new energy futures paper: batteries

technical addendum

note

This Technical Addendum is intended to accompany the Vector New Energy Futures Paper on Batteries and the Circular Economy. With special thanks to Eunomia Research & Consulting for providing primary research and Thinkstep Australasia for providing information to Vector on battery Life Cycle Assessment.

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1. legislation and policy review

This section provides an overview of existing policy and legislative environment and potential future changes that may impact the uptake of large batteries and how they are managed through their life cycle.

1.1 Waste Minimisation Act 2008

The purpose of the Waste Minimisation Act 2008 (WMA) is to encourage waste minimisation and a decrease in waste disposal to protect the environment from harm and obtain environmental, economic, social and cultural benefits.

The WMA introduced tools to facilitate these goals, including:

- Waste management and minimisation plan obligations for territorial authorities
- A waste disposal levy to fund waste minimisation initiatives at local and central government levels
- Product stewardship provisions.

In brief, the WMA:

- Clarifies the roles and responsibilities of territorial authorities with respect to waste minimisation e.g. updating Waste Management and Minimisation Plans (WMMPs) and collecting/administering levy funding for waste minimisation projects.
- Requires that a Territorial Authority promote effective and efficient waste management and minimisation within its district (Section 42).
- Requires that when preparing a WMMP a Territorial Authority must consider the following methods of waste management and minimisation in the following order of importance:
    - Reduction
    - Reuse
    - Recycling
    - Recovery
    - Treatment
    - Disposal
- Puts a levy on all waste disposed of in a landfill.
- Allows for mandatory / regulated and accredited voluntary product stewardship schemes.
- Allows for regulations to be made making it mandatory for certain groups (for example, landfill operators) to report on waste to improve information on waste minimisation.
- Establishes the Waste Advisory Board to give independent advice to the Minister for the Environment on waste minimisation issues.

Various aspects of the Waste Minimisation Act are discussed in more detail below.

1.1.1 Waste Levy

From 1st July 2009, the Waste Levy came in to effect, adding $10 per tonne to the cost of landfill disposal at sites which accept household solid waste. The levy has two purposes, which are set out in the Act:

- To raise revenue for promoting and achieving waste minimisation
- To increase the cost of waste disposal to recognise that disposal imposes costs on the environment, society and the economy.

This levy is collected and managed by the Ministry for the Environment (MfE) who distribute half of the revenue collected to territorial authorities (TA) on a population basis to be spent on promoting or achieving waste minimisation as set out in their WMMPs. The other half is retained by the MfE and managed by them as a central contestable fund for waste minimisation initiatives.

Currently the levy is set at $10/tonne and applies to wastes deposited in landfills accepting household waste. The MfE published a waste disposal levy review in 2017.[1] The review indicates that the levy may be extended in the future, and the current government has signalled their intention for it to be extended and raised, although there is no publicised timetable for this, and no indication of the potential future rate of the levy.

1.1.2 Product Stewardship

Under the Waste Minimisation Act 2008 if the Minister for the Environment declares a product to be a priority product, a product stewardship scheme must be developed and accredited to ensure effective reduction, reuse, recycling

[1] Ministry for the Environment. 2017. Review of the Effectiveness of the Waste Disposal Levy 2017. Wellington: Ministry for the Environment.

or recovery of the product and to manage any environmental harm arising from the product when it becomes waste.[2]

So far, no products have been declared to be ‘priority products’. There are, however, a number of voluntary product stewardship schemes. These can be ‘accredited’ by the Minister.

The following voluntary product stewardship schemes have been accredited by the Minister for the Environment:[3]

- Agrecovery rural recycling programme
- Envirocon product stewardship
- Fonterra Milk for Schools Recycling Programme
- Fuji Xerox Zero Landfill Scheme
- Holcim Geocycle Used Oil Recovery Programme (no longer operating)
- Interface ReEntry Programme
- Kimberly Clark NZ’s Envirocomp Product Stewardship Scheme for Sanitary Hygiene Products
- Plasback
- Public Place Recycling Scheme
- Recovering of Oil Saves the Environment (R.O.S.E. NZ)
- Refrigerant recovery scheme
- RE:MOBILE
- Resene PaintWise
- The Glass Packaging Forum

Further details on each of the above schemes are available on: http://www.mfe.govt.nz/waste/product-stewardship/accredited-voluntary-schemes

No priority products have been declared at the time of writing, although there has been notable recent progress in this space:

- The Government has announced a ban on single plastic shopping bags
- Consultation has been undertaken on proposals to declare six product groups as ‘priority products’ (further priority products may be declared later): tyres, electrical and electronic products, refrigerants and other synthetic greenhouse gases, agrichemicals and their containers, farm plastics, and packaging. The potential scope for electrical and electronic products is as follows:

a) large rechargeable batteries designed for use in electric vehicles, household-scale and industrial renewable energy power systems including but not limited to lithium-ion batteries

b) all other batteries (e.g., batteries designed for use in hand-held tools and devices)

c) all categories of waste electrical and electronic equipment (WEEE) defined in Annex II of European Directive 2012/19/EU (e.g., ‘anything that requires a plug or a battery to operate’).

The Ministry for the Environment has indicated they propose to:

- Set a framework for product stewardship, by declaring certain products as ‘priority products’
- Issue guidelines that priority product schemes applying for accreditation will be expected to meet
- Work with stakeholders to design:
  - Appropriate schemes for accreditation under the WMA
  - Ways to ‘level the playing field’ (potentially using the WMA or other regulations)
- Monitor scheme outcomes
- Enforce any regulations

1.1.3 Regulated Product Stewardship for large batteries

In May 2019 Hon. Eugenie Sage, the Associate Minister for the Environment, announced “The Ministry for the Environment is developing a mandatory product stewardship scheme for e-waste, which would make manufacturers responsible for managing the ‘end-of-life’ aspects of their products.”

As discussed above, the Ministry for the Environment (MfE) has proposed lithium-ion batteries as a category in an E-waste priority product group.

[2] Waste Management Act 2008 2(8)
[3] http://www.mfe.govt.nz/waste/product-stewardship/accredited-voluntary-schemes

Discussions with MfE staff indicate the following:

- The scheme is likely to be a regulated, co-designed model. The aim would be to ensure fairness, surety of outcomes and to avoid free riders.
- Other schemes are likely to be implemented before batteries as work on some e.g. tyres have been several years in development, but work on a battery scheme could be advanced due to the level of industry engagement.
- The scope of the scheme is likely to be end-of-life.
- MfE will use guidelines to set objectives rather than specifics.
- The Minister is interested in approaches which will see the industry have an interest in ensuring good outcomes. In setting objectives consideration needs to be given to how these will be monitored and measured, what the intended as well as unintended consequences might be, what level of access people will have to schemes (e.g. national coverage, rural areas), likely collection rates, cost of funding collection and processing etc.

Vector has convened a Battery Industry Group (B.I.G.) to design a proposal for a product stewardship scheme for large batteries with a focus on lithium-ion, which supports the circular economy. The context for B.I.G. is provided by the Vector New Energy Futures Paper on Batteries and the Circular Economy and this Technical Addendum.

