Resource Economics

Review and analysis of electric vehicle supply and demand constraints

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Energy Efficiency and Conservation Authority

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Background

The New Zealand Government has set a goal of achieving net zero emissions of long-lived greenhouse gases (GHGs), including CO_2, by 2050. In response, the Climate Change Commission (CCC) has produced a draft consultation document which sets out an “achievable, affordable and socially acceptable” path to achieving this goal.[1] Because road transportation is a large and growing source of CO_2 emissions, the CCC includes ambitious reductions in transport emissions in its path. This includes accelerated adoption of electric vehicles (EVs) in the light fleet, including cars, vans and utility vehicles (‘utes’), with no further internal combustion engine (ICE) light vehicles imported after 2032. The CCC suggests this would mean over 50% of all light vehicle travel would be in EVs by 2035 and 40% of the light vehicle fleet would be EVs by 2035. Their suggested path shows slow initial growth in registrations and rapid growth from 2025 to 2030.

This report examines whether there are practical constraints to such an ambitious pathway for EVs, from limits either to supply or demand. We examine constraints in the short run, to 2025, and the longer run, from 2030.

Findings

This report describes the results of a **rapid examination** of supply and demand constraints for EVs, including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). We also consider supplies of hybrid electric vehicles (HEVs). The supply issues discussed include those that affect available models and volumes. Demand issues include prices of EVs relative to internal combustion engine vehicles (ICEVs), developments in kilometre range limitation for BEVs and the positive performance attributes of EVs relative to ICEVs.

The report is based on a combination of a review of relevant literature, including published studies, company and other websites, along with information obtained from interviews with industry, industry organisations and others. It was completed in a short timeframe, such that some areas of the report have not been fully researched and the information provided is intended to be a synopsis of insights for a general overview only.

Supply Issues

In the short run, up to 2025, there are expected to be some supply constraints for **new EVs** because of limited EV production capacity which is initially focussed on providing supplies to markets with more stringent CO_2 policy requirements. In addition, there will be a limited number of vehicle categories available as EVs, which limits the extent to which anticipated demand can be met across all market segments. By 2030, BEV production is expected to have increased significantly such that New Zealand can expect few, if any, constraints to supply of new EVs.

Because of the significance of used vehicles to total vehicle supply, and because Japan is the primary source of supply, EV sales in Japan are critical to the short-run supply of **used EVs** to

[1] Climate Change Commission (2021)

New Zealand. Finite sales of BEVs in Japan limit how many are available for supply in the period to 2025. EV sales in Japan are expected to continue to increase, although increased competition for supplies from Australia is expected after legislative changes to liberalise import markets.

Current emerging markets are likely to become more important if New Zealand is to increase EV imports significantly. China is a major producer and consumer of EVs, although it is not a major exporter currently. It could become a significant source of EVs for New Zealand, and potentially an alternative low-cost supplier to replace used imports. However, it is unlikely that they will be a major source of supplies to New Zealand until closer to 2030.

Demand Issues

Demand for BEVs is currently constrained by issues relating to relative costs and usability issues, including kilometre range constraints.

BEVs are expected to be cost competitive with ICEVs by 2030, including purchase price parity by 2030 and total cost of ownership (TCO) parity much earlier. Purchase price differences between BEVs and ICEVs may persist longest for smaller, lower-cost vehicle categories, ie those competing with ICEVs selling for less than $35,000.

Range anxiety continues to be a concern for many BEV buyers, especially of low-cost, small-battery vehicles in the used vehicle market where Nissan Leafs have dominated sales. This will improve over time as battery prices fall and achievable vehicle ranges increase above 350km. Range anxiety will continue to be a barrier to 2025, especially for BEVs purchased as primary household vehicles, but it is not expected to be significant by 2030.

There are some concerns over end-of life management of batteries, but these will reduce if effective product stewardship schemes develop, as currently being addressed by Battery Industry Group (BIG).

EVs, and BEVs are expected to become a dominant part of the future New Zealand vehicle fleet, but such a significant change to the fleet will take time to achieve effectively and efficiently. By 2030, EVs are likely to be readily available for import across all vehicle categories at a price (even in the absence of policy incentives) that is competitive with ICEVs.

Table ES1 summarises the main issues discussed in this report and the conclusions reached.

Table ES1 Summary of Commentary on Potential EV Supply and Demand Constraints

Issues	To 2025	By 2030
Supply Constraints		
Are there limits to how many EVs can be imported?	*New vehicles:* There will be limits to what can be imported to New Zealand because of limited production capacity, focussed on supplies to more stringent policy-led markets.	*New vehicles*: There are unlikely to be supply constraints for imports of new EVs.
	Used vehicles: There are finite sales of EVs in Japan, particularly of BEVs for which there is a risk of fewer Leafs entering the market. Increased competition is expected from Australia, which will reduce potentially	*Used vehicles*: More available supplies as EV sales increase, although with the risk of increasing competition.

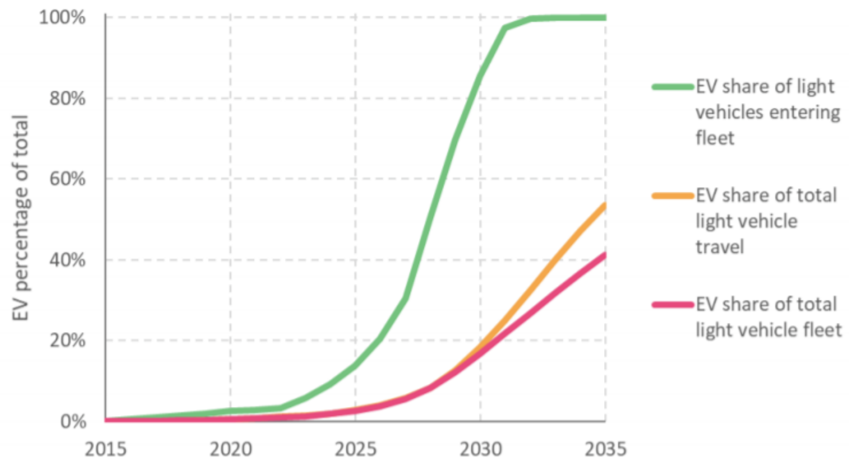
	available supplies to New Zealand and/or increase their costs.	
Can vehicles be imported across all categories of demand?	Some vehicle types, and utes in particular, may not be widely available in BEV form for several years. This issue is most pronounced for used vehicles (where utes are not available as ICEVs either).	EVs available in most, if not all, vehicle categories.
Will battery costs continue to fall?	Battery costs for vehicles may not fall immediately as a result of increasing battery sizes (to increase vehicle range) and some supply interruptions (from Covid and short-run limits in raw materials while new technologies develop). Battery costs are expected to fall most for vertically-integrated producers. This includes Tesla and manufacturers in China, Japan and Korea.	Greater vertical integration is expected to result in falling production costs. Battery costs expected to fall to relatively low levels and new battery technology (eg solid-state) expected to be widely available.
Will alternative technologies displace BEVs in the supply market?	Ongoing R&D on alternative vehicle technologies (eg FCEVs, e-fuel) may still lead to significant market penetration, particularly in Japan. However, commitment of other countries to EVs suggests it is unlikely that these technologies will displace BEVs for the foreseeable future.	Mix of vehicles available, but with no significant constraints to EV supply to New Zealand.
Will there be low-cost Chinese vehicles available?	Not in significant numbers in the short run.	China is expected to become a significant producer and exporter of EVs.
Demand constraints		
Will BEVs continue to have higher purchase prices than ICEVs?	BEVs, in general, have higher purchase prices than ICEV equivalents, and this is most pronounced for lower-cost vehicles for which battery costs are a higher percentage of total costs.	Purchase price differentials are expected to narrow, so that there is widespread price parity by 2030 or earlier.
	Parity in TCO is expected to be widespread across vehicle categories, but not all purchasers of vehicles consider full TCOs.	TCO parity expected to be widespread.
How long will range anxiety be a demand constraint?	Range anxiety will limit sales of many BEVs, affected by a combination of limited vehicle range capability and perceptions of low public charger availability. This may limit sales (particularly of low-cost, small-battery vehicles) to second household vehicles or to users with small typical trip lengths.	Range anxiety is expected to be much reduced with continual improvement in kilometre range. Range anxiety reductions depend on the roll-out of charging infrastructure, with open and interoperable technologies and smart charging capability.
Will BEVs depreciate in value more than ICEVs?	There are higher depreciation rates for those BEVs with more rapid battery degradation. This is made worse by the absence in New Zealand of reasonably-priced battery replacement services for used vehicles.	With improvements in battery technologies, factors affecting higher depreciation rates are likely to disappear.
Are end-of-life batteries an emerging environmental problem for New Zealand?	Development of product stewardship schemes are expected to allay most concerns over end-of-life management of batteries from EVs.	

1 Introduction

1.1 Background

The New Zealand Government has set a goal of achieving net zero emissions of long-lived greenhouse gases (GHGs), including CO_2, by 2050. In response, the Climate Change Commission (CCC) has produced a draft consultation document which sets out an "achievable, affordable and socially acceptable" path to achieving this goal.[2] Because road transportation is a large and growing source of CO_2 emissions, the CCC includes ambitious reductions in transport emissions in its path. This includes accelerated adoption of electric vehicles (EVs) in the light fleet, including cars, vans and utility vehicles ('utes'), with no further internal combustion engine (ICE) light vehicles imported after 2032. The CCC suggests this would mean over 50% of all light vehicle travel would be in EVs by 2035 and 40% of the light vehicle fleet would be EVs by 2035. Their suggested path to these targets is shown in Figure 1. It shows slow initial growth in registrations and rapid growth from 2025 to 2030.

Figure 1 Uptake of electric vehicles in the Climate Change Commissions draft suggested path



Source: Climate Change Commission (2021), p58.

This report examines whether there are practical constraints to such an ambitious pathway for EVs, from limits either to supply or demand. We examine constraints in the short run, to 2025, and the longer run, from 2030.

1.2 Types of EV

Different vehicle types and technologies can be classified as EVs. These include the following.

- Battery electric vehicles (BEVs) which use electricity as the only source of power. They have rechargeable batteries and no gasoline engine.
- Plug-in hybrid electric vehicles (PHEVs) have both an electric motor and an ICE. PHEVs generally have smaller batteries than BEVs which they can recharge through both

[2] Climate Change Commission (2021)

regenerative braking and "plugging in" to an external source of electrical power.[3] They can drive for a limited distance using electricity before switching to the ICE.

- Hybrid electric vehicles (HEVs) also have both an electric motor and an ICE. The battery is charged only by regenerative braking or from an ICE as there is no plug-in capability. They may only use electricity during initial acceleration, but generally electricity assists the ICE. HEVs include mild hybrid electric vehicles (MHEVs) which have a very small battery and an electric motor which only ever assists the ICE.

Additional technologies being proposed or launched include hydrogen in a fuel cell electric vehicle (FCEV) and e-fuel, a hydro-carbon fuel produced from hydrogen and CO_2.[4]

EVs are defined in legislation in New Zealand to mean "*a motor vehicle with motive power wholly or partly derived from an external source of electricity*",[5] ie BEVs and PHEVs. We use this definition here, while separately identifying HEVs.

1.3 Numbers of EVs in New Zealand

Currently there are approximately 24,500 light EVs in New Zealand, of which 75% are BEVs and 25% PHEVs (Table 1). Of the total, over 12,000 (49%) are Nissan Leafs, 12% are Mitsubishi Outlanders, 8% are Teslas (Models 3, S and X) and 5% are Toyota Prius PHEVs; there are also large numbers of Prius HEVs in New Zealand. EVs comprise approximately 0.6% of the total of just over 4 million light vehicles.

Table 1 EVs in the New Zealand light vehicle fleet

Type	Condition at import	No. in fleet (Jan 2021)	% of EVs	% of light fleet	Registrations (2020)[c]	% of EVs	% of light fleet
BEV	New	5,612	23%	0.1%	1,529	28%	0.6%
	Used	12,862	53%	0.3%	2,466	45%	1.0%
	Total	18,474	75%	0.5%	3,995	73%	1.7%
PHEV	New	3,717	15%	0.1%	757	14%	0.3%
	Used	2,290	9%	0.1%	702	13%	0.3%
	Total	6,007	25%	0.1%	1,459	27%	0.6%
BEV + PHEV	Total	24,481	100%	0.6%	5,454	100%	2.3%
HEV	New				8,017 E		3.3%
	Used				14,736 E		6.1%
	Total	51,375[a]		1.3%	22,753 E		9.4%
Light	Total	4,028,136[b]		100.0%	240,172		100.0%

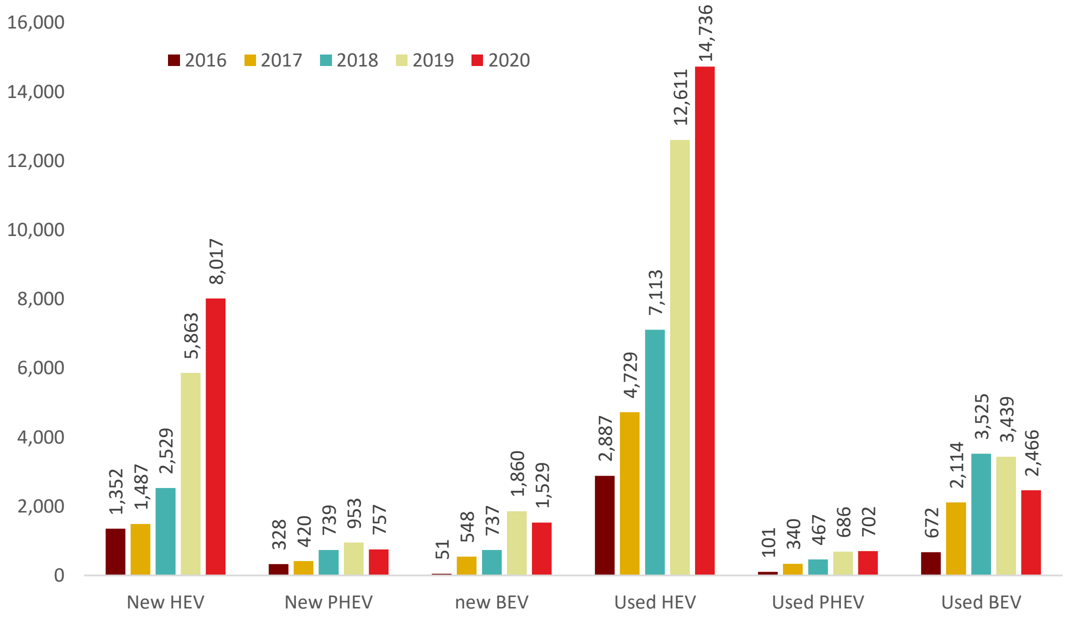
[a] 2019 total; [b] Q1 2020 total; [c] HEV registrations are estimates (E) based on data for the year to September 2020, multiplied by 1.33
Source: MoT fleet statistics

There were 5,454 registrations of EVs in 2020, which is 2.3% of the total light vehicle registrations; 73% were BEVs.

[3] Anecdotally, many people do not plug-in PHEVs, effectively using them as an HEV (Dobson, 2020 and OEM interview comments). This means real fuel consumption and CO_2 emissions are higher than in test cycles.
[4] https://www.efuel-alliance.eu/efuels
[5] Land Transport (Road User) Rule 2004

In addition, there were estimated to be 51,375 HEVs in the light fleet in 2019 (the latest year for which fleet data are published),[6] and a further 22,753 HEV registrations estimated for 2020.[7] With some expected de-registrations, HEVs are likely to total over 70,000 light vehicles currently, or approximately 1.7% of the light fleet. The high current growth in HEV registrations, compared to that for BEVs and PHEVs is shown in Figure 2.

Figure 2 Registrations of new and used HEVs, PHEVs and BEVs



Note: 2020 data for HEVs are data for the year to end of September scaled up (multiplied by 1.33)
Source: MoT fleet statistics

1.4 Policy to Encourage Electric Vehicles

The Government has developed policy to reduce the CO_2 intensity of the vehicle fleet and to encourage EV take-up. In January 2021, the Government agreed to introduce the Clean Car Standard (CCS), with legislation expected to be introduced later this year. In its current form, it aims to reduce the average emissions intensity of new cars and SUVs to 105g CO_2/km by 2025 and that for utes and vans to 132g/km. The standard is to be met as an average by individual importers, but importers can combine to meet the standard together. The CCS has lower penalties for non-compliance for used vehicle imports than for new imports.[8]

1.5 Approach and Structure

This report describes the results of a rapid examination of supply and demand constraints for BEVs, PHEVs and HEVs (including MHEVs).

