ranging package of measures to increase the uptake of electric vehicles in New Zealand". The incentive scheme targets a doubling of the combined EV and PHEV fleet each year to 64,000 vehicles in 2021 – the target is equivalent to the Waka scenario for EV and PHEV uptake at 2021. The incentives include an EV exemption from Road User Charges (RUCs), promotion of bulk EV purchasing, an annual $6 million contestable fund for initiatives that accelerate EV uptake, and funding to increase general public awareness of EVs. The 2021 target may appear ambitious, however there are potentially other incentives in the pipeline such as fringe benefit tax (FBT), road tolling and ACC levy exemptions. The Government see EVs as one of the main pathways to a lower carbon future and to meeting New Zealand's international[4] COP21 commitments.

Table: NZ Passenger and Light Commercial Vehicle Fleet Numbers (Waka Scenario)

TYPE	[3]2015 (A)	2015	2020	2025	2030	2035	2040	2045	2050
HEV	14,980	15,000	100,000	485,000	815,000	985,000	985,000	865,000	770,000
PHEV	474	25,000	25,000	95,000	270,000	540,000	820,000	995,000	875,000
EV	450	10,000	15,000	90,000	205,000	320,000	500,000	775,000	1,110,000
TOTAL	15,904	50,000	140,000	670,000	1,290,000	1,845,000	2,305,000	2,635,000	2,755,000
% FLEET	**0%**	**2%**	**4%**	**18%**	**34%**	**47%**	**57%**	**64%**	**66%**

3 Actual data for 2015 from Ministry of Transport
4 2015 United Nations Climate Change Conference – Paris 2015

3. Petroleum demand impact

The increasing uptake of electric powertrain vehicles in the light vehicle fleet materially reduces demand for existing petroleum based fuel, particularly petrol.

EVs are substantially more energy efficient than ICE vehicles – an equivalent journey requires less joules of energy input. In both Kayak and Waka scenarios, efficiency improvements in the heavy vehicle fleet are less dramatic, with electricity not assumed to have a significant penetration, other than for trains and buses.

The range of potential impact to transport petroleum consumption over time has been shown in the appended charts. The range of impact shown in the charts represents the combined impact of all primary drivers of demand over time, i.e. it does not represent the isolated impact of electric powertrain substitution.

The table below shows the range of petrol consumption for transport use over the period, driven primarily by transformation in the light vehicle fleet and reduction in personal car usage and/or ownership. The impact on petrol consumption over the period ranges from (0.7)% CAGR under Kayak to (2.5) per cent CAGR under the Waka scenario.

Table: NZ Transport Energy Demand Scenarios – Petrol (mlpa)

	2015 (A)	2015	2020	2025	2030	2035	2040	2045	2050
Kayak	3,050	3,185	3,230	3,135	2,980	2,820	2,685	2,585	2,500
Waka	3,050	2,870	2,845	2,450	1,975	1,530	1,200	1,190	1,180
△ K (cum)	-	135	180	85	(70)	(230)	(365)	(465)	(550)
△ W (cum)	-	(180)	(205)	(600)	(1,075)	(1,520)	(1,850)	(1,860)	(1,870)
△ MP (cum)	-	(20)	(10)	(260)	(570)	(875)	(1,105)	(1,160)	(1,210)

The table below shows the range of diesel consumption for transport use over the period, driven by transformation in the light vehicle fleet and reduction in personal car usage and/or ownership, offset by an increasing heavy vehicle transport task from economic growth.

Both hydrogen and biofuels become viable for heavy vehicle transport from 2040, significantly reducing demand later in the period. The impact on diesel consumption over the period ranges from (0.8) per cent CAGR under Kayak to (2.0) per cent CAGR under the Waka scenario.