1.1.4 Waste Minimisation Fund

The Waste Minimisation Fund has been set up by MfE to help fund waste minimisation projects and to improve New Zealand’s waste minimisation performance through:

- Investment in infrastructure;
- Investment in waste minimisation systems and
- Increasing educational and promotional capacity.

The latest round of the fund sought projects that would assist New Zealand in a transition to a circular economy.

Several projects relating to battery stewardship / circular economy solutions for batteries have recently sought funding from the Waste Minimisation Fund.

1.2 Emissions Trading Scheme

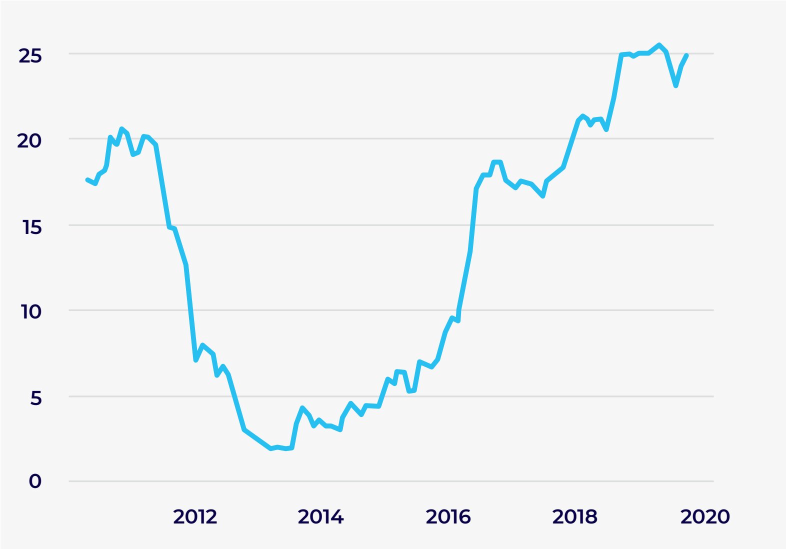
The New Zealand Emissions Trading Scheme (NZ ETS) was established in 2008 as a tool to help New Zealand meet its international climate change obligations and reduce its net greenhouse gas emissions to below business-as-usual levels.

The NZ ETS provides a mechanism that puts a price on emissions and removals, allowing them to be traded on a market. NZ ETS participant sectors are required to surrender New Zealand emissions units (NZUs) for each tonne of CO2 equivalent (CO2e) that they produce.

The NZ ETS is relevant in this context as NZU prices signal the costs of emissions to producers and consumers. A higher NZU price can drive up the price of fossil fuels, making non or low carbon emitting energy alternatives more competitive.

The values of NZUs (and hence the impact of the NZ ETS) has varied significantly over time. This is shown in the chart below:

Figure 1: Value of NZ Units Over Time (NZ$)



Source: https://en.wikipedia.org/wiki/New_Zealand_Emissions_Trading_Scheme

The drop in price around 2012-13 was due to the low international carbon price and the ability to accept cheap international units as equivalent to NZUs. The price has been as low as $2, although since, in June 2015, Government moved to no longer accept international units in NZ ETS, the NZU price has increased markedly, and has been trading around $25.

1. legislation and policy review continued

In this context liquid fossil fuels and stationary energy had full obligations under the scheme from 1 July 2010. This means that the cost of the ETS would (in theory) be reflected in petrol prices.

The level of impact from the ETS is dependent on the amount of CO2e assumed to be emitted for each litre of petrol consumed and the price of NZUs. The standard figure used in greenhouse gas (GHG) calculations for petrol is 2.33kg of CO2 for each litre of petrol consumed.[4]

With the current carbon price of approximately $25 per tonne this would add approximately $0.06 per litre. When the price was $2 per tonne[5] the added cost for petrol would have been less than one cent. The net effect of the ETS is currently 2-3% increase in cost.

Research suggests that demand for petrol does respond to changes in price, but that the price elasticity is relatively low. A 10% increase in price would lead to a 2% decrease in consumption in the medium term.[6]

A 3% increase in cost would therefore equate to a less than 1% change in consumption. This suggests that even if the cost of NZUs under the ETS were to increase substantially it is unlikely to – on its own – lead to a significant shift in consumer behaviour.

1.2.1 Proposed Changes to the NZ ETS

In December 2018, the Government announced a first tranche of decisions to improve the NZ ETS. These include:

- Aligning the Climate Change Response Act 2002 (CCRA) with the Paris Agreement and any emission reduction targets by refining the purpose of the CCRA to ensure it assists with the delivery of any new targets, and supporting the implementation of the Paris Agreement;
- Enabling a cap to be placed on emissions covered by the NZ ETS through:

  1) introducing the auctioning of New Zealand Units (NZUs) in a way that aligns the supply of NZUs in the NZ ETS with emission reduction targets; 2) retaining the ability to limit international units if a decision is made to introduce the use of international units; 3) replacing the current $25 fixed price option with a cost containment reserve through auctioning, and investigating a price floor; and 4) providing the framework for making unit supply settings in the NZ ETS over a five-year rolling period; and
- Improving the administration and operation of the NZ ETS through improvements to the compliance regime, strengthening market governance, and operational and technical improvements.[7]

The second tranche of decisions, announced in May 2019, includes the following:

- Improving transparency within the NZ ETS;
- Increasing compliance rates within the scheme;
- Paving the way for robust NZ ETS auctions;
- Ensuring that the fixed price option is removed no later than the end of 2022; and
- Enabling a price floor to be added to the NZ ETS if necessary in the future.[8]

These changes will be introduced through a single bill amending the CCRA in 2019.

1.3 Climate Change Response (Zero Carbon) Amendment Bill

The Zero Carbon Bill, which passed its third reading on 7th November 2019, aims to set an overarching legally binding framework for New Zealand to reduce its greenhouse gases to net zero by 2050. The Bill aims to:

- Set a new greenhouse gas emissions reduction target to:
  - reduce all greenhouse gases (except biogenic methane) to net zero by 2050
  - reduce emissions of biogenic methane within the range of 24–47 per cent below 2017 levels by 2050 including to 10 per cent below 2017 levels by 2030.
- Establish a system of a series of emissions budgets to act as stepping stones towards the long-term target.
- Require the Government to develop and implement policies for climate change adaptation and mitigation.
- Establish a new, independent Climate Change Commission to provide expert advice and monitoring to help keep successive governments on track to meeting long-term goals.

The consultation document, released in the lead up to the Bill being introduced, referenced economic modelling which attempts to forecast the changes that would be required and the impact on the economy from meeting the target(s). If the target is to be met, the modelling projects that 95% of the light vehicle fleet and 50% of the heavy vehicle fleet will have to transition to EV by 2050.

1.4 Electric Vehicles Programme

The electric vehicles programme is a government initiative introduced in May 2016 aimed at increasing the uptake of electric vehicles (EVs) in NZ. It has a goal of reaching approximately 64,000 EVs on our roads by the end of 2021.

The programme aims to help develop the EV market in New Zealand by reducing some of the barriers and investigating ways to further support the uptake of EVs.