[6] Table 6 in MoT Annual Fleet Statistics 2019: Data Spreadsheet https://www.transport.govt.nz/assets/Uploads/Data/NZVehicleFleet.xlsx

[7] MoT has published data to Q3 2020, so these numbers are calculated as 1.33 times the registrations to the end of Q3.

[8] The penalties are lower because used imports are expected to remain in the fleet for a shorter period (Minister of Transport, The Clean Car Standard Cabinet Paper. https://www.transport.govt.nz//assets/Uploads/Cabinet/TheCleanCarStandard.pdf)

The report is based on a combination of a review of relevant literature, including published studies, company and other websites, along with information obtained from interviews with industry, industry organisations and others.

1.5.1 Organisations Interviewed

Interviews were held largely over the period 15-26th February 2021 with one or more representatives from 19 companies and organisations listed in Table 2. These comprised:

- new vehicle importers. These were New Zealand distributors representing original equipment manufacturers (OEMs);
- used vehicle importers;
- industry organisations representing the new (MIA) and used (VIA) vehicle importers, and Drive Electric which is a member organisation for EV importers; and
- the Government fleet procurement manager in MBIE.

Table 2 Organisations interviewed

New vehicle importers and distributors (marques if > 1)	Used vehicle importers	Other Organisations
• BMW (BMW, Mini) • European Motor Distributors (VW, Audi, Porsche, SEAT, Skoda) • Ford • Great Lake (Ssangyong, LDV) • Honda • Hyundai • Kia • Mazda • Mitsubishi • Nissan • Subaru • Toyota	• GVI • Blue Cars • Good Car Co. (Australia)	• Motor Industry Association (MIA) • Vehicle Industry Association (VIA) • Drive Electric • Ministry of Business, Innovation & Employment (MBIE)

Interviewees were asked to comment on their perceptions of supply constraints, including production constraints (for vehicles and batteries), any New Zealand-specific competitive disadvantages, trends in battery performance (including degradation) and prices, trends in relative prices for new EVs and when they might become price competitive with internal combustion engine vehicles (ICEVs).

1.5.2 Structure

In the next two sections we address the issues as supply and demand constraints to increased imports of EVs. The supply issues discussed are those that affect available models and volumes, and battery supplies. Demand issues include prices of EVs relative to ICEVs, developments in kilometre range capability for BEVs and the positive performance attributes of EVs relative to ICEVs. Section 4 brings together some overall conclusions.

2 EV Supply

2.1 New Vehicle Supply Limits

2.1.1 Historical Imports to New Zealand

Table 3 shows the light vehicle types imported new from the beginning of 2015 to January 2021. There is most variety in the imports of new BEVs. Of a total of 39 imported models, over 60% of BEVs are made up of Tesla Models 3, X and S (36%), Hyundai Konas (14%) and Hyundai Ioniqs (12%). Factory Built Lloyds (8%) are small vehicles used for postal delivery. For PHEVs, there have been 32 models imported to January 2021, with Mitsubishi Outlanders comprising over half of imports (51%). Imports of new vehicles to New Zealand come from many different countries, reflecting the different locations of manufacture. For example, new Nissan Leafs sold in New Zealand are manufactured in the UK. In 2020 new EVs were imported to New Zealand from Belgium, China, France, Germany, Japan, the Netherlands, South Korea, Sweden, Turkey, the UK and the USA.

Table 3 Light New BEV and PHEV registrations in New Zealand (1 Jan 2015 - 31 Jan 2021)

BEV Type	Number	%	PHEV Type	Number	%
Tesla Model 3	1,195	22%	Mitsubishi Outlander	1,782	51%
Hyundai Kona	793	14%	Toyota Prius	323	9%
Hyundai Ioniq	653	12%	Mini Countryman	269	8%
Factory Built Lloyds	440	8%	BMW I	239	7%
Tesla Model X	407	7%	Audi A3	179	5%
Tesla Model S	368	7%	Hyundai Ioniq	155	4%
Volkswagen E-golf	329	6%	Porsche Cayenne	88	2%
Nissan Leaf	271	5%	Volvo Xc90	73	2%
Audi E-Tron	191	3%	Kia Niro	57	2%
BMW I	180	3%	Volvo Xc60	55	2%
Other	706	13%	Other	302	9%
Total	5,533	100%	Total	3,522	100%

Source: MoT Fleet Statistics (www.transport.govt.nz/statistics-and-insights/fleet-statistics)

2.1.2 Location of Sales

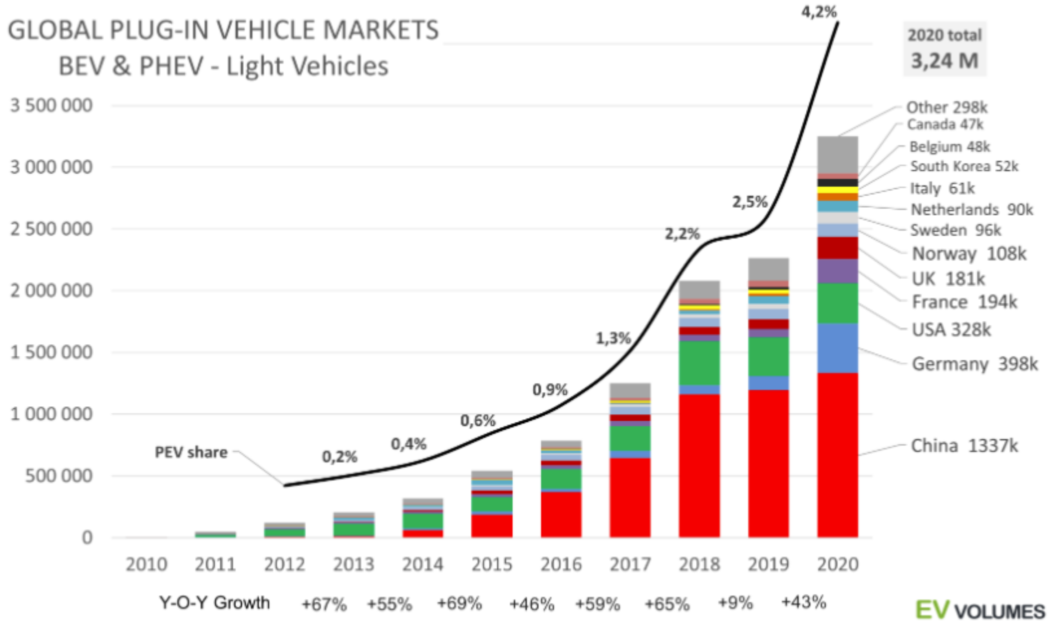
Globally EVs sales reached an estimated 3.24 million in 2020, up 43% on 2019; this represented 4.2% of light vehicle sales, up from 2.5% in 2019 (Figure 3). China has dominated sales and stocks of EVs but 2020 saw Europe (1.395 million) overtake China (1.337m) in total new sales. EVs comprised 10.5% of new vehicle sales in the EU in 2020 (up from 3% in 2019) and HEVs 11.9%.[9] New Zealand's imports of 2,286 new EVs in 2020 is less than 0.1% of global sales.

EV-Volumes note the changes in volumes of BEVs versus PHEVs. In 2020 global new registrations were dominated by BEVs (69%).[10] PHEVs decreased in total sales in 2019, partly because of legislative changes in the EU which meant most PHEVs did not meet CO_2 limits making them eligible for incentives, but changes to the installed batteries meant that they were eligible again in 2020.

[9] ACEA (2021)

[10] https://www.ev-volumes.com/

Figure 3 Annual EV registrations, market share and year-on-year growth



Note: PEV = plug-in EV (BEVs & PHEVs)
Source: https://www.ev-volumes.com/

The IEA (2020) had previously noted the softening overall growth in sales in 2019, which it suggested was a result of

- slowing in market sales of all vehicles, not just EVs;
- reductions in purchase subsidies in key markets, including China (halving of purchase subsidy) and the USA; and
- the extension of sales from early adopters to the mass market.

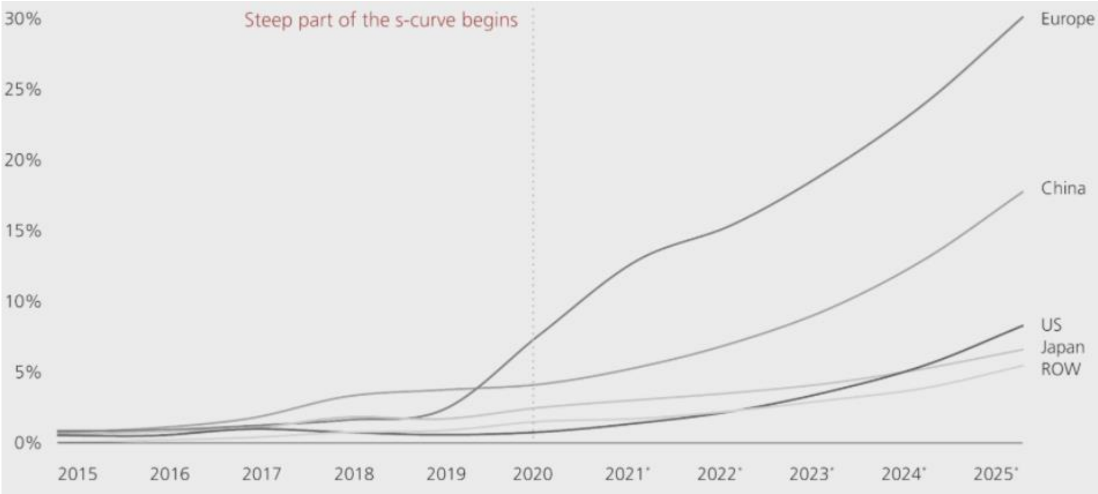
However, the trend reversal in 2020 suggests these issues are no longer significant or are compensated for by increased incentives.

The IEA (2020) suggests that much of the historical sales growth is in response to policy. It projects future uptake in the form of scenarios, including a stated policies scenario[11] under which EVs would increase to 12% of light vehicle stocks by 2030, but alternative scenarios in which they rose to 8% and 16% of stocks. The actual levels depend significantly on policy settings.

Projections of future sales suggest rapid increases across many markets, particularly Europe and China (see Figure 4).

[11] The likely consequences of existing and announced policy measures

Figure 4 Electric vehicle sales penetration by region (% of total passenger car sales)



Source: UBS (https://www.ubs.com/global/en/collections/sustainable-investing/latest/2021/trends-electric-transport.html)

2.1.3 Production Priorities

New Zealand is very small in the context of the global market. This means we only need small numbers of EVs, but we are also takers of technology produced for other major markets, especially for EVs for which there are currently relatively few models and limited numbers of production lines. New Zealand distributors interviewed suggested that large markets with the most stringent policies encouraging EVs are the focus for supplies[12] (hence EV sales totalled over 10% of new registrations in the EU in 2020 – see above).[13] This pattern is not unique to EVs, OEMs prioritise larger markets when they launch new products and supply to New Zealand is usually delayed by several months.

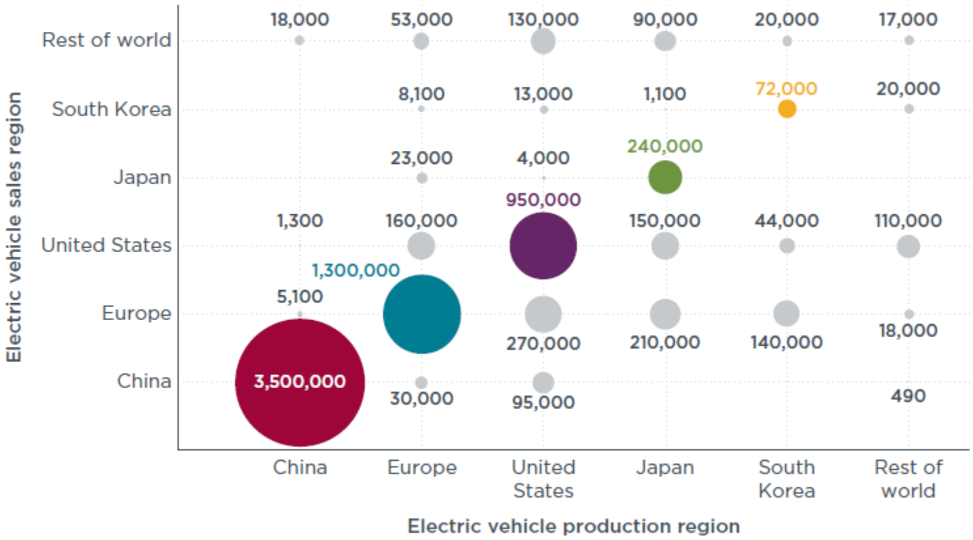
For OEMs, with current limited EV production capacity, producing EVs for New Zealand is not a priority. For many OEMs, supplies to New Zealand are grouped with those to Australia, such that the same models are made available in the two markets. As the larger market, Australia has a significant influence on the new vehicle types available for sale in New Zealand.

Globally, between 2010 and 2019, close to 80% of light-duty EVs were sold in the same region as they were produced, including sales within China, Europe and the USA (Jin et al, 2021). China exported about 25,000 light-duty EVs, less than 1% of its production, whereas Japan exported around 451,100 light-duty EVs, or 66% of its production, and South Korea, 204,000, or 74% of production. The United States (mainly Tesla) exported more than 500,000 (35% of its EV output), and Europe 227,000 (17%). JATO suggests Chinese BEVs are designed and developed for local demand, and that many of them would not meet the more complex safety standards of Europe or the USA.[14]

Figure 5 illustrates the relative size of domestic and export sales for different producing countries and regions. New Zealand is included in the Rest of world region which has small levels of production and sales.

[12] Supplying these markets reduces total corporate costs in the face of non-compliance penalties
[13] See ACEA (2020) for summary
[14] https://www.jato.com/electric-cars-cost-double-the-price-of-other-cars-on-the-market-today/

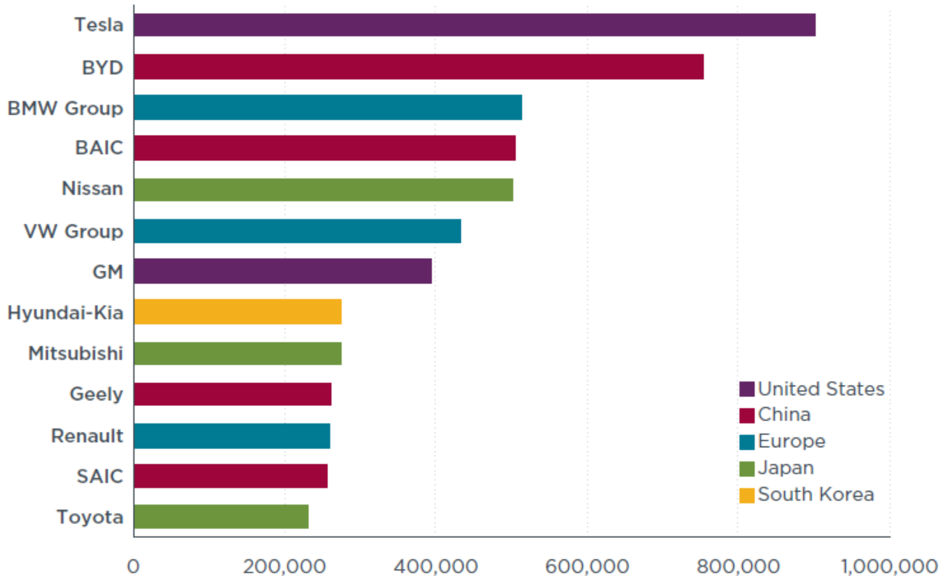
Figure 5 Total new 2010–2019 light-duty EV production and sales regions



Source: Jin *et al* (2021) using data from EV-volumes.com

Figure 6 shows 13 companies that have sold 200,000 or more EVs in 2010-19. The colours of the bars represent the region of their manufacture location. Four are Chinese brands (BYD, BAIC, Geely and SAIC), two are from the USA (Tesla and GM), three from Europe (BMW, Volkswagen and Renault) and three from Japan (Nissan, Mitsubishi and Toyota).