Table: [5]NZ Transport Energy Demand Scenarios – Diesel (mlpa)

	2015 (A)	2015	2020	2025	2030	2035	2040	2045	2050
Kayak	2,290	2,245	2,240	2,285	2,360	2,425	2,405	2,205	1,695
Waka	2,290	2,205	2,150	2,125	2,115	2,080	1,950	1,655	1,085
△ K (cum)	-	(45)	(50)	(5)	70	135	115	(85)	(595)
△ W (cum)	-	(85)	(140)	(165)	(175)	(210)	(340)	(635)	(1,205)
△ MP (cum)	-	(65)	(95)	(85)	(53)	(38)	(113)	(360)	(900)

5 Does not include diesel currently consumed in sectors other than transport (~1blpa)

4. Signposts

Underpinning the EV vehicle uptake numbers are the following key input assumptions. These represent the signposts to monitor in determining what scenario could eventuate:

(i) Price of Carbon

Table: Price of Carbon ($ per T CO_2)

	2015	2020	2025	2030	2035	2040	2045	2050
Price carbon – Waka	21	37	48	60	75	90	102	115
Price carbon – Kayak	7	9	12	18	26	37	49	60

The price of carbon has risen recently from under $10 to around $18 per T CO_2, following the Government's May 2016 budget announcement on changes to the Emissions Trading Scheme (ETS). The announced changes see the phasing out of the one-for-two subsidy by January 2019, however the $25 price cap remains in place. At the cap level the impact of the ETS on the price of petrol is approximately 6.6cpl, and 7.7cpl for diesel, levels that on their own are unlikely to drive mass adoption of alternative powertrains for transportation. Regulation is a critical uncertainty as to what could happen to both the future price of carbon and the uptake of EVs; the uncertainty is whether successive governments will err towards a more light-handed or a more interventionist regime for promoting uptake.

(ii) Battery technology advancement

Table: Battery Cost Curve (NZ$/kWh)

	2015	2020	2025	2030	2035	2040	2045	2050
Battery cost curve – Waka	365	310	270	240	215	195	175	160
Battery cost curve – Kayak	330	270	235	210	195	180	170	160

Both scenarios support a continuing trend of rapidly reducing battery cost with actual cost in 2015 estimated to be around [6]$400 per kWh. It is not possible to determine a completely reliable projection of future battery cost, however some manufacturers such as General Motors and Tesla have more ambitious cost estimates of reaching $160 per kWh in the 2020s.

The difference in price between a conventional ICE and an EV is primarily due to the cost of batteries. As lithium-ion battery technology advances and battery cost comes down, the price premium barrier to consumers in purchasing EVs will also likely reduce.

Correlated with reducing battery cost trends is an increase in battery energy density (kWh/kg), which in turn improves EV range capability – a key consumer concern with EVs.

6 US Department of Energy monitored cost estimates

5. Speculative uncertainties

The following uncertainties could stretch the boundaries of what future scenario actually eventuates, and are sufficiently speculative as to timing and impact, to warrant maintaining an ongoing watching brief:

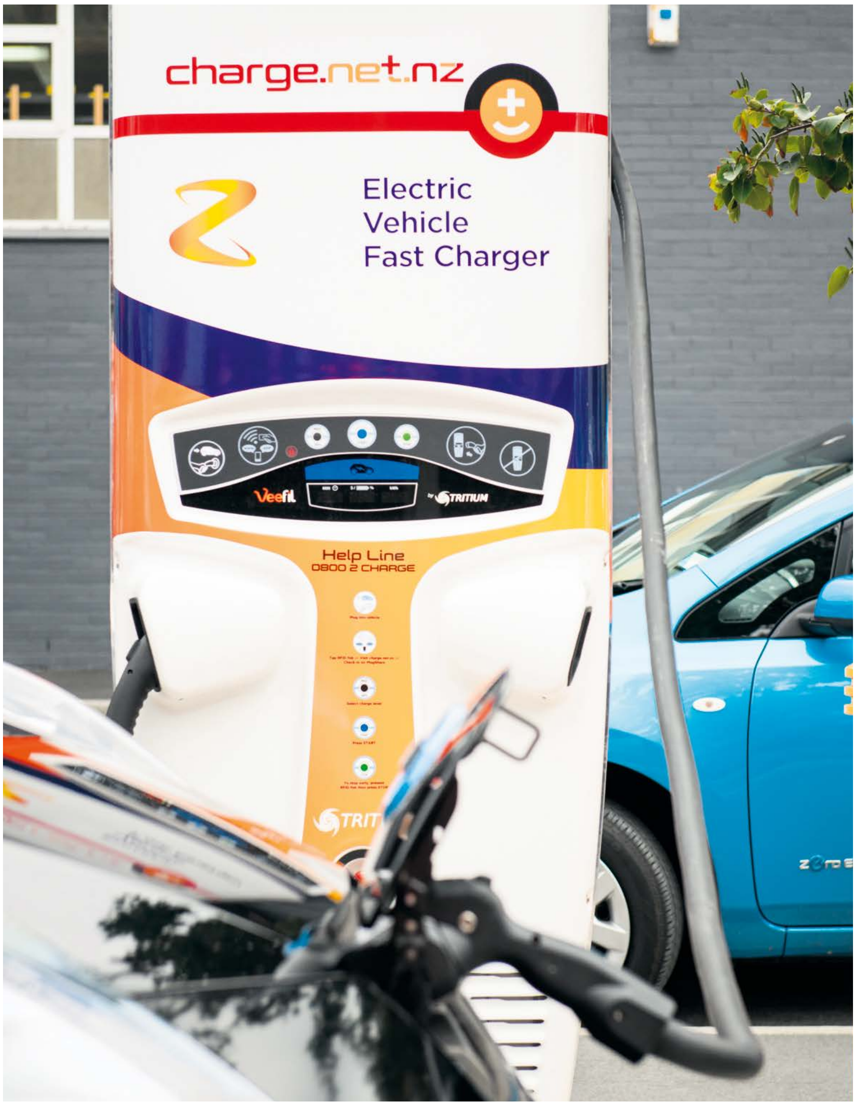
(i) Mobility as a service through autonomous vehicles