Key initiatives of the programme are:

- Extending the road user charges (RUC) exemption on light EV vehicles until they make up two percent of the light vehicles fleet.
- RUC exemption for heavy electric vehicles until they make up 2 per cent of the heavy vehicle fleet. The exemption applied from 1 Sept 2017.
- Work across government and the private sector to investigate the bulk purchase of EVs. The main initiative here is to encourage the purchase of EVs in the government vehicle fleets through New Zealand Government Procurement (NZGP). There are 15 models approved under the NZGP 'all of government' procurement contract. In addition, there is a pilot programme for EV purchases.
- Coordination and support for the roll out of EV charging infrastructure. This includes guidance on the development of public charging infrastructure.[9]
- $1 million annually for a nationwide EV information and promotion campaign over five years.
- A contestable fund of up to $7 million per year to encourage and support innovative low emission vehicle projects. The fund will provide up to 50% of project costs. To date 69 projects have been approved for funding. The projects range from establishing charging stations to building electric vehicles and setting up EV car sharing schemes.[10]
- Enabling road controlling authorities to allow EVs into special vehicle lanes on the State Highway network and local roads. Road controlling authorities are able to make bylaws to allow EVs access to special vehicle lanes (including transit, high occupancy vehicle, priority bypass, and bus lanes). There was a one-year trial in Auckland which has now been completed. A survey following the trial found that being able to use priority lanes was not a significant factor in motorists' decisions on whether or not to purchase and EV. The outcomes of the trial are being fed in to a review.[11]
- Review of tax depreciation rates and the method for calculating fringe benefit tax for EVs to ensure these are not being unfairly disadvantaged.
- Review ACC levies for plug-in hybrid EVs. ACC levy rates for 2017/18 and 2018/19 will see owners of all EVs (including owners of plug-in hybrid EVs) pay reduced ACC levies as part of their annual vehicle licensing. This reflects a saving of around $68 per annum for EV owners. The changes took effect on 1 July 2017.
- Establishing an EV leadership group across business, local and central government.

[4] http://www.mfe.govt.nz/publications/climate-change/guidance-voluntary-corporate-greenhouse-gas-reporting-data-and-methods-7
[5] https://carbonmatch.co.nz/
[6] Kennedy, D., Wallis, I. 2007. Impacts of fuel price changes on New Zealand transport. Land Transport New Zealand Research Report 331.
[7] https://www.mfe.govt.nz/node/25172
[8] https://www.beehive.govt.nz/release/latest-emissions-trading-scheme-reforms-target-transparency-and-compliance

[9] https://www.nzta.govt.nz/planning-and-investment/planning/transport-planning/planning-for-electric-vehicles/national-guidance-for-public-electric-vehicle-charging-infrastructure/
[10] https://www.eeca.govt.nz/funding-and-support/low-emission-vehicles-contestable-fund/low-emission-vehicles-contestable-fund/
[11] https://www.nzta.govt.nz/media-releases/auckland-electric-vehicle-priority-lane-trial-ends-this-week/

1.5 Electric Vehicles Programme

In July 2019, The Ministry of Transport (MoT) published a discussion paper on a Clean Car Standard and Clean Car Discount. The policies being consulted on in the discussion paper are focused on reducing emissions in the light vehicle fleet, which account for almost two-thirds of transport emissions.

The Clean Car Standard would focus on:

- Improving the vehicles entering the fleet (i.e. new and used imports)
- Reducing vehicle fuel consumption and the amount of CO2 emitted by vehicles
- Incentivising the supply of zero- and low-emissions vehicles such as EVs and petrol hybrids

To support the Clean Car Standard, the Government is proposing the Clean Car Discount to influence consumer demand. The Clean Car Discount is a feebate scheme and aims to make fuel efficient and low-emissions vehicles more affordable for New Zealanders to purchase.

With the proposed Clean Car Discount, consumers would either receive a discount or pay a fee, or avoid both, depending on the CO2 emissions of the vehicle they are buying. The discounts and fees would be displayed on vehicles available for sale. Less emissions-intensive vehicles, including EVs, would receive discounts, while vehicles with higher emission would incur fees. Mid-range emitting vehicles would face neither a discount nor a fee. The Clean Car Discount will be timed to replace the exemption from RUC, an initiative in the electric vehicles programme.

Submissions on the proposed Clean Car Standard and Clean Car Discount closed on 20 August 2019.

1.6 Voluntary Codes of Practice

1.6.1 Motor Industry Association: Code of Practice - Recycling of Traction Batteries (2014)[12]

The Motor Industry Association of New Zealand Inc (MIA) represents the official importers and distributors of new cars, trucks and motorcycles to New Zealand. It is a voluntary organisation with 41 members representing 78 brands. It provides an industry voice for new vehicle sector.

The code of practice states the following:

> MIA members will have suitable systems in place to monitor the use, capture, return, re-furbish/re-use or recycle/dispose of traction batteries from EV/PHEV/HEVs[13]. The systems will include recovery mechanisms capable of maximizing the value from re-use of finite resources with the aim of no traction batteries ending up in landfills. MIA members may use internal company processes that comply with all relevant legislation or standards. Members will provide information to vehicle owners/operators on their preferred battery recycling program. Alternatively MIA members may join a battery recycling program that is accredited by the New Zealand Government.

Outline of Process

- The holder of a traction battery (e.g. dealer, repairer) inspects traction battery
- If the battery is leaking, damaged or has reached the end of its practical life, then contact OEM for recycling details
- OEM implements their internal process for recycling

The code of practice is voluntary, and it is not known to what extent it is monitored.

1.6.2 Australian Battery Recycling Initiative (ABRI)[14]

The Australian Battery Recycling Initiative (ABRI) is a not-for-profit organisation established in 2008 to promote responsible environmental management of batteries at end of life. ABRI has 37 members and affiliates including battery manufacturers, consumer electronics suppliers, recyclers, government agencies and environmental organisations.

ABRI is actively involved in negotiations to establish a national stewardship program for handheld batteries.

[12] https://www.mia.org.nz/Portals/0/MIA-CodesAndPractice/Code%20of%20Practice%20for%20Recyling%20of%20Traction%20Batteries.pdf
[13] EV refers to electric vehicles, HEV to hybrid electric vehicles and PHEV to plug-in hybrid electric vehicles
[14] https://www.batteryrecycling.org.au/home

1.7 International Agreements

1.7.1 Basel Convention

The 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (commonly called the Basel Convention) aims to reduce the amount of waste produced by signatories and regulates the international traffic in hazardous wastes. It requires prior approval of hazardous waste imports and exports and requires exporting countries to ensure that hazardous waste will be managed 'in an environmentally sound manner'. The Convention emphasises the principle of 'generator responsibility' for disposal of wastes and requires parties to minimise the environmental effects of the movement and disposal of hazardous waste.[15]

In terms of batteries, the Basel Convention only specifically identifies batteries containing mercury, cadmium and lead as hazardous waste. It does not recognize the presence of other constituents in alkaline manganese and zinc carbon batteries (e.g. zinc and copper compounds) as sufficient to render them hazardous; accordingly, these batteries are non-hazardous waste.[16]

However, the main way that the Basel Convention is applied in NZ is through the Imports and Exports (Restrictions) Prohibition Order (No 2) 2004[16] Under this Prohibition Order lithium-ion batteries would be classified as hazardous waste (and therefore be controlled) due to having flammable, spontaneous combustion or corrosive properties.