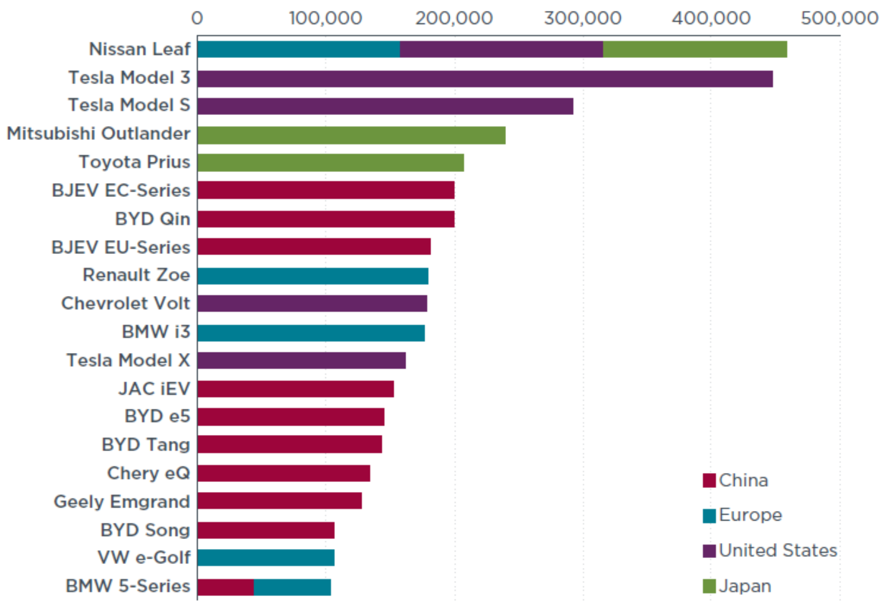
Figure 6 Light EV sales by manufacturer



Source: Jin *et al* (2021) using data from EV-volumes.com

Sales of the top 20 models are shown in Figure 7. The top five are vehicles which are also amongst the top new registrations in New Zealand (Table 3). Chinese sales are distributed across a wider variety of vehicle models. Jin et al (2021) suggest "*the China market has far more companies competing, and major powerful passenger vehicle brands that appeal to both domestic and global consumers have yet to be formed.*" However, they note that Chinese brands do have international influence in the commercial vehicle market, with BYD accounting for more than 20% of the European battery-electric bus market, and nearly 30% of the Japanese market. BYD is scheduled to establish in New Zealand in 2021.[15]

Figure 7 Top EV models sold 2010-19



Source: Jin *et al* (2021) using data from EV-volumes.com

Several distributors interviewed raised the added issue that there is a more limited number of significant right-hand drive (RHD) markets internationally (although see full list in Table 4). New Zealand will be dependent on the production of vehicles for these other RHD markets, in the same way as it is for ICEVs.

Table 4 Right-hand drive countries

Region	Countries
Asia	Bangladesh, Bhutan, Brunei, East Timor, Hong Kong, Indonesia, India, Japan, Macau, Malaysia, Nepal, Pakistan, Singapore, Sri Lanka, Thailand
Africa	Botswana, Kenya, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe
Atlantic Ocean Islands	Bermuda (UK), Falkland Islands (UK), Saint Helena, Ascension and Tristan da Cunha (UK), South Georgia and South Sandwich Islands (UK)
Australia and Oceania	Australia, Christmas Island (Australia), Cocos Islands (Australia), Cook Islands (NZ), Fiji, Kirbati, Nauru, New Zealand, Niue, Norfolk Island (Australia), Papua new Guinea, Pitcairn Islands (UK), Solomon Islands, Tokelau (NZ), Tonga Tuvalu
Europe	Cyprus, Guernsey (UK), Ireland, Isle of Man (UK), Jersey (UK), Malta, UK
Indian Ocean Islands	Maldives, Mauritius, Seychelles
South America & West Indies	Guyana, Surinam Anguilla (UK), Antigua and Barbados, Bahamas, Barbados, British Virgin Islands(UK), Cayman Islands (UK), Dominica, Grenada, Jamaica, Monserrat (UK), Saint Kitts and Navis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos Islands (UK), Virgin Islands (USA)

Source: http://carsexport.eu/lhdcars.htm

[15] Barry (2021)

The limitations of RHD markets are not regarded as a significant constraint by all OEMs, with one suggesting that RHD and LHD vehicles can be produced on the same production line, while others suggest that even if this is so, there are still considerable additional costs associated with producing both. The additional costs mean that RHD vehicles may not be prioritised, or if they are produced for the larger markets (such as the UK), New Zealand will expect to be limited to vehicles supplied to those markets (UK, Japan, Australia particularly).

The market prioritisation suggested by many OEMs interviewed is, first domestic sales, then international markets with the most stringent policy requirements (ensuring policy costs are minimised). New Zealand obtains supplies to the extent that there is spare production capacity and, for many OEMs, it is grouped with Australia for the purpose of decisions on models supplied.

2.1.4 Capacity Investments

Currently investments in vehicle production capacity are focussed on China and Europe, with smaller capacity investments in the USA, South Korea and Japan. Table 5 shows announced industry capacity investments, with the country of origin of the investor represented by the rows and the columns the destination of investment. German companies are the largest expected investors, with investments split between China (49%) and Germany (51%). China is estimated to be receiving US$136 billion in new investments, 50% of which is from Germany (including Volkswagen/Audi/Porsche with $45.5 billion and Daimler, $22 billion) and 42% from Chinese companies.

Table 5 Announced industry electric vehicle investments ($billion) by origin (rows) and destination (columns)

Origin	China	Germany	USA	S Korea	Japan	France	Other	Total
Germany	$67.8	$71.7						$139.5
China	$57.0							$57.0
USA[a]	$5.0		$34.0					$39.0
Japan	$4.8				$18.9		$0.7	$24.4
S Korea				$20.0				$20.0
France	$0.4					$10.4		$10.8
India							$6.4	$6.4
UK							$2.3	$2.3
Sweden	$0.7							$0.7
Total	$135.7	$71.7	$34.0	$20.0	$18.9	$10.4	$9.4	$300.1

[a] includes Fiat Chrysler
Source: Lienert and Chan (2019)

Further detail about announced investments is provided in Table 6, alongside projected sales and numbers of models.

Based on the announcements summarised in Table 6, Slowik *et al* (2020) summarise the sales estimates for the individual manufacturers in Figure 8. The largest sales are estimated from the Nissan-Renault-Mitsubishi alliance, within which Mitsubishi is specialising in PHEVs, with BEVs produced by the other two members. Toyota, with Suzuki, Mazda and Subaru are also investing significantly in EV capacity, despite Toyota's additional commitment to development of hydrogen vehicles (see Section 2.2). Volkswagen is investing significantly in EV production and rapidly increasing sales, including the ID3 which is its rival to the Nissan Leaf.

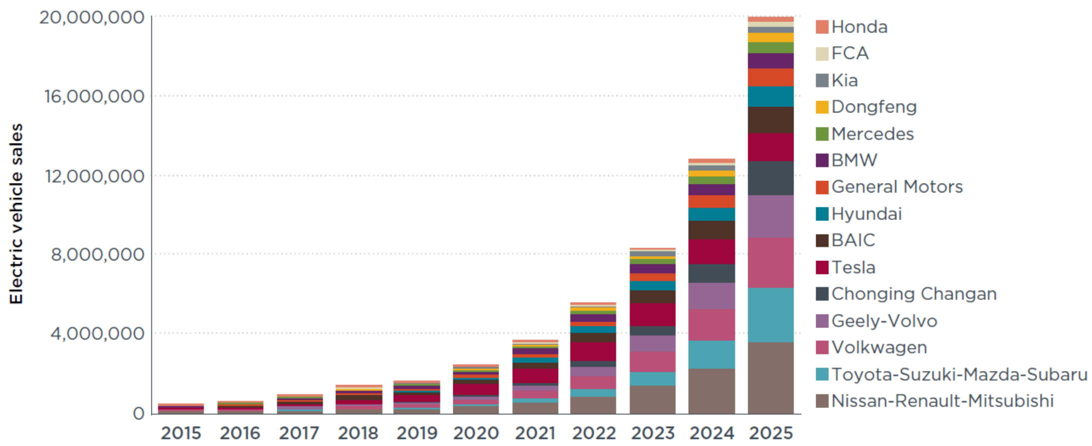
Table 6 Manufacturer investment announcements, model offerings and sales targets

Automaker group	Announced investment	Electric models	Annual global electric sales (share)
Volkswagen Group	$40 billion manufacturing plant by 2022 $60 billion battery procurement	70 electric models by 2028 300 electric models by 2030	4–5 million (40%) by 2030
Nissan-Renault-Mitsubishi	$9.5 billion over 2018–2022 (China)	20 electric models by 2022 (China)	3 million (30%) by 2022
Toyota-Suzuki-Mazda-Subaru	$2 billion over 2019–2023 in Indonesia	All vehicles hybrid, battery, or fuel cell electric by 2025	2–3 million (15%) by 2025
Honda	$430 million facility in China $300 million for battery plants	100% hybrid or electric sales in Europe by 2025 20 electric models in China by 2025	2 million (30%) by 2030
Chongqing Changan	$15 billion by 2025	21 electric models by 2025 12 plug-in hybrid models by 2025	1.7 million (100%) by 2025
Mercedes	$13 billion manufacturing plant $1.2 billion battery manufacturing $22 billion battery procurement	10 electric models by 2022 50 electrified models by 2025	1.5 million (50%) by 2030
BAIC	$1.5 billion by 2022 $1.9 billion (with Daimler)	(not available)	1.3 million (100%) by 2025
Geely	$3.3 billion	Al models hybrid or electric by 2019 (Volvo)	1.1 million (90%) by 2020
Tesla	$5 billion factory in Shanghai $4.4 billion factory in Berlin	6 all-electric models	1 million (100%) by 2022
Hyundai	$16 billion through 2025	23 BEV, 6 PHEV, 2 FCEV by 2025 (Hyundai Motor Group)	1 million (15%) by 2025
BMW	$11 billion battery procurement from 2020–2031	13 electric models by 2025 12 plug-in hybrid models by 2025	900,000 (30%) by 2030
General Motors	$2.3 billion battery factory $2.2 billion electric vehicle plant	20 electric models by 2023	1 million (12%) by 2026
Kia	$25 billion through 2025	11 battery electric vehicles by 2025	500,000 (15%) by 2026
Fiat Chrysler	$22 billion to develop hybrid and electric vehicles through 2022	30 nameplates will have hybrid or electric options by 2022	250,000 (10%) by 2025 in China, North America
Smart	(not available)	Only all-electric options from 2020 in Europe and the USA	100,000 (100%)
Ford	$11 billion by 2022	16 all-electric models by 2022	(not available)
PSA Group	$250 million in electric motors $90 million in transmissions	Hybrid or electric options of all models by 2025	(not available)
Great Wall	$2–8 billion over 10 years	(not available)	(not available)

BYD	$3 billion on battery factories by 2020 $1.5 billion Changzhou NEV factory	(not available)	(not available)
Jaguar Land Rover	$18 billion over 2019-2022	Hybrid or electric options of all models by 2020	(not available)
Infiniti	(not available)	All new models plug-in hybrid or electric by 2021	(not available)

Source: Slowik *et al* (2020)

Figure 8 Annual EV sales (to 2019) and future sales estimates based on manufacturer intentions



Source: Slowik *et al* (2020)

The implications for New Zealand are that there is significant expected investment in EV production capacity and significant increases in sales. New Zealand would expect to increase imports in-line with these global trends. This means that, **in the longer run, eg by 2030, there are expected to be no significant limits to EV supply.** However, in the immediate term the focus of OEMs is likely to be on increasing capacity to meet demand growth in China and Europe.

2.1.5 Missing Markets

There are expected to be some categories of vehicle that are either unavailable or not readily available in BEV form. For New Zealand the most widely cited missing type of vehicle is a BEV ute. Utes are relatively niche vehicles used in the Australasian market. US Pick-up trucks, for example, are generally larger (and produced as LHD vehicles). Batteries may not provide enough power to lighter utes as typically sold in New Zealand, if they are carrying heavy loads or towing significant weights. We also note, because of the absence of demand in Japan, New Zealand does not import used ICE utes currently.[16]

Great Wall[17] and Tesla cybertrucks[18] are some of the only potential EV ute examples, although neither are currently available. There is thought to be little chance of much else (eg Rivian[19]) being produced in RHD vehicles in the near future, although Toyota is talking about producing a

[16] Small numbers have been imported from Australia.
[17] https://www.driven.co.nz/news/great-wall-s-electric-ute-and-its-new-zealand-power-play/
[18] https://www.tesla.com/en_nz/cybertruck
[19] https://rivian.com/r1t; https://www.evspecifications.com/en/model/8b4391

(mild) hybrid Hilux.[20] Converting ICEVs to operate as EVs might be an alternative way to produce electric utes for NZ.[21]

One interviewee suggested an absence of large EV people carriers, although we note announcements that include the Citroën eSpace Tourer, which could seat up to nine and with a maximum range of 230km,[22] and the Nissan E-NV200 COMBI, which includes a 7-seater model.[23]

There are a number of other specialist vehicle demands, eg the space requirements of police vehicles, and these may not be easily met using the limited number of EVs available in the next few years.

In the short run, some vehicle categories (utes in particular) will not be available in EV form in New Zealand. However, the increasing penetration of BEVs into the global vehicle market is expected to see a multiplication of the varieties available, so that by 2030 it is likely that most, if not all, vehicle categories will have models available in EV form.

2.1.6 Market Response to Policy

Short run (to 2025) supply limits mean OEMs' achievement of the CCS requirements will vary significantly.

Some OEMs are likely to achieve the 105g/km standard and become potential credit sellers in the system. This includes Tesla (selling only EVs) and Toyota which has HEV, PHEV or BEV options across much of their fleet.

Others will not produce the right mix of vehicles and may not be able to reach joint arrangements either. Subaru, for example, has no BEVs planned until 2030. Mitsubishi has an agreement within its alliance with Nissan and Renault to only supply PHEVs for the immediate future. These decisions made at a corporate level may affect some companies costs under the CCS. Some OEMs interviewed suggested this could result in withdrawals from New Zealand, citing Holden as an example (albeit for quite different reasons).[24] They argue that New Zealand is vulnerable to withdrawals as a small market that contributes little to corporate sales and profit. The actual response is uncertain currently and we know of no current withdrawal intentions.

There is some expectation that New Zealand will be able to achieve a rapid transformation to its import mix because of the stringency of policy elsewhere, eg in the EU where a standard of 95g CO_2/km applies,[25] means vehicles are available for sale to enable this fast transition. However, there are constraints.

[20] https://www.driven.co.nz/news/a-hybrid-version-of-the-toyota-hilux-ute-is-on-its-way/
[21] We note this company offering a service in NZ: https://www.thesurgery.co.nz/services/electric-vehicle-conversions/
[22] https://www.autofutures.tv/2020/06/12/100-electric-people-carrier-with-up-to-nine-seats-the-new-citroen-e-spacetourer/
[23] https://www.voltvehicles.co.nz/env200/
[24] The example was used to suggest even long-established brands might withdraw if unfavourable market conditions develop.
[25] From 2021, and phased in from 2020, the EU fleet-wide average emission target for new cars is 95g CO_2/km (Regulation (EU) 2019/631 https://eur-lex.europa.eu/eli/reg/2019/631/oj)

- The EU is starting from a quite different current average emission rate. In New Zealand, the average emissions rate for imported light vehicles was 167g/km at the end of 2020, with an average of 176g/km for new vehicles and 158g/km for used vehicles.[26] In contrast, the EU had concentrations at this level 20 years ago; the average emissions intensity of new passenger cars imported to the EU was 122g CO_2/km in 2019,[27] down from 167g/km in 2002.[28] Amongst other things, the differences in average emission rates reflects the demand for a different mix of vehicle categories.

- OEMs have plants and/or production lines dedicated currently to EVs, with others to ICEs. If the EV production lines are at capacity producing for European markets, additional supplies may not be available to New Zealand.

Although policy costs may be high initially, high policy costs are expected in other countries also. Automotive Analyst, David Harrison, estimates OEM compliance costs in the EU of €7.8bn, with fines of €4.9bn in 2021.[29] He suggests this will halve profits, making Europe less attractive to OEMs.

If there are significant total compliance costs in New Zealand, these would be expected to be passed on in higher average vehicle import prices, and result in a mix of reduced import volumes (and to retaining current vehicles for longer) and a shift towards purchase of lower cost vehicles, including used imports. Ultimately, the response is uncertain currently, but is likely to become easier and lower cost as the price differentials between EVs and ICEVs narrow; we address that issue in Section 3.2.