Uncertainty regarding the rate of technology development and acceptance of autonomous vehicles impacts whether or how quickly mobility as a service becomes plausible for New Zealand's major urban cities. Adoption of autonomous vehicles could reduce transportation energy demand through lower light duty vehicle ownership and reduced vehicle kilometres travelled.

The intersection of EV uptake with future acceptance of self-driving technology could unlock an evolution of transportation-as-a-service through car sharing. While arguably EV technology is available today, the development and acceptance of autonomous vehicles could have a greater long term horizon impact. Supporting this concept are recent announcements from car manufacturers such as Ford and Tesla, announcing plans for a future car sharing service offer built around their respective self-driving vehicles. The opportunity is not limited to the traditional car manufacturers either with giants such as Google, Apple and Uber all prominent in this development space.

(ii) Heavy vehicle fleet technology adoption

The uncertainty is over what alternate technology to fossil fuels will prevail, and to what extent, in the heavy vehicle task – trucking[7]. The impact of this uncertainty will occur over a longer term horizon than for plausible EV uptake in the light vehicle fleet.



“Self-driving technology could unlock an evolution of transportation-as-a-service through car sharing.”

7 Tesla has announced as part of their Master Plan 2 “expanding the electric vehicle product line to heavy duty vehicles”

6. External context insights

A scan of relevant external context provides useful insight into testing whether what could occur under the range bounded by both scenarios remains plausible, and/or provide insight into what one of the scenarios may eventuate – refer to the table below.