A Basel permit must be granted to enable hazardous waste to be shipped to other parties who are a part of the Basel Convention. This applies whether the wastes are being shipped for the purposes of recovery or treatment and disposal.

1.7.2 Waigani Convention

The Waigani Convention is a regional agreement under the 1989 Basel Convention. It applies the strict controls of the Basel Convention to the South Pacific area and ensures that hazardous waste cannot travel from New Zealand or Australia to another Pacific country, or to Antarctica.

1.7.3 Australian Product Stewardship Act 2011

The Product Stewardship Act 2011 provides the framework to effectively manage the environmental, health and safety impacts of products, and in particular those impacts associated with the disposal of products and their associated waste. The framework includes voluntary, co-regulatory and mandatory product stewardship. The passage of the legislation delivered on a key commitment by the Australian Government under the National Waste Policy; a policy that was agreed by governments in November 2009 and endorsed by the Council of Australian Governments in October 2010.

The Act supports the National Television and Computer Recycling Scheme (NTCRS) through the Product Stewardship (Televisions and Computers) Regulations 2011. The scheme has recycled approximately 230,000 tonnes of electronic waste since its inception. This review is an important opportunity to continue to update and improve the NTCRS.

The Minister's Product List is established by the Act and is updated annually. The list informs the community and industry of those products being considered for accreditation or regulation under the Act.[17] At present the Minister's Product Stewardship list currently includes: plastic microbeads and products containing them, batteries, photovoltaic systems, electrical and electronic products, and plastic oil containers.

In Australia, the Minister for the Environment has listed batteries in the 2017-18 product list in accordance with Section 108A of the Product Stewardship Act 2011 (see Section 1.6.2). The Government, as at the date of notice 30 June 2017, expects that industry will establish a product stewardship scheme to ensure that arrangements are in place to deal safely and efficiently with these batteries before they begin to enter the waste stream in more significant quantities.

Work on a scheme for smaller, hazardous batteries is ongoing. The Queensland Government and industry are leading this process, with support from the Australian and other state and territory governments. Batteries weighing up to 5kg were first listed in 2014-15 and the listing was expanded to include all batteries in 2016-17.[18]

[15] http://www.mfe.govt.nz/more/international-environmental-agreements/multilateral-environmental-agreements/key-multilateral-0
[16] https://www.nema.org/Policy/Environmental-Stewardship/Documents/Treatment%20Basel%20Convention.pdf
[17] http://www.environment.gov.au/protection/waste-resource-recovery/product-stewardship/consultation-review-ps-act-incl-ntcrs
[18] Source: https://www.environment.gov.au/protection/waste-resource-recovery/product-stewardship/legislation/product-list-2017-18

1.8 Future Policy Signpost: Productivity Commission Report

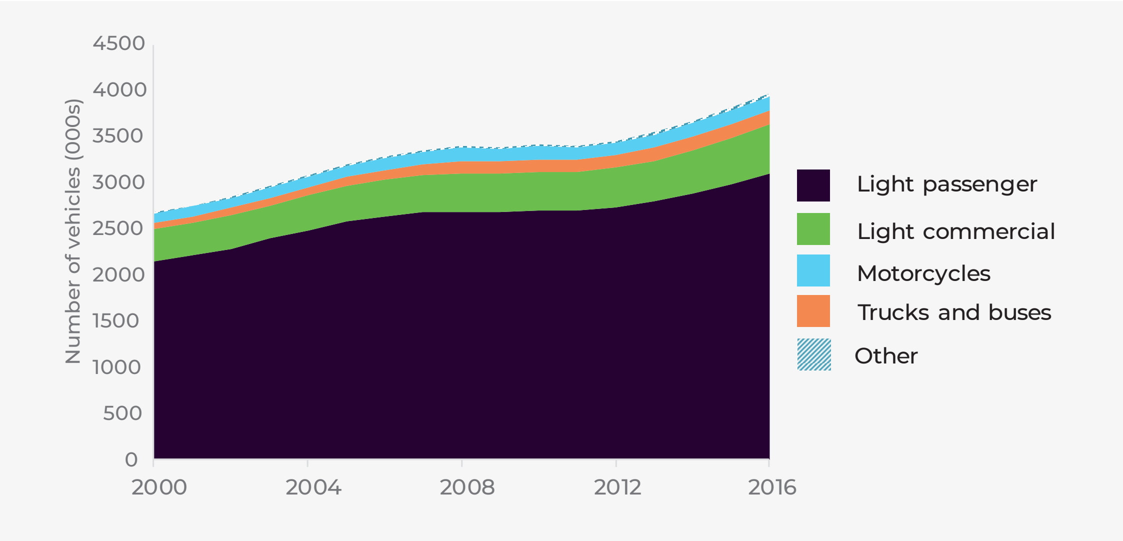
The Productivity Commission (PC) released its final report on a 'Low Carbon Economy' on 3 Sept 2018.[19] The report includes sections on electrifying New Zealand's vehicle fleet and on electricity generation. Each of these are discussed separately below:

1.8.1 Electrifying New Zealand's Vehicle Fleet

The PC report calculates that for the vehicle fleet to be largely zero emission by 2050, all vehicles entering the fleet will need to be zero emission by 2030. This would imply a very steep trajectory over the next 12 years.

There are currently just over 4 million vehicles in NZ. About 335,000 vehicles are added to the fleet each year with 170,000 leaving.[20]

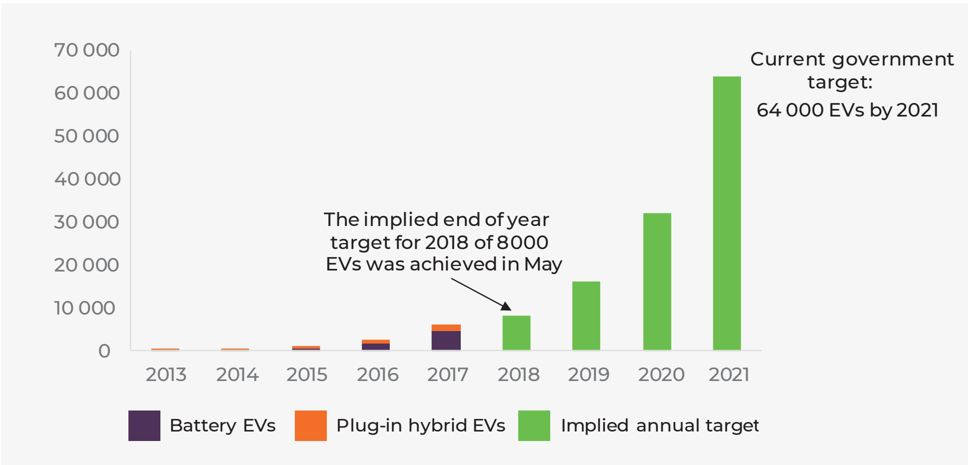
Figure 2: Number of Vehicles in New Zealand Over Time



Source: New Zealand Productivity Commission. (2018). Low-emissions economy: Final report. Available from https://www.productivity.govt.nz/sites/default/files/Productivity%20Commission_Low-emissions%20economy_Final%20 Report_FINAL.pdf

To meet the Government's target of 64,000 electric vehicles by 2021, a doubling of the numbers of EVs is required each year between 2016 (base year) and 2021. This is shown in the chart below.