2.2 Battery Supply Limits

Concerns have been raised by OEM interviewees that there may be limits to battery supply, particularly because of limits to raw materials supply.

2.2.1 Battery Production

Figure 9 shows estimated growth in battery production capacity in different regions. The growth is expected to be greatest in China and Europe.

There are economies of scale in battery production[30] and one industry interviewee suggested that at-scale production is only occurring in China, because individual OEMs elsewhere (Japan, Korea, USA, Europe) are specifying battery requirements separately, so that scale economies are not achieved. It was suggested economies of scale would only be achieved with standardisation of batteries.

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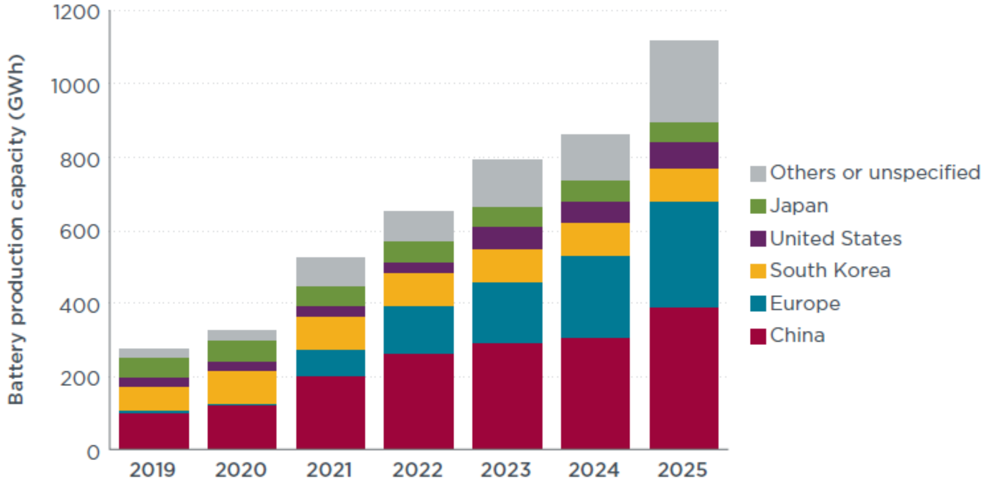
[26] MoT Fleet Statistics
[27] And reportedly 111g/km in early 2020 (Mathieu and Poliscanova, 2020).
[28] https://www.eea.europa.eu/data-and-maps/indicators/average-co2-emissions-from-motor-vehicles/assessment-2
[29] Harrison (2019)
[30] Mauler et al (2021)

Figure 9 Estimated announced battery production capacity for 2019–2025, by region



Source: Jin *et al* (2021) based on Slowik *et al* (2020)

McKinsey & Co examine issues facing the European vehicle industry and note the benefits of integrated supply chains upstream from batteries to mineral production and downstream to vehicle manufacture, and European vehicle manufacturers reluctance to go down that route.[31] They note that "*Currently, a handful of Chinese, Japanese, and Korean cell manufacturers dominate the market and much of the value chain, with control extending, in some cases, as far as the mines that extract lithium and other key metals*." In the USA, Tesla is also pursuing a strategy of deep vertical integration into all stages of manufacturing its batteries, including processing the raw materials and even buying lithium deposits still in the ground.[32]

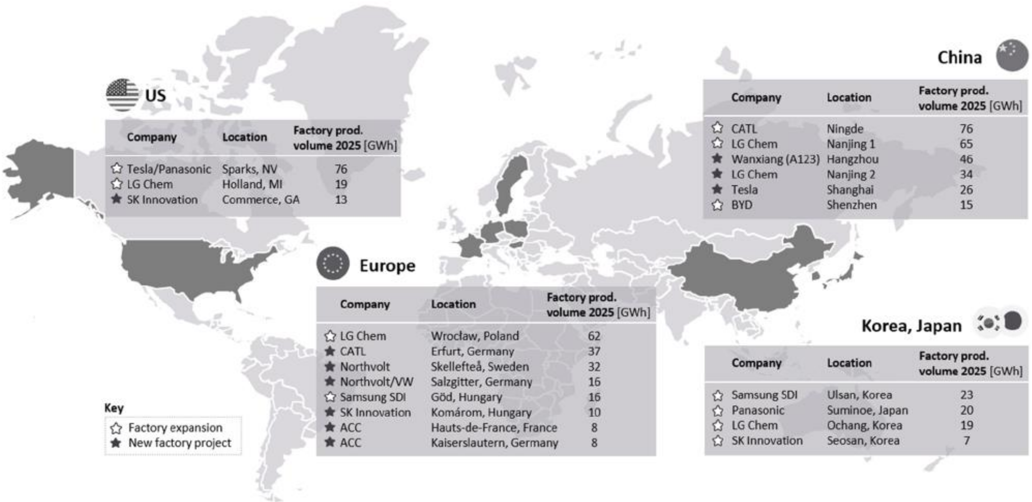
McKinsey & Co identify risks for European EV manufacturers from not investing in battery production, especially for latecomers to production.[33] More recently, Mauler *et al* (2021) list current announcements of new battery production capacity. There is considerable capacity planned for Europe, the USA, Korea, Japan and China (Figure 10).

How the battery market develops and the level of integration with EV production is uncertain currently, let alone the implications for New Zealand supply of EVs or their costs. This is a rapidly developing market and there may be challenges and reversals of price trends on the way to a more stable future market with lower battery costs.

Shifts to vertical integration in the industry, and the falling costs that go with this, may lead to some consolidation in the vehicle supply industry. This may reduce costs of production, with the offsetting risks of reduced competition, which might mean consumers do not obtain the full benefits in lower prices, although, some consolidation may occur simply for OEMs to maintain competitiveness rather than introducing a risk of anti-competitiveness. And we also note the growing number of Chinese OEMs, some at least of which are expected to export vehicles in the future; this will increase competition in BEV supply.

[31] Eddy et al (2019)
[32] Waters (2020)
[33] Eddy et al (2019)

Figure 10 Selected battery cell manufacturing plants announced for 2025



Source: Mauler et al (2021)

2.2.2 Raw Material Prices

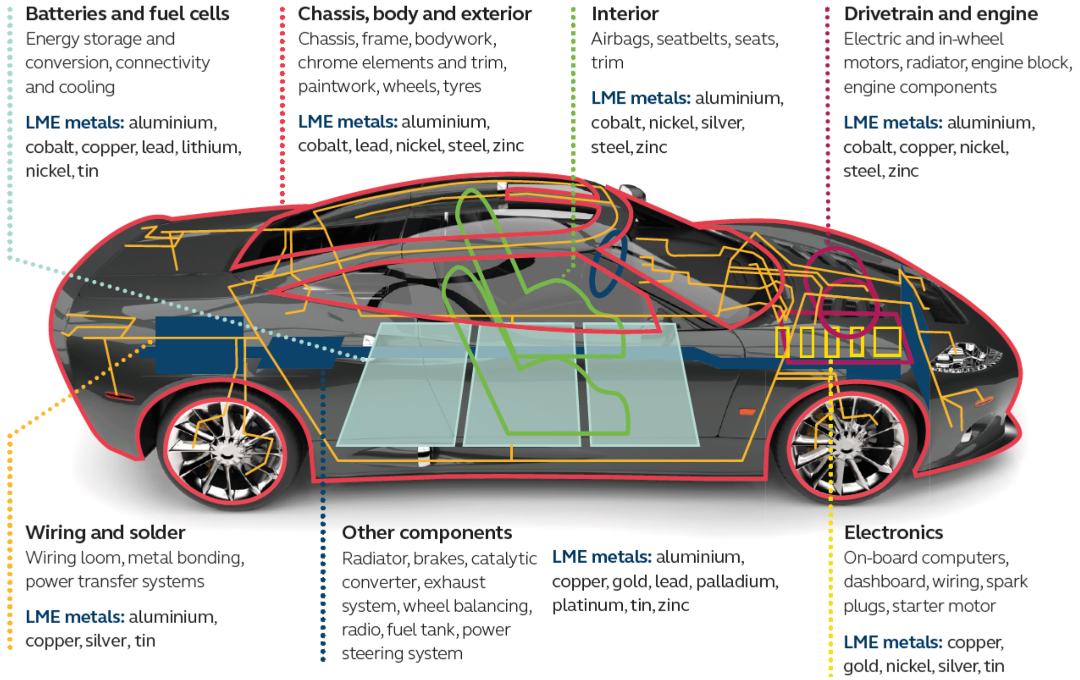
Some industry commentators have suggested there are current global capacity limits to battery production for EVs,[34] including via short-run constraints to mineral production.[35] Slowik *et al* (2020) compared the projected increase in demand for EVs and associated batteries, with the known reserves of the raw materials. They estimate the main limiting factor will be cobalt. From 2025 to 2035, the cumulative use of cobalt as a percentage of known reserves is forecast to increase from about 3% to about 14%, whereas demand for lithium and nickel increases from about 1% of known reserves to about 8%.[36] Cobalt is recyclable from batteries, but ex-EV batteries may also have a long run future for domestic electricity storage, delaying any recycling. It is not clear at this stage whether raw materials will be limiting, or if changes in battery technology will keep pace with any decline in reserves.

One way to examine emerging scarcity is via price trends. Noting the importance of raw materials prices to EV supply costs, the London Metals Exchange (LME) is identifying the key materials and developing reporting standards and prices. Their “LME Car” lists the key metals required for vehicle manufacture, with batteries and fuel cells dependent on aluminium, cobalt, copper, lead, lithium, nickel and tin (Figure 11).[37]

Cobalt has been suggested as a material in limited supply, but a review of cobalt prices gives a slightly more complex picture. Benchmark cobalt prices on the London Metal Exchange peaked in 2018/19 and have fallen since but are now rising again (Figure 12).

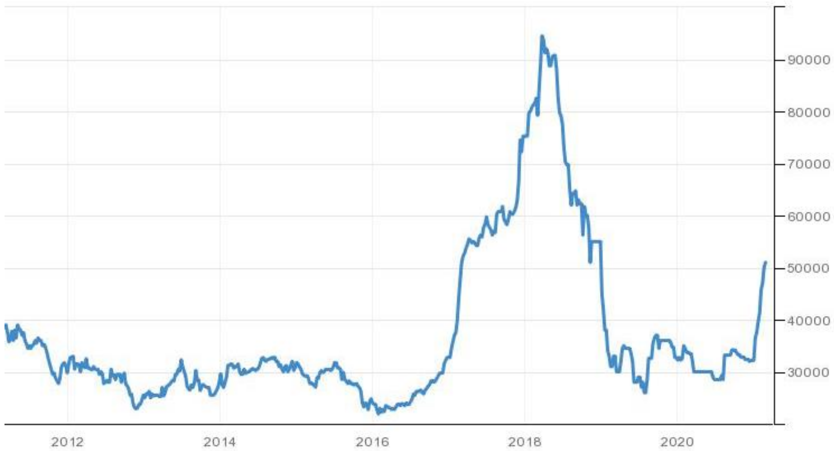
[34] See for example https://jalopnik.com/the-problem-that-could-derail-the-electric-car-revoluti-1796728488
[35] Olivetti *et al* (2017)
[36] *ibid*
[37] LME notes some components found in HEVs and PHEVs are not used in BEVs.

Figure 11 Metals used in vehicle manufacture



Source: https://www.lme.com/-/media/Files/About/Responsibility/LME-Sustainability-Electric-Vehicles.pdf

Figure 12 London Metal Exchange Benchmark Cobalt price (US$/tonne)



Source: https://tradingeconomics.com/commodity/cobalt

Writing about the 2019 crash in prices from highs in 2018, *International Banker* suggests this is because:[38]

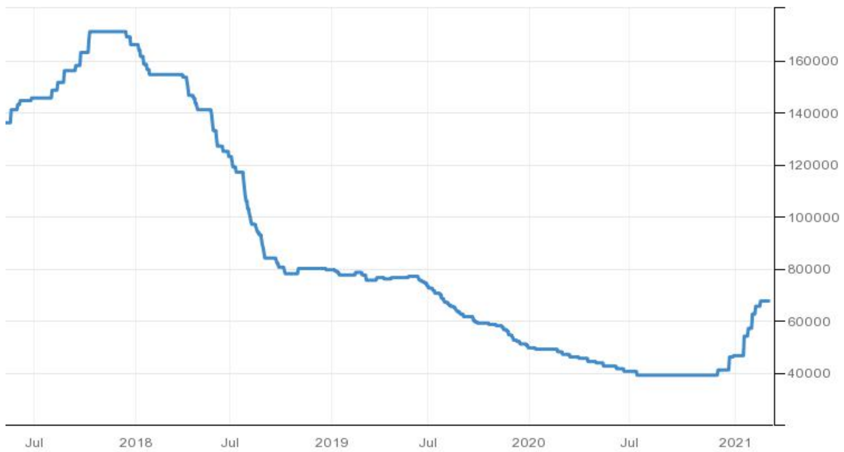
- growth rates for the EV sector have not been as great as the initial ‘hype’ suggested;
- projections of demand led to a significant increase in mining capacity, including “artisanal mines” in the Democratic Republic of the Congo (DRC), home to more than 60% of the world’s mined cobalt output;

[38] https://internationalbanker.com/brokerage/why-have-cobalt-prices-crashed/

- demand and prices were reduced by assertions made to Tesla shareholders in May 2018 by the company's founder, Elon Musk, that he believed he could reduce cobalt content in Tesla EVs to "almost nothing". And we note Tesla has used cobalt-free batteries for some of its cars made in Shanghai.[39]

It is likely that Covid-related impacts on global trade has also been a significant factor in price movements for Cobalt, and for Lithium, for which prices have also fallen since 2018 but are currently rising (Figure 13).

Figure 13 Spot prices for Lithium Carbonate (US$/tonne)



Source: https://tradingeconomics.com/commodity/lithium

The commodity price charts are not demonstrating a clear signal of price rises that would affect the otherwise downward movement in battery costs. This may change if EV demand continues to rise and developments to increase battery density or to shift to alternative battery technologies do not keep pace with sales.

Concerns over raw material supplies would be diminished if new battery types (such as cobalt-free solid-state batteries)[40] develop soon. According to some reports, Toyota plans to commercialise an EV equipped with a solid-state battery in the early 2020s, with other OEMs to follow.[41] And as noted above, Tesla is experimenting with cobalt-free varieties.

2.3 Alternative Technologies

Alternative technologies to that used in BEVs, PHEVs and HEVs are being pursued by some companies, particularly in Japan. This is of concern in this report only to the extent that these developments result in more limited supplies of used EVs (as discussed further in Section 2.4.

Several models have been launched and there is a possibility that one or more of these alternatives may see more widespread sales. The Japanese Government in its recent statements on pursuit of reduced CO_2 emissions has used wording that suggests a mix of technologies for vehicles.[42] And the Ministry of Economy, Trade and Industry (METI) produced a 2018 *Long-Term*

[39] Wong (2020)
[40] See Vector Ltd (2019) for a useful summary of battery technologies
[41] https://asia.nikkei.com/Spotlight/Most-read-in-2020/Toyota-s-game-changing-solid-state-battery-en-route-for-2021-debut
[42] Government of Japan (2019); Ministry of Economy, Trade and Industry (2021)

Goal and Strategy of Japan's Automotive Industry for Tackling Global Climate Change which included the expectations of the following diffusion rate of next-generation cars by 2030: HEVs (30-40%), BEVs and PHEVs (20-30%), Fuel Cell Electric Vehicles (FCEVs) (c.3%) and clean diesel (5-10%).[43] Notably this suggests significant ongoing supply and use of HEVs.

Three companies, Toyota, Honda and Hyundai, have launched FCEV models, which are available for sale in California as well as Japan.[44] Other companies are pursuing different technologies.

- Nissan has developed and used its hybrid, e-power technology.[45] Nissan launched the e-power Note in 2016 with a theoretical range of 1300 km and a fuel economy of as little as 2.9L/100km.[46] Nissan has suggested there has been a recent shift towards purchasing e-power vehicles and away from EVs (and from the Leaf in particular), partly because of limits to the practical use of EVs in Japan where many residents do not have a garage or easy ability to charge vehicles at home and where public charging infrastructure is still not widespread. The recently (December 2020) relaunched Note has seen significantly higher sales than expected.[47] An e-power version of the Qashqai compact SUV has recently been launched in the USA;[48] it is expected in New Zealand in 18 months or so.