Table: EV supply chain considerations

Insight	Scenario plausibility
1. Can the rate of new and used imports into NZ meet exponential demand growth for EV's?	
Key supply markets for new and used light duty vehicles into New Zealand are Asia (primarily Japan) and Europe. These markets accounted for 77 per cent and 20 per cent of the record 285,000 new and used vehicles imported into New Zealand in 2015, on the back of relatively strong economic conditions. Japan is a member of Electric Vehicles Initiatives (EVI), a multi-government policy forum representing the majority of global EV car stock. EVI has a goal of achieving 20 million EV cars by 2020. Japan currently has 16 per cent of the global car stock of EVs at 0.13 million, with a committed target to get to one million by 2020. The Japanese government provides financial incentives for EV cars, including purchase price subsidies and tax exemptions. France, Germany, Italy, Netherlands, Norway, Portugal, Spain, Sweden and the United Kingdom are also members of EVI, with most having announced aspirational commitments to the goal of 20 million EV cars by 2020[8]. Motor vehicle importers consistently report that they could respond quickly to increased demand if New Zealand sales of EVs take off[9]. Under the Waka bounded scenario ~500,000 additional HEV, PHEV or EV vehicles enter the light duty vehicle fleet over the five year period from 2020 to 2025. For this to occur on average ~100,000 or 35 per cent of new or used imports per annum would have electric powertrains – a significant rise from a total of ~3,000 vehicles in 2015. Manufacturers' research and development focus is now predominantly electric powertrains, with some manufacturers intending to stop any further internal combustion engine R&D by 2025. The six renowned Japanese automobile manufacturers (Toyota, Nissan, Honda, Suzuki, Mazda and Mitsubishi) all have expansive targets and plans to increase production capacity of EV car models. Similarly, the main European manufacturers that supply the New Zealand car market (Volkswagen, BMW, Mercedes-Benz, Audi and Renault) have consistent plans. The most prominent example is BMW with its recent public announcement that "the future is electric – a new strategy to roll out more electric cars and add self-driving features faster than their rivals".	It is reasonable to assume that growth in EV adoption in NZ's key vehicle supply markets of Japan and Europe will be sufficient to support an exponential demand growth scenario for NZ. The current rate of turnover of the New Zealand light duty vehicle fleet makes a more aggressive EV demand growth scenario than Waka seem implausible. Volume and number of models of EVs coming to market is going to increase significantly, reducing a consumer purchase barrier of limited vehicle segments and brands being available.

8 International Energy Agency Global EV outlook 2016
9 Emission Impossible final report for Ministry of Transport 30 June 2015

2. Can the electricity sector meet the additional demand requirements from EVs?

New Zealand is one of the most EV-ready countries in the world with its high base of renewable electricity and essentially the necessary network infrastructure to support PHEV uptake, if only because of all the suburban garages with an ordinary three-pin socket. Although there is some uncertainty over how smart charging could manage electricity distribution flexibility, New Zealand is uniquely placed in having planning consent for enough wind farms, hydro and geothermal power stations to cover about a 25 per cent increase in demand for electricity[10].

No constraints with enough renewable generating capacity consented but unbuilt to power every car in the country.

3. Will the rate of available EV charging infrastructure support exponential EV uptake?

International trends show the availability of charging infrastructure is a factor positively correlated to growth in EVs.

The Electricity Networks Association [ENA] comprises a working group of representatives from lines companies along with Contact Energy, Mercury and Drive Electric, looking at a co-ordinated approach to accessible public charging infrastructure. The association is working towards putting in place a 'renewables highway' that provides public accessibility to charging[11].

The renewables highway would potentially see a network of charging locations at key stopping points and tourism locations along State Highway 1, expanding to regional routes over time. This backbone could then encourage further charging infrastructure by other businesses including airports, retailers, supermarkets, tourist destinations and other places where people park their vehicles.

Auckland-based private company, Charge.Net.NZ is also rolling out a national network of fast-charging stations with over 100 sites already in place. A fast charger can fully charge a car in 10-25 minutes. While many public AC chargers are free, a fast DC charger can cost up to $40,000 to install.

Charging infrastructure development is relatively low cost and underway to support future EV uptake, alleviating consumer anxiety over short range and long charging times.

"New Zealand is one of the most EV-ready countries."

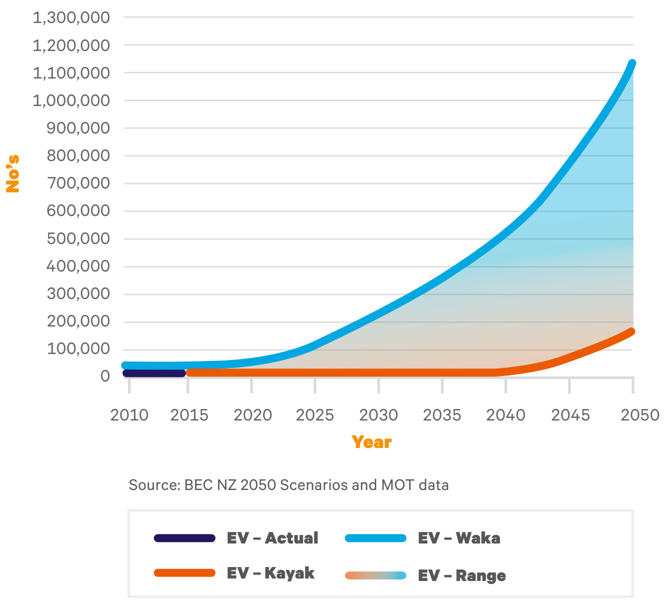
10 From public statements made by Mercury (formerly Mighty River Power)