Figure 3: Adoption of EVs Over Time



Source: MoT (2018a) Note: The implied yearly targets are calculated from a baseline of 2000 EVs in 2016, doubling each year to 64, doubling each year to 64000 in 2021.

[19] New Zealand Productivity Commission. (2018). Low-emissions economy: Final report Available from www.productivity.govt.nz/low-emissions
[20] Ministry of Transport Annual fleet statistics 2017

As of September 2019, there were 17,026EVs registered in NZ, which is ahead of the target number for 2019.[21]

The PC report identifies the key barriers to uptake of EVs as:

- the upfront price premium compared to petrol and diesel vehicles;
- limited travel range, and associated range anxiety;
- the lack of public awareness and understanding of EVs; and
- constraints on supply and lack of model options.

The biggest of these barriers it considers to be the upfront price. It identifies four key components of a policy package to support EV uptake:

- **Introduction of a feebate scheme.** Vehicles would be assessed for the GHG emissions potential. Emissions above a given benchmark would incur a fee based on the level of emissions, while those below the benchmark would receive a rebate. This would impact the cost of ownership for both EVs and non-EVs. The scheme could be revenue neutral.
- **Government leadership in procurement.** Government organisations own about 25,000 light vehicles, and purchase about 4,000 vehicles each year. The Government's coalition agreement sets out a goal of achieving an "emissions-free" government fleet, where practical, by 2025/26. The Government has however recently revised this target to a commitment that after mid-2025, all new vehicles entering the fleet will be emissions-free.[22]
- **Sufficient provision of charging infrastructure.** The report notes that the charging infrastructure is growing rapidly, and the majority of the state highway network is within 75km of a fast charger. However, it also notes that some gaps still exist.
- **Better regulation of fossil fuel vehicles.** The PC report recommends introducing CO2 emissions standards for vehicles entering the NZ fleet. It also recommends the removal of existing tariffs for EVs (buses, motor homes, ambulances) and EV parts.

1.9 Summary of Legislative and Policy Context

The current legislative and policy environment in New Zealand is broadly conducive to the uptake and expansion of battery power systems, there are not currently any strong drivers (such as subsidies to purchase EVs, or emissions standards), or impediments that would unduly limit battery uptake. However, the Government has announced their intention for incentives to encourage the uptake of EVs. The PC recommends a number of minor changes to facilitate the uptake of EVs and battery storage but does not put forward any aggressive measures that would ensure an accelerated uptake. More recently, the Government has announced proposals based on the PC recommendations for a 'feebate' scheme which will provide incentives of up to $8,000 for zero and low emission vehicles newly imported into NZ, with the cost of the incentives met by charges of up to $3,000 on high emission vehicles newly imported into NZ.[23]

The management of end of life/end of use batteries is, at present, largely unregulated. There are no product stewardship schemes in place for large batteries and, beyond the need to comply with export requirements, there are no restrictions around establishing e-waste and battery recycling operations. Other than voluntary codes of practice, there are no established procedures or guidelines for how end of life batteries should be managed.

[21] https://www.transport.govt.nz/mot-resources/vehicle-fleet-statistics/monthly-electric-and-hybrid-light-vehicle-registrations/
[22] https://i.stuff.co.nz/motoring/news/116395302/government-abandons-electric-vehicle-target-for-public-service-fleet
[23] https://www.driven.co.nz/news/news/government-signals-subsidy-for-electric-car-imports-3000-fee-for-gas-guzzlers/

2. battery types and technology

The purpose of this section is to identify the key types of batteries that are most likely to have to be dealt with at the end of life and their key characteristics.

Batteries can have a range of performance characteristics which make them more or less suitable for particular applications. The key characteristics of batteries are:[24]

- **Specific Energy:** The total amount of energy stored in the battery
- **Specific Power:** The amount of load that can be drawn from a battery at a given time
- **Cost:** Cost is often expressed in cost per kWh
- **Life:** The number of charge and discharge cycles a battery will last for before it degrades too much to be useful
- **Safety:** Batteries can have issues with combustion or corrosiveness (if they leak), as well as toxicity if the materials are ingested or enter the environment
- **Operating Range:** The wider range of temperature within which a battery works the more useful it will be
- **Long Shelf life:** Batteries need to be usable years after they are manufactured

2.1 Large Battery Chemistry

Excluding lead-acid, which is outside the scope of this report, there are two main types of large batteries: nickel metal hydride (NiMH) and lithium-ion.

2.1.1 Nickel Metal Hydride

NiMH batteries are now considered a relatively mature technology. While less efficient (60–70%) in charging and discharging than even lead-acid, they have a higher energy density than lead-acid (30–80 Wh/kg). NiMH batteries can have very long lives, as has been demonstrated in their use in hybrid cars and surviving NiMH EVs that still operate well after 100,000 miles (160,000 km) and over a decade of service. Downsides include the poor efficiency, high self-discharge, the need to take care during charge cycles (overcharging or complete discharge can damage cells), and poor performance in cold weather.[25]

2.1.2 Lithium-ion

There are a range of different lithium-ion battery chemistries. The table below lists five main types of large lithium-ion batteries and their main types of applications.

[24] http://www.visualcapitalist.com/our-energy-problem-battery-context/
[25] https://en.wikipedia.org/wiki/Electric_vehicle_battery, https://en.wikipedia.org/wiki/Nickel%E2%80%93metal_hydride_battery

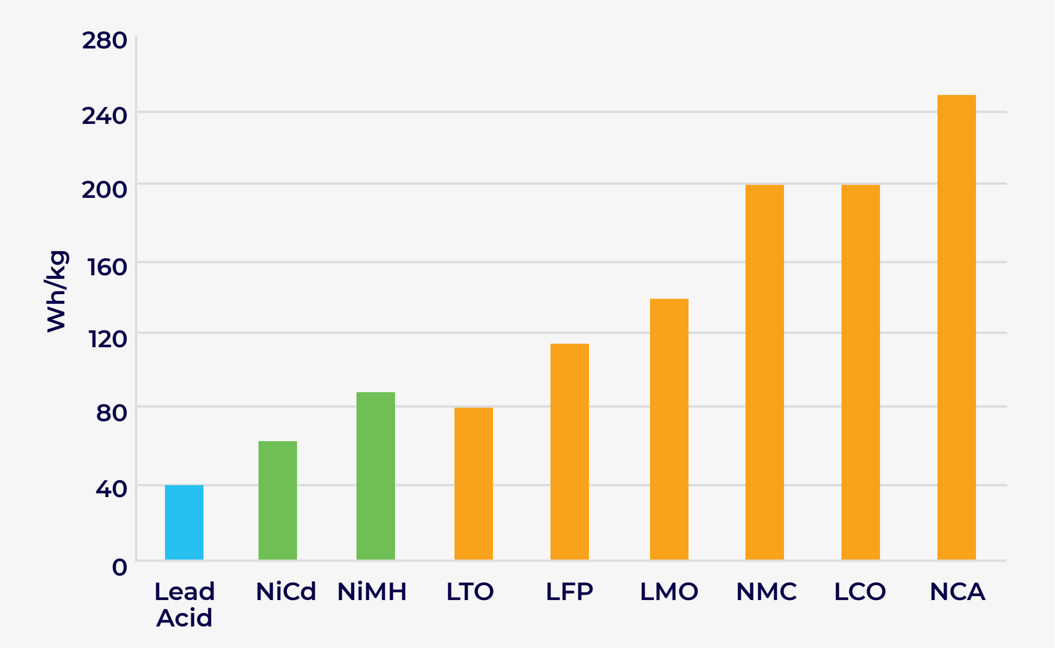
Table 1: Main Types of Lithium Ion Battery Cell Chemistry