- Mazda is developing e-fuel as part of the European e-fuels alliance.[49] eFuels are hydrocarbons made from hydrogen obtained from water by means of electrolysis, which is combined with CO_2 in a Fischer-Tropsch process to produce a liquid fuel. This produces a fuel which could be used in a conventional ICE but with no net CO_2 emissions (the emissions that do occur are from carbon recently absorbed from the atmosphere).

Representatives from the different companies all see these alternative fuels and technologies as having a potential future, and that all have the potential to be at least a significant component of sales in the longer run. This introduces some risk for supplies of BEVs and PHEVs in Japan, and for supplies of used EVs to New Zealand.

Although European countries, including the RHD UK and Irish markets, appear more likely to invest in EV infrastructure, Japan appears to be keeping options open. And some of the issues raised by Nissan about the difficulties of access to home-charging facilities in urban areas where there is no off-street parking apply in other countries also, although we also note examples such as the roll-out of on-street public charging scheme in the UK, funded by Government grants of up to £7,500 (c.NZ$15,000) per charge point.[50] At the moment, the development of alternatives does not appear to be a significant enough trend to have a major impact on used EV supplies.

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43 Available at: https://policy.asiapacificenergy.org/node/4191; and https://www.eu-japan.eu/sites/default/files/imce/meti.pdf
44 Toyota Mirai (https://www.toyota.com/mirai/), Honda Clarity (https://automobiles.honda.com/clarity-fuel-cell) and Hyundai Nexo (https://www.hyundaiusa.com/us/en/vehicles/nexo)
45 https://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/e_power.html
46 https://www.autocar.co.nz/car-reviews-app/quick-ev-drive-2017-nissan-note-e-power
47 https://www.greencarcongress.com/2021/02/20210202-epower.html
48 https://www.driving.co.uk/news/new-cars/nissan-reveals-2021-qashqai-suv/
49 https://www.efuel-alliance.eu/
50 https://pod-point.com/guides/business/on-street-chargepoint-scheme

2.4 Used EV Supply Limits

2.4.1 Historical Imports

Used EV imports are dominated by the Nissan Leaf (91% of BEV imports), Mitsubishi Outlander (48% of PHEV imports) and Toyota Prius (34% of PHEVs) (Table 7). Supplies are not for all vehicle types, and as noted for new vehicles, to date there are no available supplies of utes, for example (and no supplies of used ICE utes either).

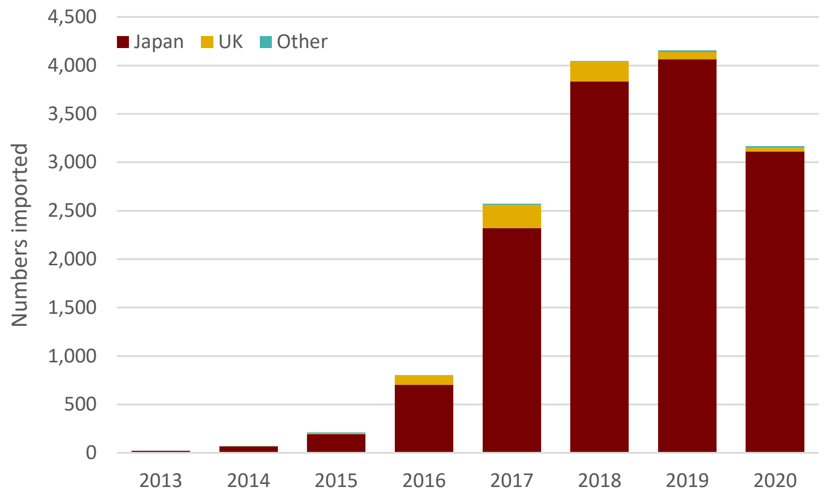
Table 7 Used BEV and PHEV registrations (1 Jan 2015 - 31 Jan 2021)

BEV Type	Number	%	PHEV Type	Number	%
Nissan Leaf	11,820	91%	Mitsubishi Outlander	1,108	48%
Nissan E-NV200	529	4%	Toyota Prius	781	34%
BMW I3	133	1%	BMW I3	253	11%
Renault Zoe	106	1%	Volkswagen E-golf	32	1%
Mitsubishi I-Miev	91	1%	BMW 330e	32	1%
Mitsubishi Minicab	43	0%	Mercedes-Benz C350	23	1%
Tesla Model S	40	0%	BMW I8	19	1%
Smart Fortwo	35	0%	BMW 330	9	0%
Kia Soul	26	0%	Audi A3	9	0%
Volkswagen E-Golf	13	0%	BMW 530e	8	0%
Other	91	1%	Other	34	1%
Total	12,927	234%	Total	2,308	42%

Source: MoT Fleet Statistics (www.transport.govt.nz/statistics-and-insights/fleet-statistics)

Used vehicle imports to New Zealand are very largely from Japan, with some also from the UK and Thailand (see Figure 14). In 2020, 98% were from Japan.

Figure 14 Sources of used EVs imported to New Zealand



Source: MoT fleet statistics

2.4.2 Sales in Japan

In the year to September 30th 2020, there were 122,257 used light passenger vehicles (LPVs) imported, 58% of total LPV imports (211,999). Used imports have been 62% of EV registrations to date and 70% of BEV registrations. If this pattern continues, total New Zealand EV registrations will be highly dependent on numbers available from Japan and other used vehicle exporting countries.

To estimate the percentage of Japanese sales that New Zealand importers are taking, we compare annual imports to New Zealand of used BEVs and PHEVs with the average number sold in the 4, 5 and 6 years previously (Table 8).[51] Incentivised by subsidies,[52] Japan registered 38,890 EVs in 2019/20 (55% of which were BEVs), which is approximately 1% of total light vehicle sales that year of 3.8 million.[53] New Zealand imports of BEVs are over 20% of average annual historical sales of BEVs in Japan, while used PHEV imports are approximately 5% of Japan sales. These numbers are significant, in the face of competition from domestic Japanese consumers and other countries, including Australia, Sri Lanka and Russia.

Table 8 NZ used imports as % of earlier Japanese sales

	Japanese sales of new vehicles				NZ Used imports (# and % of Japan)[1]			
Year	**BEVs**	**PHEVs**	**Fuel cell**	**Hybrids**	**BEVs**	**PHEVs**	**BEVs**	**PHEVs**
2009/10	1,078	0	0	347,999	1	0		
2010/11	2,442	0	0	481,221	1	0		
2011/12	12,607	15	0	451,308	4	0		
2012/13	13,469	10,968	0	887,863	4	0		
2013/14	14,756	14,122	0	921,045	41	2		
2014/15	16,110	16,178	7	1,058,402	116	4	6.6%	
2015/16	10,467	14,188	411	1,074,926	391	23	7.3%	
2016/17	15,299	9,390	1,054	1,275,560	1,255	189	13.2%	5.2%
2017/18	18,092	36,004	849	1,385,343	2,979	458	21.9%	5.5%
2018/19	26,533	23,230	612	1,431,980	3,810	508	25.8%	3.7%
2019/20	21,281	17,609	685	1,472,281	2,878	666	20.9%	4.5%

[1] The percentages are NZ imports as a percentage of sales in Japan 4-6 years earlier, eg 20.9% for BEVs in 2019/20 is 2878/((14756+16110+10467)/3)
Source: MoT Fleet data

To date, over 90% of the imports of used BEVs to New Zealand have been Nissan Leafs. There is currently a risk of fewer Leafs entering the market as Nissan has seen a recent shift in demand towards HEV (e-power)[54] vehicles in Japan (as discussed in Section 2.3 above). It is currently too early to tell whether this represents a more widespread shift away from BEVs towards other technologies. The Japanese Government has set a target of between 50% and 70% of new vehicles using electric, fuel cell or other non-gasoline engines by 2030,[55] or approximately 2.0 to 2.8 million annually (based on assumed total sales of 4 million). A Green Growth Strategy released in 2021 suggested Japan aims to: [56]

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[51] For example, 20.9% for BEVs in 2019/20 is 2878/((14756+16110+10467)/3)
[52] BEVs: maximum of ¥400,000 (NZ$5,333); PHEVs: maximum of ¥200,000 (NZ$2,667); FCEV: maximum of ¥2,250,000 (NZ$30,000). Subsidy levels for BEVs and PHEVs are expected to double (temporarily), and those for FCEVs to rise by several hundred thousand Yen: https://www.electrive.com/2020/12/16/japan-doubles-electric-vehicle-subsidies/
[53] http://jamaserv.jama.or.jp/newdb/eng/index.html
[54] https://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/e_power.html
[55] Government of Japan (2019)
[56] Ministry of Economy, Trade and Industry (2021); and Reuters *Factbox-Japan's green growth strategy to help achieve carbon neutral goal* (https://www.reuters.com/article/us-japan-economy-green-factbox/factbox-japans-green-growth-strategy-to-help-achieve-carbon-neutral-goal-idINKBN28Z0IR)

- eliminate sales of new ICEVs by the mid-2030s, shifting to EVs including hybrid vehicles and fuel cell vehicles (FCEVs); and
- reduce the cost of batteries, to 10,000 yen ($97) or less per kilowatt hour by 2030.

The ICEV replacements will not all be EVs. And another Japanese Government objective is to promote a hydrogen society. However, even with growth in alternative vehicle technologies, the growth in BEV and PHEV sales is still likely to be significant.

2.4.3 Competition from Australia

Increases in demand from other countries could affect available supplies. Historically, Japan has exported used vehicles to countries that include Australia, Russia and Sri Lanka, in addition to New Zealand. Australia may be a more significant importer of used EVs in the future, despite historically importing relatively few used vehicles.

A recent report for the Australian Renewable Energy Agency (ARENA), noted that there is significant and growing demand for EVs but new vehicles are expensive and used vehicle imports are restricted.[57] Importing used vehicles is limited under the Motor Vehicle Standards Act 1989 which restricts the recognition of compliance with safety and other standards; this had protected the Australian vehicle manufacturing industry, but all production in Australia has stopped following the closure of General Motors' last Holden plant in 2017. Replacement legislation, the Road Vehicle Standards Act 2018 (RVSA), is expected to come into force in mid-2021[58] and will remove some barriers to imports of used vehicles.

The current restrictions mean that vehicles currently sold new in Australia (such as 40kWh battery Nissan Leafs) cannot be imported as used vehicles; only those not available, such as earlier generation Leafs.[59] The new legislation does not change that restriction, but is expected to lead to easier entry of vehicles not sold in Australia because of changes to the rules governing recognition of compliance and the removal of limits on how many vehicles can be imported annually by a Registered Automotive Workshop (RAW).[60]

Changes to allow easier import of used vehicles into Australia represent a potentially significant threat to the availability or costs of supply of used EVs to New Zealand. The rules around the new legislation are still being developed and the impacts of these changes will become clearer over the next 12 months.

2.4.4 China as a Source of Supply

As noted above, China is a very large current market for EVs and is the destination of significant investment by domestic and international OEMs. Production of EVs in China is showing considerable growth but this has been largely to meet domestic demand to date with relatively few exports. This is expected to change rapidly with major investments by Chinese and foreign investors driving a shift towards exports.[61]

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57 Evernergi
58 https://www.infrastructure.gov.au/vehicles/rvs/news/draft_determinations.aspx
59 Anton Vikstrom, Good Car Co. (www.goodcar.co), personal communication
60 A RAW is a business that has been approved to import and plate up to 100 used vehicles (per vehicle category), per year.
61 Williams (2020); Wong (2020)

Although many industry interviewees during this study expect LPV exports from China to initially focus on LHD markets (particularly Europe and the USA), some exports of Chinese ICEVs have already come to New Zealand. This is mainly in the commercial market (eg LDV), but Great Wall is selling utes and SUVs here.[62] And significantly, Great Wall has produced and displayed an electric ute[63] in China and it may be the first electric ute for sale in New Zealand. In addition, BYD is expected to start exporting BEVs to New Zealand in 2021.[64]

China may become a significant source of low-cost light EVs, but the industry expectation is that this will start slowly in the next five years.

2.5 Insights from Supply Analysis

2.5.1 New Vehicles

Constraints on supply are different over the short and long run.

To 2025:

- There will be limits to what can be imported to New Zealand because OEMs have limited EV production capacity and they prioritise larger markets and/or those with more stringent CO_2 policies as they increase production and introduce new models. Supplies to New Zealand are delayed by several months and for some OEMs are constrained to the models supplied (and in demand) in Australia.

- Some vehicle types, and utes in particular, may not be available in BEV form for several years.

- Battery costs for vehicles may not fall immediately because of increasing battery sizes (to increase vehicle range) and some supply interruptions (from Covid and short-run limits in raw materials while new technologies develop). Battery costs are expected to fall most for vertically integrated producers. This includes Tesla and many Chinese manufacturers.

- The NZ motor industry suggests it is likely that initially, because of limits to vehicles available to the New Zealand market, some, if not most OEMs will not be able to meet standards under the CCS, either individually or in combination. This may result in payment of significant penalties, passed on in higher retail prices.

By 2030

- There are unlikely to be supply constraints for imports of new EVs across the majority of (if not all) vehicle types. There is a substantial expected increase in capacity and production of EVs in all major markets, particularly of BEVs.

[62] https://gwmhaval.co.nz/
[63] White (2020)
[64] Barry (2021)

- Ongoing R&D on alternative vehicle technologies (eg FCEVs and e-fuel) may still lead to significant market penetration, particularly in Japan. However, commitment of other countries to EVs suggests it is unlikely that these technologies will displace BEVs for the foreseeable future.

- Greater vertical integration of mining, battery production and vehicle manufacture is expected to result in falling production costs. Although there may be market consolidation and some reduced competition amongst existing OEMs, there is a growing number of Chinese OEMs expected to become vehicle exporters and ensure ongoing competition and thus falling EV prices.

2.5.2 Used Vehicles

To 2025:

- There are finite sales of EVs in Japan, particularly of BEVs for which there is a risk of fewer Leafs entering the market as Nissan has seen a recent shift in demand towards e-power vehicles in Japan.

- Increased competition is expected from Australia, which will reduce potentially available supplies to New Zealand and/or increase their costs.

- A limited range of vehicles is available as EVs, including utes which are not available as used ICEVs either.

By 2030

- New Zealand is expected to import vehicles from manufacturers in several different countries. The prospect of supplies of new EVs from emerging markets, such as China, at a sufficiently low-cost to be competitive with used imports, is uncertain. China is currently exporting very few vehicles and is likely to start by targeting left-hand drive (LHD) markets.

3 Demand Drivers

3.1 Drivers of Demand

In the absence of physical supply constraints, EV import numbers will be determined by consumer demand, driven by relative price (or costs), including the effects of any Government incentive schemes, modified by factors which determine how effective EVs are as substitutes for ICEVs. Issues relevant to substitutability include kilometre range constraints for BEVs (coupled with differences in customer-specific use patterns), perceived availability of charging stations and differences in driving performance. There are concerns for some consumers about the management of end-of-life vehicles, or their batteries.

3.2 Relative Costs of EVs

3.2.1 Cost Components

The relative costs of EVs and ICEVs differ with the time period. Differences in initial purchase price may be very different from differences in the total costs of ownership (TCO) over the period of ownership which include ongoing costs for fuel, maintenance and insurance, offset by the future resale value (reflecting the rate of depreciation in value).

Because BEVs are regarded as the end-game in the shift to EVs, analyses of relative costs focus on differences between ICEVs and BEVs, rather than with PHEVs or HEVs. Currently BEVs have (generally) higher initial purchase prices than ICEVs (largely because of the significant costs of batteries)[65] but lower fuel costs. There is some disagreement over differences in other costs. Because the technology is rapidly improving, some analysts suggest depreciation rates for BEVs are higher than for ICEVs,[66] whereas others suggest they are now the same.[67] It is likely that it will differ between vehicles reflecting the battery technology used. In addition, there are savings in repair and maintenance costs of BEVs because of the smaller number of moving parts,[68] and these costs are lower for PHEVs than for ICEVs also.[69]

All factors combined suggest that the relative costs of purchasing ICEVs and EVs depend on the time over which costs are measured and use levels (which determine fuel consumption). However, the differences are amplified for lower-cost cars for which batteries are a greater percentage of total costs.