11 http://ena.org.nz/lets-get-the-electric-vehicle-revolution-going/

Appendix A

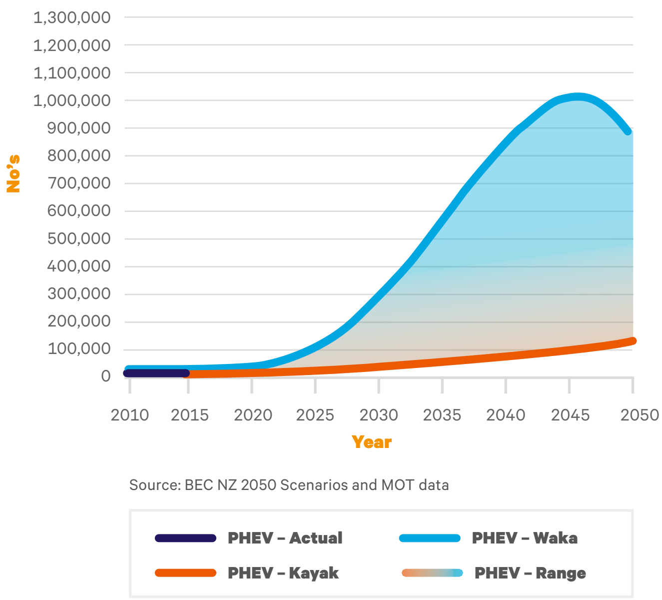
Charts for EV uptake

Electric vehicle scenarios



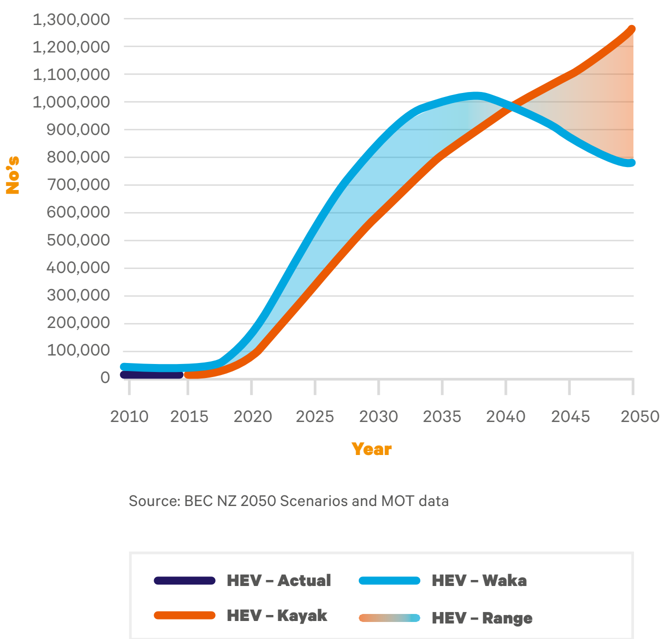
Source: BEC NZ 2050 Scenarios and MOT data