Type	Description	Applications
Lithium Manganese Oxide (LMO)	Has a moderate specific power, moderate specific energy and a moderate level of safety compared to other lithium-ion batteries. It is also low cost, but has a poor operating range and short lifespan.	Electric powertrains
Lithium Nickel Mangansese Cobalt Oxide (NMC)	High specific energy, moderate specific power, safety, lifespan and operating range. It can be optimised to have either a high specific power or high specific energy.	EVs, industrial applications
Lithium Iron Phosphate (LFP)	Low specific energy but a high specific power. Moderate operating range. High level of safety and lifespan and low cost.	Portable and stationary applications needing high load and endurance
Lithium Nickel Cobalt Auluminium Oxide (NCA)	Very high specific energy. Moderate cost, specific power, operating range and lifespan. Relatively low level of safety.	EVs
Lithium Tintanate (LTO)	High safety good operating range and long lifespan, but low specific energy, and only moderate specific power. Very fast recharge time. Very high cost.	EVs

Source: https://batteryuniversity.com/learn/article/types_of_lithium_ion

The chart below illustrates the typical specific energy of NiMH, lead acid and lithium-ion batteries. It is clear from the chart why chemistries such as NCA are preferred for EV applications as they can potentially provide much greater range than other chemistries.

Figure 4: Typical specific energy of lead-, nickel- and lithium-based batteries.

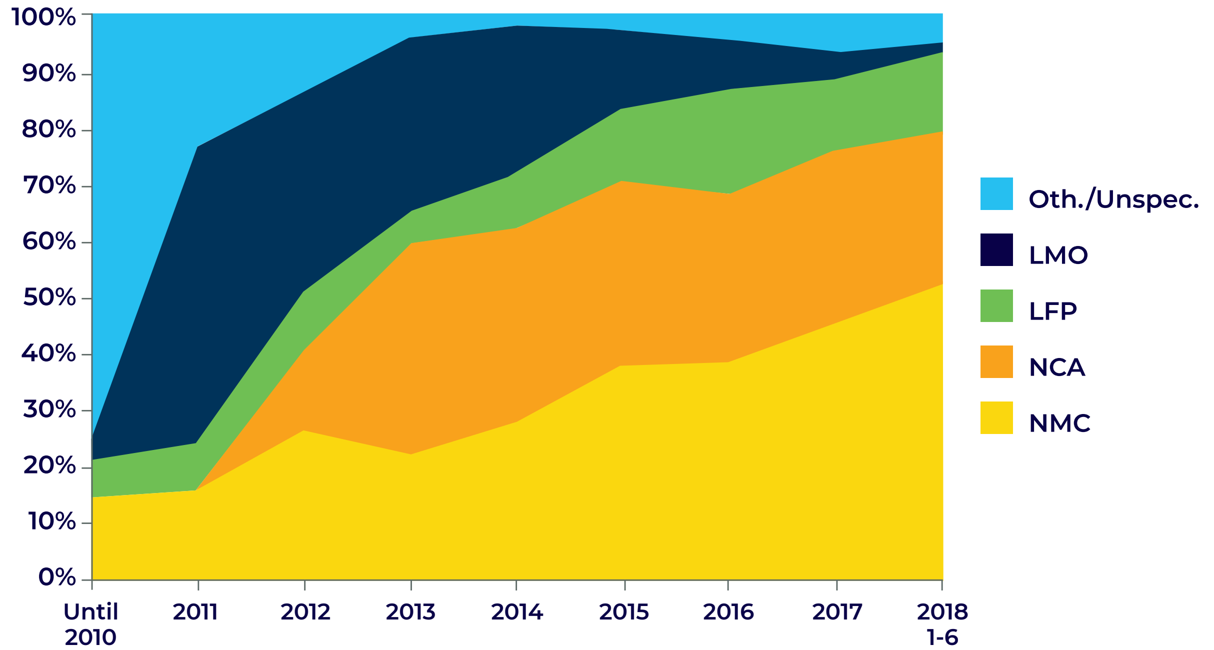


Source: https://batteryuniversity.com/learn/article/types_of_lithium_ion

2. battery types and technology continued

The shift towards the higher capacity lithium ion battery chemistries over time can be seen in the chart below:

Figure 5: Delivery of Battery Capacity by Cathode Chemistry



https://cleantechnica.com/2018/09/30/chart-global-shifts-in-ev-battery-chemistry-electric-car-sales-grow-66/

2.2 Battery Construction

The method of construction varies between manufacturers and depends on the applications they are intended for.

There may be a number of different components to a battery. These include:[26]

- Cells. EV battery packs for example may have hundreds of individual cells. These are usually arranged in modules
- Battery management system
- Cooling mechanisms and temperature monitors
- Relays which control the distribution of the battery pack's electrical power to the output terminals
- Temperature, voltage, and current sensors
- Cabling
- Contacts
- Metal and or plastic casings
- Other electronics, such as inverters, may be integrated into battery design for certain applications

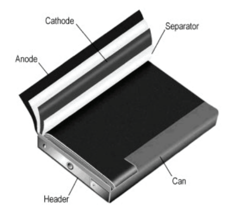
While the majority of the weight of a battery generally consists of the cells, there can be a range of other materials from a battery that can potentially be recovered at end of life.

[26] https://en.wikipedia.org/wiki/Electric_vehicle_battery

2.2.1 Cell Types

There are three main types of cells used in battery packs. These are shown in the table below.[27]

Table 2: Main Cell Configurations

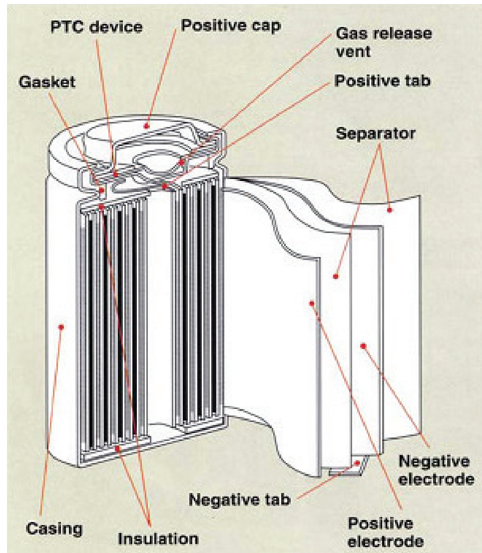
Cell type		Description
cylindrical		The cylindrical cell is one of the most common forms for rechargeable and non-rechargeable batteries. The advantages are ease of manufacture and good mechanical stability. The tubular cylinder can withstand high internal pressures without deforming. These cells are the type used in automotive battery packs such as Tesla.
Prismatic		This flat cell style is commonly found in mobile phones and electronic devices. Prismatic cells are also available in large formats. Packaged in welded aluminium housings, the cells are primarily used for electric powertrains in hybrid and electric vehicles.
Pouch		Rather than using a metallic cylinder and glass-to-metal electrical feed-through, conductive foil-tabs are welded to the electrodes and brought to the outside fully sealed. The pouch cell makes most efficient use of space and achieves 90–95 per cent packaging efficiency; the highest among battery packs. Pouch cells are suitable for energy storage systems because fewer cells simplify the battery design. Pouch cells allow for battery expansion but can make temperature management more difficult.