3.2.2 Time Before Cost Parity

TCO Parity

Interviews with a selection of new vehicle importers and distributors in New Zealand (February 2021) suggests an expectation of TCO parity by 2025-2030. Some analysts estimate broad TCO

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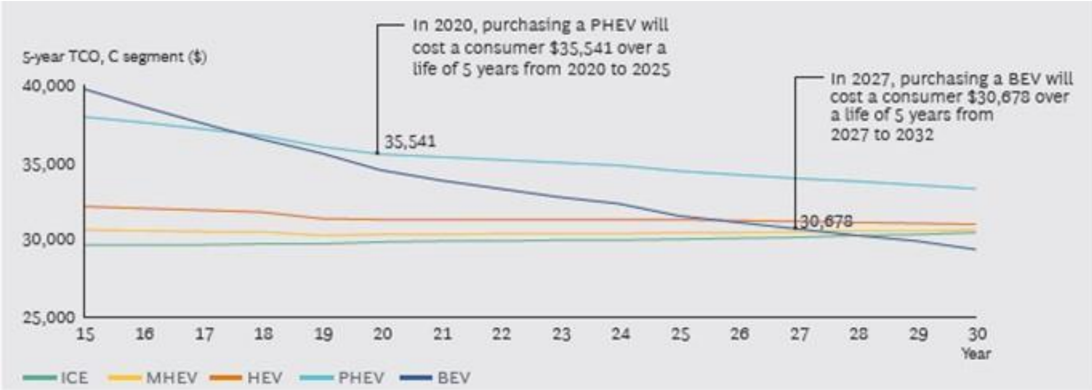
[65] See example comparison by Baik *et al* (2019)
[66] Breetz and Salon (2018)
[67] Raustad (2017); Hagman et al (2016)
[68] Hasan *et al* (2021)
[69] Propfe *et al* (2012); Noori and Tatari (2016)

parity has already been achieved,[70] others that it will be achieved by 2023 or earlier,[71] and others putting it closer to 2030 (see Figure 15).

Figure 15 Total costs of ownership - estimates for the USA



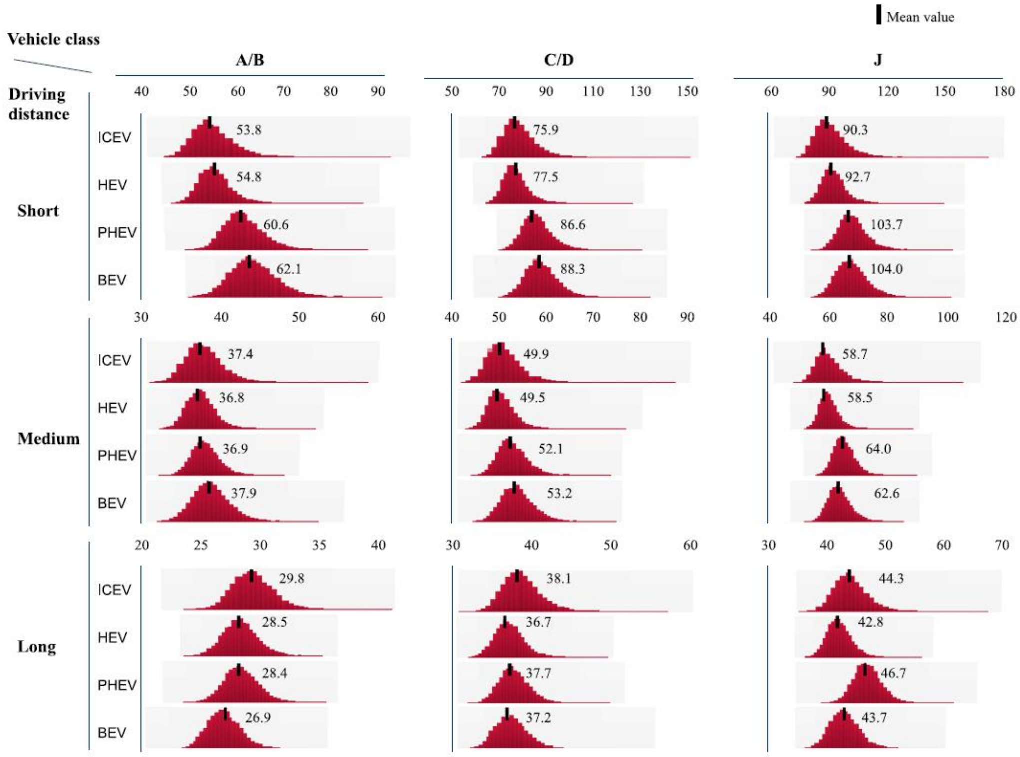
Note: MHEV = mild (or 48V) hybrid electric vehicles
Source: Mosquet et al (2018)

In New Zealand, a recent analysis has included the relative TCO for eight-year old used cars as well as new cars.[72] The authors suggest the TCO for a used BEV is lower than for a used ICEV, but the TCO for a new BEV is higher than for an ICEV. The used car result is influenced considerably by the less significant purchase price (and hence depreciation cost). Similar results were suggested by Verdant Vision (2017).

The assumptions used in analysis are important to the TCO results. A 2014 analysis of the German market (by Wu *et al*, 2015) suggests that BEVs have a lower relative TCO by 2025 only if travelling long distances. This is not likely for vehicles with limited range, used as second vehicles by households. Wu *et al* (2015) also examined the distribution of estimated 2025 costs around the mean (Figure 16), noting that in all size/distance categories, there were large overlaps between the costs for ICEVs, HEVs, PHEVs and BEVs, so that even if the mean cost of BEVs is estimated to be lower cost than ICEVs, there will still be ICEVs with each vehicle class that are lower cost than some BEVs. These broad findings are expected to continue to apply, such that assuming the ongoing availability of filling stations, servicing capability etc, ICEVs would be expected to continue to be purchased without deliberate policy interventions to eliminate them from the market.

[70] Harto, 2020
[71] Concept Consulting (2019); UBS (2017)
[72] Hasan *et al* (2021)

Figure 16 Distribution of TCO results in 2025 (all results in ct € per km)



Notes: A/B = small vehicles (eg Smart Fortwo, Fiat Panda, VW Polo, Mini Cooper); C/D = medium vehicles (eg VW Golf, Audi A3, BMW 3-series, Mercedes-Benz C-class); J = large/SUV vehicles (eg BMW X3, Nissan Qashqai, VW Tiguan). Driving distances: Short = 7,483km/yr; Medium = 15,184km; Long = 28,434km
Source: Wu *et al* (2015)

Purchase Price Parity

Industry analysts JATO estimate that the average retail price of an electric car was 81% higher than other cars bought by consumers in the first half of 2019. Bloomberg (2020) suggests purchase-price parity between BEVs and ICEVs by mid-2020s (without subsidies) in most vehicle segments, but with wide variation, eg large cars in Europe achieve parity by 2022, while small vehicles in India and Japan do not hit parity until after 2030 because of very low average current purchase prices in these segments.

Excluding battery cost, Navigant Consulting forecasts BEVs being 20% cheaper than comparable ICEVs to manufacture.[73] BEVs are lower cost to produce on the basis of raw materials, and a less complex drive-train than an ICEV; these cost savings are likely to be achieved by the mid-2020s. The overall purchase cost comparison with ICEVs then depends on the additional costs of batteries.

Purchase price differences are thought most likely to persist for lower-cost vehicles;[74] in New Zealand this is expected to be those under $35,000. In contrast, Table 9 shows a New Zealand price comparison for higher cost vehicles: Mini Coopers (close to $60,000) and BMW x3s (over $100,000), where prices are currently very similar for EVs and ICEVs.

[73] As reported by Energeia (2018)
[74] Soulopoulos (2017)

Table 9 New Zealand Price comparison for BMW and Minis

Model	Price	Notes
MINI Cooper SE BEV	$59,900	233km electric range
MINI Cooper S (similar equipment)	$58,000	
BMW X3 xDrive 30e PHEV	$107,700	55km electric range
BMW X3 xDrive 30i	$102,900	

Source: BMW NZ

In contrast, the Hyundai Kona comes in a petrol version (RRP of $31,490 - $41,990), but the similarly specified Kona Electric is priced from $78,990 to $85,990.[75] The latest model 40kWh Nissan Leaf has a current (February 2021) purchase price of $61,990[76] compared to a new Honda Civic with a current entry-level price of $32,990[77] and a Toyota Corolla at $29,990 or a hybrid version at $33,690.[78] For these price differences to narrow would require significant reductions in battery costs. Based on predicted large reductions in battery costs for Tesla production, Elon Musk has hinted at a US$25,000 BEV Tesla car by approximately 2023,[79] although its selling price in New Zealand is predicted to be closer to NZ$45,000.[80]

Some vehicle manufacturers are taking steps that could simplify and significantly reduce the costs of BEV manufacture. This includes Hyundai that has developed its Electric-Global Modular Platform (E-GMP), which is a standardised vehicle chassis onto which different vehicle models can be added.[81]

3.2.3 Battery Price Trends

The IEA (2020) notes that sales-weighted battery pack prices in 2019 were an average of US$156 per kWh, down from more than US$1,100/kWh in 2010 and Bloomberg estimated the price had fallen further to US$137/kWh in 2020.[82] Prices as low as $100/kWh have been seen in China,[83] but these low prices are not expected in other markets in the short run.

Boston Consulting Group summarised their own and other estimates of estimated battery price reductions over time (Figure 17); they estimate pack prices reaching $70-$90/kWh by 2030. Bloomberg (2020) suggests even lower prices, with pack prices falling below $100/kWh by 2024 and reaching $61/kWh by 2030, while noting high levels of investment will be needed to keep prices falling. This investment appears to be happening, as discussed above (Section 2.2.1).

75 Prices from Hyundai NZ, February 2021
76 https://www.nissan.co.nz/vehicles/browse-range/leaf/specs-and-prices.html
77 https://www.honda.co.nz/civic-hatch/
78 https://www.toyota.co.nz/new-car/corolla/corolla-hatch
79 https://www.forbes.com/sites/jamesmorris/2020/09/26/teslas-25000-electric-car-means-game-over-for-gas-and-oil/?sh=29a99321ee71
80 Hansen (2021)
81 https://www.hyundai.news/eu/brand/hyundai-to-lead-charge-into-electric-era-with-ev-platform-e-gmp/
82 https://www.bloomberg.com/news/articles/2020-12-16/electric-cars-are-about-to-be-as-cheap-as-gas-powered-models
83 https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/

Figure 17 Estimates of battery price changes over time

Source: Mosquet *et al* (2018)

Although battery prices are falling (and energy densities increasing), much of this efficiency gain has been taken up to date by increasing the size of the battery in a given size of vehicle. Thus, rather than the battery cost falling, the vehicle kilometre range is increasing.

The IEA (2020) suggests the average battery pack size for light BEVs and PHEVs was 44 kWh in 2020, up from 37 kWh in 2018, and BEV cars in most countries are in the 50-70 kWh range. They suggest average battery sizes for BEVs of 70-80 kWh by 2030. Near-term developments are enabling energy densities of up to 325 Wh/kg (up from c.110Wh/kg in 2010) and the IEA suggests pack-level energy densities could reach 275 Wh/kg, approaching the upper performance bounds of Li-ion technology.

Lithium-ion (Li-ion) batteries are the main type used for EVs and are expected to remain so for the next decade,[84] but after 2030 several potential technologies might see densities improve further. These include the lithium-metal solid state battery, lithium-sulphur, sodium-ion or even lithium-air.

Some interviewees in the current study are sceptical of falling prices reported by Bloomberg and others, suggesting that prices quoted are influenced by those in China where there are significant economies of scale and vertical integration in production. They also suggest the scarcity (and rising cost) of raw materials for batteries. The analysis in Section 2.2 above has not identified conclusive evidence that battery costs are not falling, while noting an expectation of long run reductions in battery costs.

3.2.4 Depreciation

Depreciation is the cost the purchaser faces. It is the purchase cost minus the discounted value of the future sale price as a used vehicle. Usually this is expressed as an annual percentage loss of value.

Depreciation rates are estimated to be high in New Zealand because of the higher levels of competition in supplies of used vehicles, which include both New Zealand new and imported used vehicles. This is true for EVs as well as other vehicle types. *Carspring* estimated three-year depreciation rates for new cars in New Zealand (not necessarily EVs) of 53.67%, which was

[84] IEA (2020)

higher than in all other countries examined and equivalent to a constant annual depreciation of 22.6%.[85] The Dog and Lemon Guide suggests 40% in the first year and 20% per year thereafter.[86]

International analyses have, with some exceptions,[87] suggested higher depreciation rates for BEVs than for ICEVs.[88] It seems likely that depreciation rates will be higher for BEVs while the technology and range expectation is increasing. This means next year's model is expected to be better than this year's, and a purchaser buying a one-year-old vehicle will discount the used vehicle significantly relative to a newly available vehicle with better kilometre range (or other capabilities).

Depreciation costs also reflect the time of battery replacement being brought closer, just as they also reflect future maintenance costs for ICEVs coming closer in time. Batteries are a significant component of BEV costs and they may need replacing after several years because of degradation (See Section 3.3.2). Analysis of Nissan Leafs for sale on TradeMe suggests Gen1 (8 or 9-year-old) Leafs have open road driving ranges of less than 80km (and slightly higher urban ranges).[89] This is significant in New Zealand because of their prevalence in the market, but as experience of other vehicles with improved battery technology increases, the fear of rapid depreciation is expected to recede.

3.2.5 Alternative Finance and/or Ownership Models

Alternative finance and ownership models, as being developed by the market, may be important to the increased penetration of EVs, given their current higher purchase prices but low running costs. Finance or ownership arrangements that spread costs over time can make vehicles more affordable for those with income constraints and reduce the cost differences between BEVs and ICEVs.

Several interviewees mentioned the UK experience, where reportedly 70-80% of new light vehicles are purchased using personal contract purchases (PCPs). PCPs are similar to lease arrangements, and include kilometre limits and penalties for vehicle damage, but unlike most leases they include options for purchase at a guaranteed price at the end of the term.[90] The monthly amount paid is equivalent to annual agreed depreciation of capital and interest payments. This reduces the monthly charge compared with traditional finance models which pay off the whole value of the vehicle (plus interest) over similar time periods, eg three or four years.

Similar arrangements are emerging in New Zealand, including Ford's Assured Future Value scheme[91] and Toyota's Choices Finance.[92]

Alternative approaches have different ownership arrangements, so that vehicles are held as long-term lease arrangements, for example. This is the approach used in the USA for the Honda

85 https://www.fleeteurope.com/en/features/depreciation-league-table-different-countries-different-values
86 https://dogandlemon.com/sites/default/files/depreciation_new_zealand.pdf
87 Raustad (2017); Hagman et al (2016)
88 De Clerck *et al* (2018); Breetz and Salon (2018); Lebeau et al (2013); https://www.nimblefins.co.uk/nissan-leaf-vs-pulsar-depreciation
89 Urban ranges achieved are longer because of lower air resistance at lower speed
90 https://www.moneyadviceservice.org.uk/en/articles/financing-buying-car-personal-contract-purchase-pcp
91 https://www.ford.co.nz/shopping/ford-assured-future-value/
92 https://www.toyota.co.nz/toyota-finance-leasing/finance-and-lease-options/

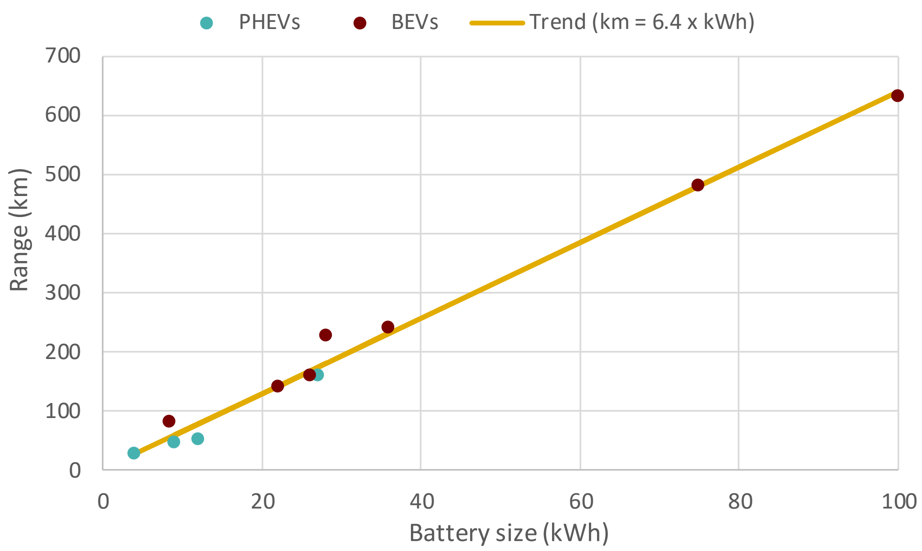
Clarity FCEV, which is only available as a lease vehicle.[93] In addition, EVs are available in New Zealand under car-sharing schemes.[94] These also make EVs more readily available.