PHEV scenarios



Source: BEC NZ 2050 Scenarios and MOT data

HEV Scenarios

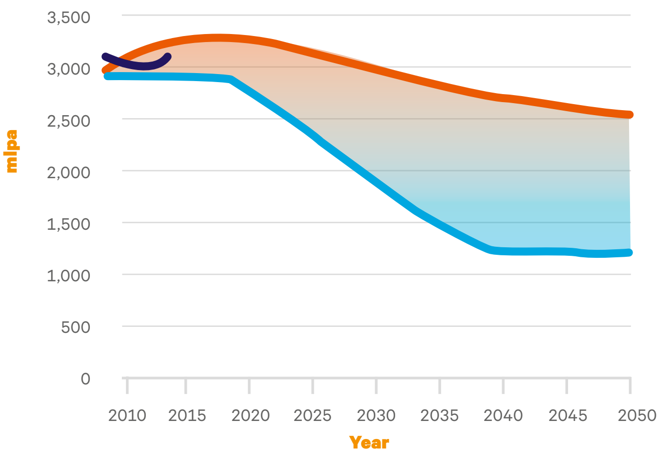


Source: BEC NZ 2050 Scenarios and MOT data

Appendix B

Charts for petroleum demand impact

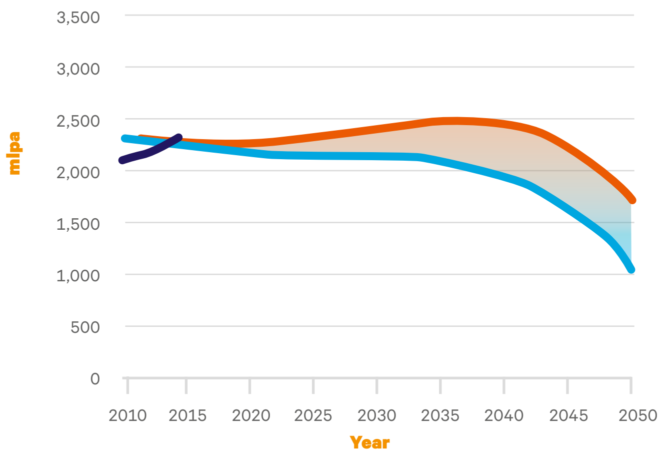
Transport fuel consumption scenarios – petrol



Source: BEC NZ 2050 Scenarios and MOT data

Petrol Consumption Actual **Petrol – Waka (ml)**
Petrol – Kayak (ml) **Petrol Consumption Range**

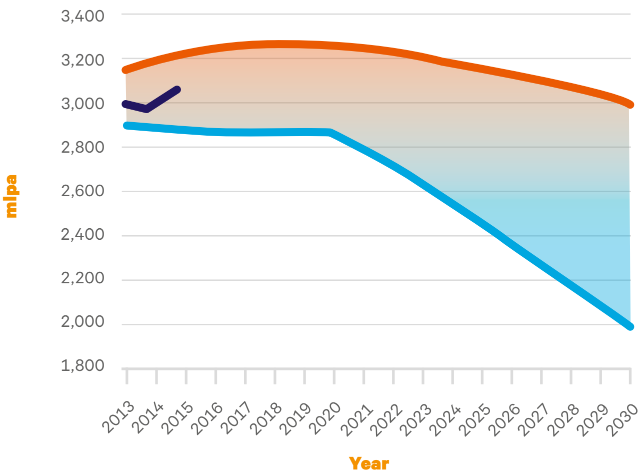
Transport fuel consumption scenarios – diesel



Source: BEC NZ 2050 Scenarios and MOT data

Diesel Consumption Actual **Diesel – Waka (ml)**
Diesel – Kayak (ml) **Diesel Consumption Range**

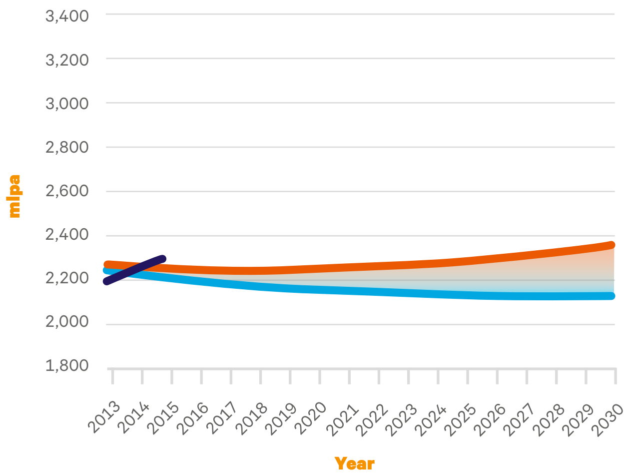
Transport fuel consumption scenarios – petrol



Source: BEC NZ 2050 Scenarios and MBIE data

Petrol Consumption Actual **Petrol – Waka (ml)**
Petrol – Kayak (ml) **Petrol Consumption Range**

Transport fuel consumption scenarios – diesel



Source: BEC NZ 2050 Scenarios and MBIE data

Diesel Consumption Actual **Diesel – Waka (ml)**
Diesel – Kayak (ml) **Diesel Consumption Range**

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