While the cost per kilowatt hour (kWh) of cylindrical cells has historically been lower, the costs of the other cell designs is coming down and costs are expected to reach parity.[28]

2.2.2 Cell Construction

A cutaway of a cylindrical type cell is shown in Figure 6.

Figure 6:
Construction of Cylindrical Cell



[27] https://batteryuniversity.com/index.php/learn/article/types_of_battery_cells
[28] https://batteryuniversity.com/learn/article/types_of_battery_cells

2.2.3 Lithium-ion Battery Composition

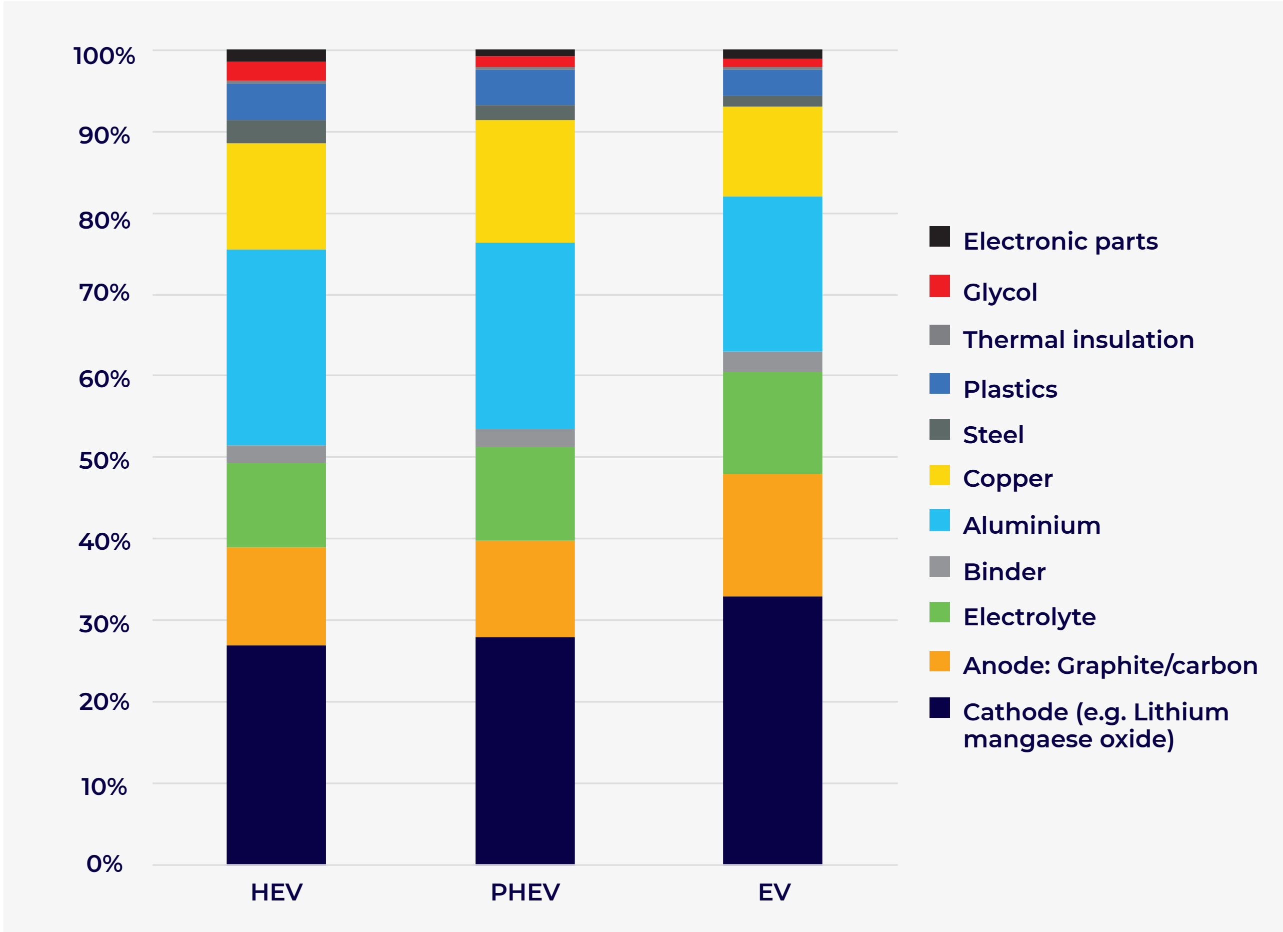
Typical compositions for lithium-ion vehicle batteries are shown in the table and chart below.

Table 3: Lithium-ion Battery Composition by (% by Weight)

	HEV	PHEV	EV
Cathode (e.g. Lithium manganese oxide)	27%	28%	33%
Anode: Graphite/carbon	12%	12%	15%
Binder	2%	2%	3%
Copper	13%	15%	11%
Aluminium	24%	23%	19%
Electrolyte	10%	12%	12%
Plastics	4%	4%	3%
Steel	3%	2%	1%
Thermal insulation	0.4%	0.3%	0.3%
Glycol	2%	1%	1%
Electronic parts	2%	1%	1%
Typical weight (kg)	15-70kg	70-100kg	200-600kg

Source: JB. Dunn et al (2012) Material and Energy Flows in the Material Production, Assembly, and End-of Life Stages of the Automotive Lithium-Ion Battery Life Cycle. Argonne National Laboratory, US Dept of Energy.