3.3 Relative Usability of EVs

3.3.1 Battery Sizes and Vehicle Range

The kilometre range of a vehicle increases with the size of a battery. A review of the relationship between the manufacturer's stated battery size and suggested range is shown in Figure 18. It suggests a range of 6.4km/kWh, equivalent to an electrical requirement of 15.6kWh/100km. Other analyses include that of *Autoevolution* which suggest stated claims imply an efficiency range of 8–18kWh/100km.[95]

Figure 18 Relationship between battery size and kilometre range



Source: Denne and Stroombergen (2018)

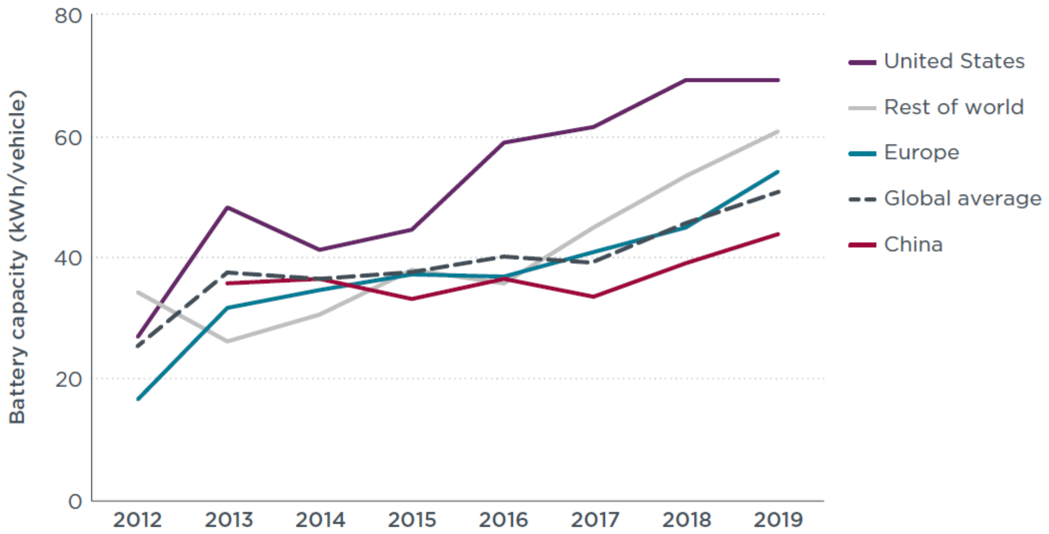
In practice the range will be different,[96] reflecting factors including driving behaviour (eg speed),[97] vehicle weight, ambient temperature and the battery's state of charge (SOC) relative to capacity.[98] Range varies significantly between urban use at low speeds, where air resistance is low, and open-road driving with greater air resistance. The open road range can be 20% or more less than that of urban driving.[99]

The limiting factor for extending vehicle range has been battery weight because of existing densities and price. As energy densities increase and per kWh prices fall, so does the potential for increasing battery capacity and kilometre range for a given price.

[93] https://automobiles.honda.com/clarity-fuel-cell
[94] See, for example: https://www.zilch.nz/ev-subscription/
[95] https://www.autoevolution.com/news/what-are-today-s-most-efficient-evs-139801.html
[96] Metcalfe and Sridhar (2016)
[97] Bi *et al* (2018)
[98] Varga *et al* (2019)
[99] This is identified from claimed kilometre ranges in TradeMe adverts for Nissan Leafs (February 2021)

Average battery sizes for light vehicles have been increasing over time in all markets (Figure 19), with sizes of 50-60kWh equivalent to a range of approximately 320-380km.

Figure 19 Average battery capacity in light vehicles



Source: Jin et al (2021) using data from EV-volumes.com

The EV kilometre range of vehicles, even early model Leafs, is greater than average trip lengths.[100] Whether this is an acceptable range for potential purchasers is debatable, particularly if people purchase their vehicles on the basis of occasional trips (eg holiday travel) rather than average daily trip length (as suggested by several vehicle industry interviewees). In New Zealand, 90% of daily vehicle travel is 90 km or less and the average around 30 km,[101] well within the single charge range of all available EVs. The Ministry for the Environment (MfE) suggests the driving range barrier may be psychological, based on what people are used to from ICEVs. They suggest "*it may be inevitable that some will see the shorter EV range as a significant 'loss' and, therefore, a major barrier*."[102]

A study by Deloitte used a survey to identify what minimum kilometre range people would find acceptable for them to consider purchasing a BEV alongside the percentage of people that drove 80km or less per typical working day. The results are shown in Figure 20 for a selection of countries included in the survey. It suggests that 73% to 94% of people travel 80km or less per day, but that acceptable driving distances were of at least 320 km for 40 to 60% of people and 480 km for 63% to 91% of people. The acceptable driving distances were longest in Germany (only 40% would find 320 km acceptable) and the USA (only 63% would find 480 km acceptable). However, this survey is over ten years' old and improvements in charging infrastructure and understanding of EVs may have changed the perceptions of required range.

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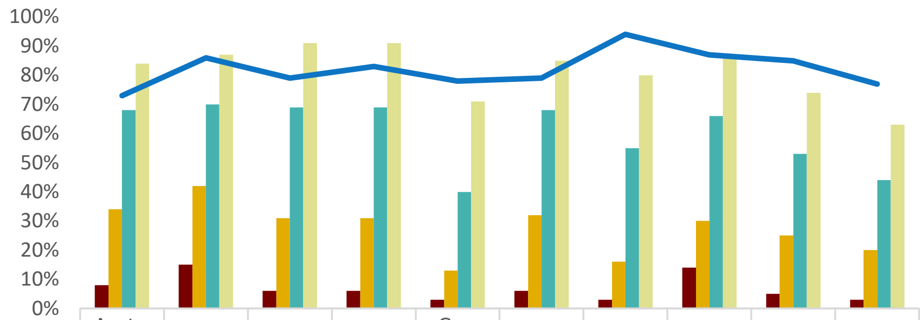
[100] LEK Consulting (2018)
[101] https://www.transport.govt.nz/statistics-and-insights/household-travel/by-vehicle/
[102] Ministry for the Environment (2018)

Figure 20 Range expectations for EV purchase

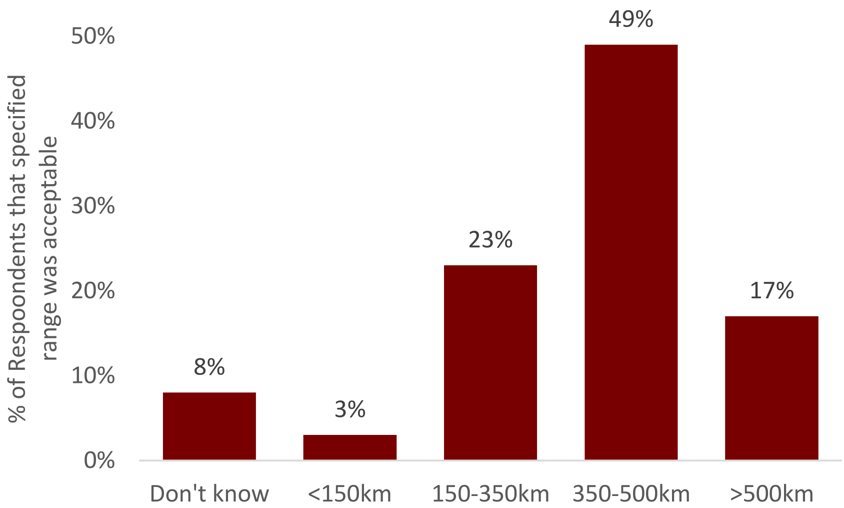


	Australia	Canada	China	France	Germany	Italy	Japan	Korea	UK	US
80 km	8%	15%	6%	6%	3%	6%	3%	14%	5%	3%
160 km	34%	42%	31%	31%	13%	32%	16%	30%	25%	20%
320 km	68%	70%	69%	69%	40%	68%	55%	66%	53%	44%
480 km	84%	87%	91%	91%	71%	85%	80%	87%	74%	63%
Drive ≤80 km	73%	86%	79%	83%	78%	79%	94%	87%	85%	77%

Source: Giffi *et al* (2011)

A similar New Zealand survey suggested that 26% of people would find a range of 350km or under acceptable and 75% of people would find a driving range of 500km or under acceptable (Figure 21). A range of 350-500km which would achieve a high level of acceptability is equivalent to a battery size of 55 to 80 kWh (Figure 18). Battery sizes in this range are becoming more common and are likely to be more widely available in the future. The IEA (2020) suggests that by 2030, BEVs will have average battery sizes of 70-80 kWh.

Figure 21 Desired range for purchasing an EV



Source: Zhu (2016)

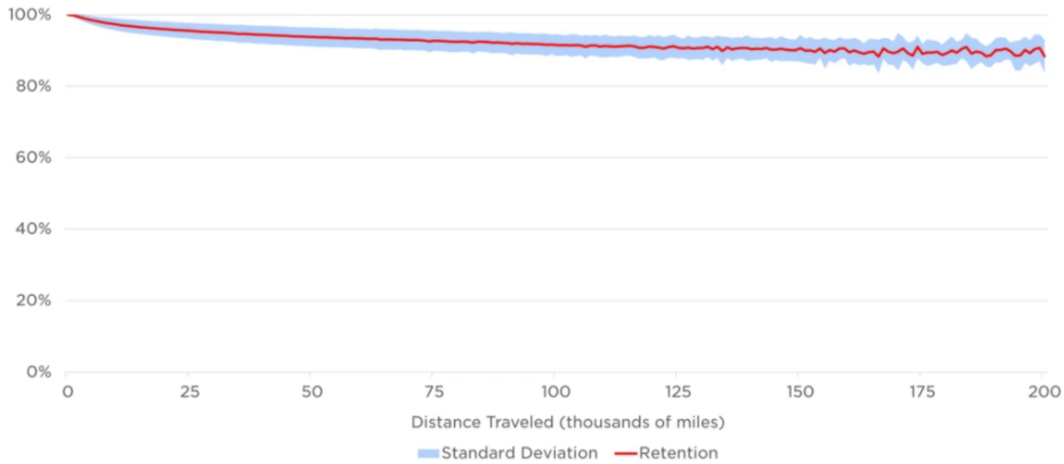
Although home-charging (see below) and short trips dominate the current use of EVs, longer range (along with improved public charging infrastructure) will be required for EVs to fulfil roles as primary vehicles for households rather than second vehicles, which (anecdotally) is the role they mainly fill currently.

3.3.2 Battery Degradation

Batteries degrade such that the vehicle range will fall over time and energy use per kilometre driven will increase. The rate of degradation provides a barrier to adoption of BEVs because it affects the future value of the vehicle and thus its annual depreciation. The degradation rate differs with the battery technology used, such as whether they have thermal management systems (eg Tesla does but Nissan Leafs do not). Without thermal management battery temperatures can rise during recharging and this leads to faster degradation.[103] There is some suggestion that fast-charging increases the rate of battery degradation, but the empirical results appear to be mixed.[104]

Figure 22 shows the relationship between battery age and capacity for Tesla S and X models. It shows around 10 to 15% battery degradation between 150,000 to 200,000 miles (240,000-320,000 kms). In contrast, research suggested the rate of degradation in the State of Health (SoH) of Nissan Leafs of 9.9% per annum reduction (30kWh battery version)[105] and a recent UK analysis of the performance of the 40kWh battery Leaf suggested a 15% degradation after 26,000 miles (41,600 km) and 34% after 56,000 miles (89,600km) (Figure 23).

Figure 22 Tesla Model S/X Battery Capacity Retention per Distance Travelled



Source: Lambert (2020)

Range degradation is also affected by ambient temperature. Yang *et al* found that under US state-level average driving conditions, batteries degraded in capacity by 30% in 5.2 years in Florida and 13.3 years in Alaska.[106] To our knowledge there is no detailed analysis of rates of degradation in New Zealand conditions.

Manufacturers are increasingly offering performance warranties, generally specifying them as guaranteeing between 75-80% of original battery capacity after 5-10 years.[107] This reduces risks to purchasers. However, these guarantees are not available to used vehicle purchasers, which are eligible for much reduced guarantees, eg GVI offers a 12-month guarantee on the battery against very fast degradation /failure.[108]

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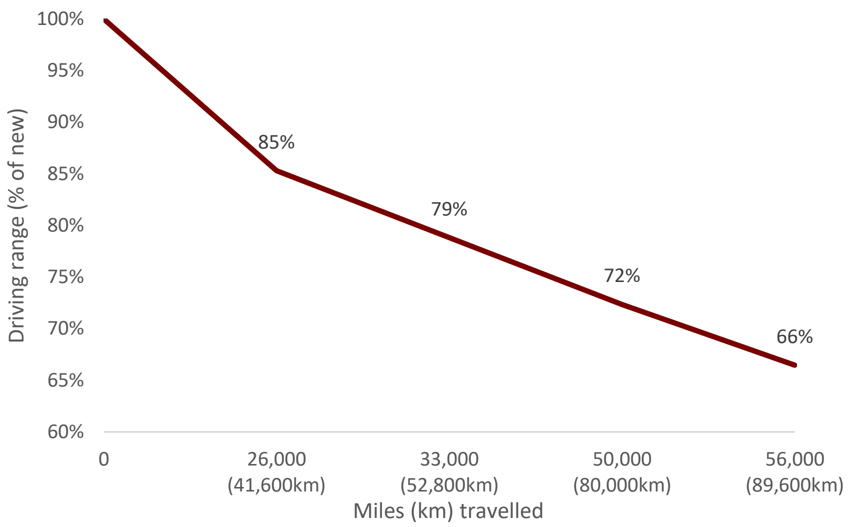
103 Karthik *et al* (2020)
104 https://www.myev.com/research/interesting-finds/is-dc-fast-charging-bad-for-your-electric-car
105 Myall *et al* (2018a,b)
106 Yang et al (2018)
107 Verdant Vision (2017)
108 Hayden Johnston, GVI, personal communication

Figure 23 State of Health of Nissan Leaf batteries



Source: Yurday (2020)

Battery degradation rates appear to differ significantly between vehicles. Degradation is affected by a wide range of factors, including cycle count, ie how often the battery is discharged and recharged.[109] This occurs more frequently for small battery vehicles. The degradation rate appears to be part of the reason that used Nissan Leafs can be purchased at such low cost (less than $7,000 on TradeMe for a Gen1 vehicle). The low range limits their use to second vehicles or to purchasers with very low usual travel distances. New Zealand buyers wanting a vehicle with greater range capability, and/or certainty that the vehicle will continue to provide adequate range for some years to come, need to pay considerably more.

3.3.3 Battery Refurbishment

A related issue of potential concern is the lack of supply of replacement batteries. Nissan NZ does not provide replacement batteries, although it does do cell repairs (if a few cells are damaged only). Currently there is no domestic source of genuine replacement Leaf batteries. One company (Blue Cars) is experimenting with domestic manufacture of batteries for Nissan Leafs. However, their current costs of manufacture are high ($20,000 per battery). It would often be lower cost to replace the vehicle with another used import. GVI is in discussions with another manufacturer about a similar service.

Lower cost replacement batteries are available in other countries. According to an on-line article in an Australian publication, Nissan Australia has "*introduced a subsidised battery exchange program for vehicles sold by its Australian dealers. Nissan Australia will exchange a working 24kWh battery, with a state of health of 8 bars or less, with a new 24kWh battery for $9,990 plus the cost of fitment*."[110]

If these issues are not resolved, they are likely to result in a higher level of price depreciation in EVs in New Zealand than in other countries, at least for some vehicles.

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[109] https://batteryuniversity.com/learn/article/bu_1003a_battery_aging_in_an_electric_vehicle_ev
[110] Aldons (2019)

In addition to replacement, some experimental refurbishments of batteries in New Zealand have been able to improve the battery SoH and this may extent the period before replacement is required.[111]

3.3.4 Ease of Charging

Recently, the president of the European Automobile Manufacturers' Association (ACEA) has suggested the shift to EVs to achieve the more stringent regulations will require a much more developed charging infrastructure, otherwise consumer demand will not meet policy makers' expectations.[112]

Most charging of light vehicles in New Zealand is using at-home, slow chargers. Public chargers supplement this, particularly for longer trips. The widespread assumption is that the charging infrastructure in New Zealand will expand with demand[113] and will not be a significant limiting factor, although this may need some coordination to ensure standardisation of equipment; we note that EECA is developing guidelines for EV chargers for domestic and commercial use.[114] The Waka Kotahi NZ Transport Agency set a vision in 2017 of fast/rapid DC charging stations every 75 kms across the state highway network, which is very largely complete.[115]

Currently the perceived level of public charging infrastructure is a barrier to vehicle owners considering switching to EVs; according to EECA research, in 2020 35-40% of survey respondents saw difficulties in finding public charging stations as a barrier to purchasing a BEV.[116] EECA is addressing this barrier directly through co-funding of public charging infrastructure.[117]

- Unless all there-and-back trips are within range, the low availability of charging stations reduces the effective range of an EV. People will recharge earlier than otherwise because of the risks of the next location being occupied or not working.

- The speed of charging diminishes with the percentage charged, especially when the battery is 80% or more charged. This means, when time-limited, BEV users may leave the charging station with a battery 80% charged or less,[118] thus limiting the effective range of the vehicle

Bloomberg (2020) suggests the ratio of EVs to public charging points varies widely but they suggest it will converge at around 40-50 for Europe and the USA by 2040. New Zealand currently has close to 500 available charging sites (40% of which are rapid DC-charging points),[119] suggesting a ratio of approximately 37 light BEVs per charging point. This is a greater

[111] http://www.thebatteryclinic.co.nz/nissan-leaf-ev-battery-reconditioning/
[112] https://www.euractiv.com/section/electric-cars/opinion/plugging-into-the-green-deal-europe-needs-charging-infrastructure/
[113] See current distribution here: https://www.journeys.nzta.govt.nz/ev-chargers
[114] https://www.eeca.govt.nz/our-work/product-regulations/standards-and-regulations-projects/publicly-available-specifications/
[115] See maps at: https://nzta.govt.nz/planning-and-investment/planning/transport-planning/planning-for-electric-vehicles/national-guidance-for-public-electric-vehicle-charging-infrastructure/enabling-a-nationwide-network-of-public-charging-infrastructure/
[116] Burroughs (2021)
[117] EECA, Low Emission Vehicles Contestable Fund (LEVCF)
[118] This is seen in other countries also, see: https://batteryuniversity.com/learn/article/bu_1003a_battery_aging_in_an_electric_vehicle_ev
[119] https://www.leadingthecharge.org.nz/charging-sites

density than the ratio suggested by Bloomberg, but the ratio is not necessarily a good indicator of the ease of finding a charger. When there are relatively few BEVs, even if there is a relatively high ratio of chargers to BEVs, there may still be relatively few chargers.

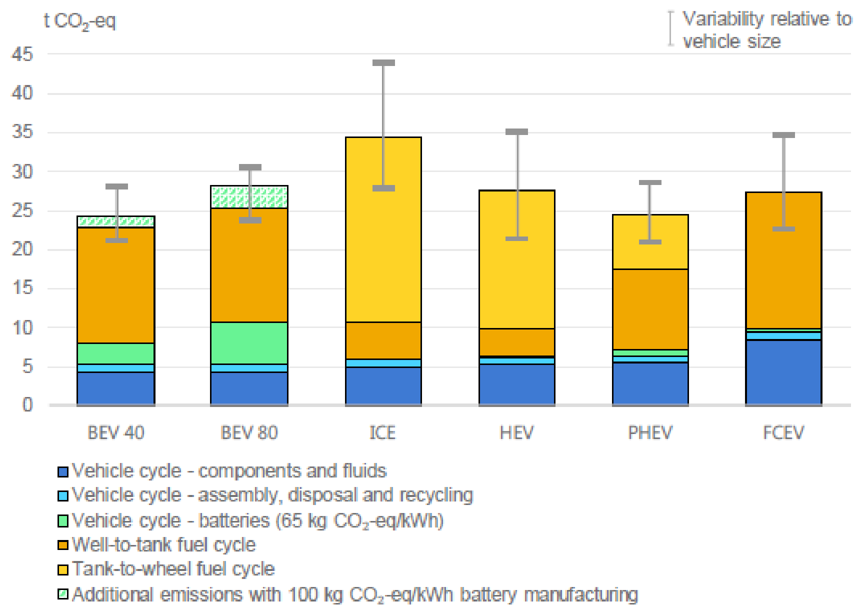
The importance of public chargers depends partly on whether charging requirements can be met at home. In Japan, many households do not have off-street parking, and this has limited demand for BEVs in the absence of a widespread public charging network. Similar constraints are likely to apply in Europe, although (as noted above) there are examples such as the roll-out of the government-funded on-street public charging scheme in the UK. This issue may be less problematic in New Zealand as, according to MoT data, about 92% of vehicles are parked on the resident's property overnight.[120] However, it becomes a perceived problem where BEVs are also intended for use for longer trips, even if only occasionally.

3.4 Disadvantages of EVs

According to industry interviewees, some disadvantages of EVs have been raised as concerns by potential purchasers that might reduce demand.

The relative GHG benefits of EVs is not straightforward, with ICEs having greater in-use (tank-to-wheel) emissions, but EVs having grater up-stream or manufacture (well-to-tank) emissions (see Figure 24). It is possible that these complexities, if more widely understood, might reduce relative demand amongst some potential purchasers. This is in addition to any concerns over disposal of batteries.

Figure 24 Comparative life-cycle GHG emissions over ten year lifetime of an average midsize car (2018)



Source: IEA (2020)

Battery disposal has become a concern for some potential purchasers of BEVs in New Zealand, ie it is mentioned by visitors to showrooms. The extent to which batteries can be repurposed (eg for home electricity storage) or recycled after use is being assessed by the Battery Industry

[120] Ministry of Transport (2015)

Group (BIG).[121] BIG is proposing a product stewardship scheme for large batteries under which importers would (voluntarily) take on responsibility for end-of-life recycling or reuse of the battery, at no cost to the vehicle owner.[122] This might be a necessary development to provide assurance to some customers.

3.5 EV Advantages

Although there are some barriers which limit demand for EVs, there are also advantages of BEVs over ICEVs in addition to fuel savings and lower maintenance costs. These would be expected to lead to increased demand, even if there is cost parity. These include better acceleration, lower engine noise and reduced emissions.

The lower environmental impacts in use (CO_2 and local airborne emissions) will also attract many buyers, at least amongst early adopters (see below).

3.6 Characteristics of Early Adopters

Current demand reflects the preferences of early adopters. Research by McKinsey in Shanghai and New York suggests they are mainly higher-income consumers with a distinct set of attitudes and behaviours.[123] They comprise two subgroups which the authors defined as: “trendy greens” (trendy, environmentally conscious, and willing to try new technology) and “TCO sensitives” (care about TCO, willing to change travel habits). Similarly, in Norway, early adopters are primarily high-income, well-educated consumers who are looking to save money, are concerned about the environment, or both.[124]

In the USA, consistent with EV buyers being high-income earners, 1.2% of new cars sold were EVs in 2017 but 24.1% were Tesla Model S and X which start at US$74,500; in contrast only about 1.5% of ICEVs sold in the USA were priced at more than $74,500.[125]

The profile in New Zealand is different, with 62% of EV registrations to January 2021 being used imports, of which 78% (or 48% of total registrations) have been used Nissan Leafs. These can be purchased for less than NZ$15,000. Teslas make up 8% of the total imports of EVs to date in New Zealand. The lowest cost Tesla, the Tesla 3 (60% of Tesla imports to NZ) has a lowest price of approximately $74,900.[126]

Because of the availability of used imports in New Zealand, BEVs are appealing to quite different market participants in low and high-cost ends of the market.

3.7 Insights from Demand Analysis

Potential demand constraints differ over the short and long run. They include the following.

To 2025:

[121] https://big.org.nz/
[122] BIG (2021)
[123] Amsterdam Roundtables Foundation and McKinsey & Company (2014)
[124] *ibid*
[125] Woo and Magee (2018)
[126] https://www.aa.co.nz/cars/buying-a-car/car-buying-guide/new-cars/new-car-prices/tesla/

- BEVs, in general, have higher purchase prices than ICEV equivalents, and this is most pronounced for lower-cost vehicles, ie those under $35,000. This is because battery costs, with acceptable range, are a higher percentage of total costs.

- Parity in TCO is expected to be widespread across vehicle categories, but not all purchasers of vehicles consider full TCOs, instead many focus more on the purchase price.

- Range anxiety, affected by limited vehicle range and perceived lack of public charging infrastructure, will continue to limit sales of many BEVs, particularly lower-cost, smaller-battery models, to second household vehicles or to users with small typical trip lengths.

- There are higher depreciation rates for those BEVs with more rapid degradation of batteries. This includes Nissan Leafs. This is made worse by the absence in New Zealand of reasonably priced battery replacement services.

- Development of product stewardship schemes are expected to allay most concerns over end-of-life management of batteries from EVs.

- Offsetting these constraints, EVs provide enhanced driving experiences, significantly lower running costs and reduced environmental impact, increasing their attractiveness to many drivers.

By 2030

- Purchase price differentials are expected to narrow, so that there is widespread price parity by 2030 or earlier.

- Range anxiety is expected to be much reduced with continual improvement in kilometre range. An acceptable range for most households is thought be 350-500 km, achievable with a battery of 55 to 80 kWh at current typical efficiencies. Batteries of this size are expected to be widely available in BEVs by 2030.

- Although most people charge their EVs at home, because they use them for longer trips also, range anxiety reductions depend on the roll-out of charging infrastructure, with consistent technologies and fast charging capability.

4 Conclusions

Table 10 below summarises the main issues discussed in this report and the conclusions reached.

4.1 Supply Issues

In the short run, to 2025, there are expected to be some supply constraints for new EVs because of limited EV production capacity which is initially focussed on providing supplies to markets with more stringent CO_2 policy requirements. In addition, there will be a limited number of vehicle categories available as EVs, which limits the extent to which anticipated demand can be met across all market segments. As global production rates increase this problem reduces and there are unlikely to be significant constraints by 2030.

Finite domestic sales of BEVs in Japan limits what is available as a pool of used vehicles available to import to New Zealand. And there are recent reductions in sales of New Zealand's most numerous import, the Nissan Leaf, in favour of HEV alternatives. Although EV sales will increase in Japan, increased competition for supplies from Australia is expected, with proposed legislative changes to liberalise import markets.

China is a major producer and consumer of EVs, although it is not a major exporter currently. Supplies from China in the future are likely to start with LHD markets, but in the long run (by 2030) they could be a significant source of EVs for New Zealand, and potentially an alternative to low-cost used imports.

The rate at which policy is targeting increases in EV supply is expected to have significant cost impacts on some OEMs, unable to avoid penalties under the CCS. The costs are likely to be passed on in higher retail prices, with some associated impacts on total demand and/or vehicle mix.

4.2 Demand Issues

Demand for BEVs is constrained by issues relating to relative costs and usability.

BEVs are expected to achieve purchase price parity with ICEVs by 2030, and TCO parity much earlier. However, differences are expected to persist longest for smaller, lower-cost vehicle categories, ie those competing with ICEVs selling for less than $35,000.

Range anxiety continues to be a concern for many BEV buyers, especially of low-cost, small-battery, vehicles. This will improve over time as battery prices fall and vehicle achievable ranges increase above 350km. Range anxiety will continue to 2025 but is not expected to be significant by 2030.

High depreciation rates for BEVs are associated with degrading batteries (and achievable ranges) and the absence of widespread battery replacement services, for some models at least (and notably Nissan Leafs). This is expected to improve as kilometre ranges improve and ancillary services develop (eg for battery replacement) with the increased market size.

There are some concerns over end-of life management of batteries, but these will reduce if effective product stewardship schemes develop, as currently being addressed by BIG.

EVs, and BEVs are expected to become a dominant part of the future New Zealand vehicle fleet, but such a significant change to the fleet will take time to achieve effectively and efficiently. By 2030, EVs are likely to be readily available for import across all vehicle categories at a price (even in the absence of policy incentives) that is competitive with ICEVs.

Table 10 Summary of Commentary on Potential EV Supply and Demand Constraints

Issues	To 2025	By 2030
Supply Constraints		
Are there limits to how many EVs can be imported?	*New vehicles:* There will be limits to what can be imported to New Zealand because of limited production capacity, focussed on supplies to more stringent policy-led markets.	*New vehicles*: There are unlikely to be supply constraints for imports of new EVs.
	Used vehicles: There are finite sales of EVs in Japan, particularly of BEVs for which there is a risk of fewer Leafs entering the market. Increased competition is expected from Australia, which will reduce potentially available supplies to New Zealand and/or increase their costs.	*Used vehicles*: More available supplies as EV sales increase, although with the risk of increasing competition.
Can vehicles be imported across all categories of demand?	Some vehicle types, and utes in particular, may not be widely available in BEV form for several years. This issue is most pronounced for used vehicles (where utes are not available as ICEVs either).	EVs available in most, if not all, vehicle categories.
Will battery costs continue to fall?	Battery costs for vehicles may not fall immediately as a result of increasing battery sizes (to increase vehicle range) and some supply interruptions (from Covid and short-run limits in raw materials while new technologies develop). Battery costs are expected to fall most for vertically-integrated producers. This includes Tesla and manufacturers in China, Japan and Korea.	Greater vertical integration is expected to result in falling production costs. Battery costs expected to fall to relatively low levels and new battery technology (eg solid-state) expected to be widely available.
Will alternative technologies displace BEVs in the supply market?	Ongoing R&D on alternative vehicle technologies (eg FCEVs, e-fuel) may still lead to significant market penetration, particularly in Japan. However, commitment of other countries to EVs suggests it is unlikely that these technologies will displace BEVs for the foreseeable future.	Mix of vehicles available, but with no significant constraints to EV supply to New Zealand.
Will there be low-cost Chinese vehicles available?	Not in significant numbers in the short run.	China is expected to become a significant producer and exporter of EVs.
Demand constraints		
Will BEVs continue to have higher purchase prices than ICEVs?	BEVs, in general, have higher purchase prices than ICEV equivalents, and this is most pronounced for lower-cost vehicles for which battery costs are a higher percentage of total costs.	Purchase price differentials are expected to narrow, so that there is widespread price parity by 2030 or earlier.

	Parity in TCO is expected to be widespread across vehicle categories, but not all purchasers of vehicles consider full TCOs.	TCO parity expected to be widespread.
How long will range anxiety be a demand constraint?	Range anxiety will limit sales of many BEVs, affected by a combination of limited vehicle range capability and perceptions of low public charger availability. This may limit sales (particularly of low-cost, small-battery vehicles) to second household vehicles or to users with small typical trip lengths.	Range anxiety is expected to be much reduced with continual improvement in kilometre range. Range anxiety reductions depend on the roll-out of charging infrastructure, with open and interoperable technologies and smart charging capability.
Will BEVs depreciate in value more than ICEVs?	There are higher depreciation rates for those BEVs with more rapid battery degradation. This is made worse by the absence in New Zealand of reasonably-priced battery replacement services for used vehicles.	With improvements in battery technologies, factors affecting higher depreciation rates are likely to disappear.
Are end-of-life batteries an emerging environmental problem for New Zealand?	Development of product stewardship schemes are expected to allay most concerns over end-of-life management of batteries from EVs.	

Glossary

ARENA	Australian Renewable Energy Agency
BEV	Battery Electric Vehicle
CCC	Climate Change Commission
CCS	Clean Car Standard
EECA	Energy Efficiency and Conservation Authority
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
LHD	Left Hand Drive
LPV	Light Passenger Vehicle
MBIE	Ministry of Business, Innovation and Employment
MHEV	Mild Hybrid Electric Vehicle
MIA	Motor Industry Association
MoT	Ministry of Transport
MSRP	Manufacturer's Suggested Retail Price
OECD	Organisation for Economic Cooperation and Development
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle
RHD	Right Hand Drive
SUV	Sports Utility Vehicle
US EPA	United States Environmental Protection Agency
VIA	Vehicle Industry Association

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