Figure 7: Lithium Ion Battery Composition by (% by Weight)

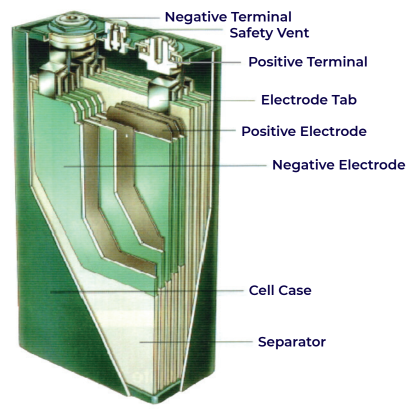


The above table and chart illustrate the fact that a large proportion of the battery consists of materials such as recoverable metals as well as graphite, and plastics. The electrolyte and cathode (which may contain lithium) make up half to a third of the weight. Lithium in fact makes only about 1%-2% of the composition of the battery by weight.[29]

2.2.4 NiMH battery composition

NiMH cells have an alkaline electrolyte, usually potassium hydroxide. The positive electrode is nickel hydroxide, and the negative electrode is hydrogen ions, or protons. The hydrogen ions are stored in a metal-hydride structure that is the electrode.[30]

Figure 8: Construction of NiMH Cell



[29] https://www.researchgate.net/post/What_is_the_content_of_pure_lithium_eg_kg_kWh_in_Li-ion_batteries_used_in_electric_vehicles
[30] Kopeara (2004) Inside the Nickel Metal Hydride Battery, report for Cobasys, and; https://www.google.co.nz/search?q=nickel+metal+hy-dride+battery+construction&sa=X&ved=0ahUKEwjN9MWUjK3dAhUKQN4KHajoDrYQ1QIInAEoAQ&biw=1777&bih=793

2. battery types and technology continued

Typical composition for a NiMH battery pack are shown below.

Table 4: Indicative Nickel Metal Hydride Composition by (% by Weight)

	Composition by weight
Cell	73%
Steel	22%
Copper	1%
Recyclable plastic	1%
Non-recyclable plastic	3%

2.3 Uses of Large Batteries in New Zealand

Large batteries in NZ are used in the following broad applications:

- Hybrid, plug-in hybrid and battery EVs
- Stationary storage for local use (such as solar power and off-grid systems)
- Stationary storage for utilities
- Buffer units for fast charging stations
- Industrial applications (such as cell towers or data centres)

There are also a range of potential emerging uses. For example, technology start-ups such as Kitty Hawk and Zunum are investing in electric planes, and ships are using large battery power to manoeuvre into port to reduce local emissions.

2.4 Lifespan

The lifespan of batteries is an important dimension in planning a product stewardship response as this represents the time delay between when batteries are sold and when they reach the end of their life.

Chemical processes that occur over time within a battery (particularly during use) reduces the battery's ability to deliver energy. Eventually, the battery will be considered to be 'spent' and no longer suitable for its intended purpose. In some cases, a battery that is considered 'spent' for one purpose could still be useful for a lower-demand purpose.[31]

The lifespan of batteries depends on their applications and how they are used. Stationary applications will typically have longer lifespans because they are subject to fewer temperature fluctuations and do not necessarily have the same need for high specific power. Guaranteed lifespans of 8-10 years are typically quoted for lithium ion batteries deployed in EVs and 10-12 years for stationary applications, although the expectations are that most batteries would last 15 years or more. The expectation for EV batteries is that 8-10 years is when their capacity will have reduced to approximately 70% but that they may be able to be deployed in stationary applications as a secondary use. NiMH batteries generally have a longer life of around 15 years. There are NiMH batteries in HEVs that are 14 years and older are still operational.

2.5 Technology Changes

Development of battery technology is being undertaken by a large number of organisations from the major battery manufacturers and auto makers to research institutions. There are many possible technologies, but one thing that all appear to have in common is that there is a long gestation period between what is theoretically possible in a laboratory and the eventual commercial production of a viable battery. For the purposes of this exercise we have confined ourselves to the technologies that, in the literature, appear to be regarded as having the best chance of commercial viability in the next 10 years or so.

[31] https://www.li-cycle.com/blog

Table 5: Key Battery Advances and Timelines

Battery advance	Key characteristics
Incremental improvements to lithium ion	This includes aspects such as improving the efficiency of manufacturing, cell design, battery management, and small changes to the chemistry to improve the energy density and reduce the use of expensive ingredients (like cobalt). These improvements are happening constantly and are what has driven down the price of batteries in recent times. It is expected that further gains in energy density and cost will continue to be seen.[32]
Solid state	In solid state batteries the liquid electrolyte is replaced by a solid polymer. The advantages are said to be up to twice the energy density possible compared to liquid electrolytes, and fast charging times. The hope is that solid state batteries could avoid the use of cobalt, although this has not yet been proven in practice.[33] The technical challenges that need to be overcome include low specific power, poorer operating range, and poorer battery life. Despite these challenges some reports indicate that solid state batteries could be being produced commercially by between 2020 and 2025.[34]
Lithium air	This technology uses a catalytic air cathode that supplies oxygen, an electrolyte and a lithium anode. It promises to deliver up to 10 times greater energy density than lithium-ion. However, it requires pure oxygen and supplying this to the battery is an issue. The other downside is that it has a very short lifespan (50 cycles). There are no timelines for commercial production.
Lithium metal	In this technology the anode is made out of (or has a high proportion of) lithium metal instead of graphite. The advantages are potentially twice the specific energy and half the weight of lithium-ion batteries. The problems are safety and very short lifespan. These types batteries are in production and commercial use[35] and have been used in prototype EVs.[36]
Lithium sulphur	This technology uses a lithium metal anode and a sulphur-based cathode. It has three times the specific energy of lithium-ion and high specific power. The downsides are poor battery life and poor operating range.
Sodium ion	Although specific energy is not as good as lithium ion, sodium-ion is considered a potentially lower-cost alternative. It is much safer and can be completely discharged without stressing the battery. Technical issues include a relatively short lifespan and the degree to which the battery expands when it is fully charged.
Hydrogen fuel cells	Hydrogen fuel cells combine hydrogen and oxygen to produce electricity. The fuel cells themselves are very efficient and produce only water vapour as a by-product. They can be refilled in less than 10 minutes, making them similar to petrol in vehicle applications. The downsides come in the inefficiencies of producing hydrogen and storing and transporting it. Hydrogen fuel cells are fully functional, and a small number of vehicles have been produced. A number of vehicle manufacturers have identified hydrogen fuel cells as the next stage of vehicle evolution beyond batteries and, while investment is not as large as in battery technology, there is significant research and development taking place. Due to the challenges of providing infrastructure, significant uptake of hydrogen fuel cell vehicles is considered a medium-term prospect.
Flow batteries	Flow batteries[37] consist of two tanks of liquid, which simply sit there until needed. When pumped into a reactor, the two solutions flow adjacent to each other past a membrane and generate a charge by moving electrons back and forth during charging and discharging. This type of battery can offer almost unlimited energy capacity simply by using larger electrolyte storage tanks. It can be left completely discharged for long periods with no ill effects, making maintenance simpler than other batteries. These types of batteries are not suited to vehicle applications but they may be able to outperform lithium-ion for some stationary storage applications. Vanadium flow batteries are in commercial production.[38]

[32] For example, LION Smart, a German battery management company has recently unveiled a battery pack with a claimed 80% improvement in specific energy over other similar sized Li-ion systems, using standard 18650 cells but with an optimised layout and battery management system. https://cleantechnica.com/2018/09/07/just-for-fun-bmw-i3-with-100-kwh-battery-from-lion-smart/

[33] https://cleantechnica.com/2018/06/26/the-solid-state-lithium-ion-battery-has-john-goodenough-finally-done-it/; https://www.alphr.com/science/1008867/solid-state-battery-dyson-toyota

[34] https://batteryuniversity.com/learn/article/experimental_rechargeable_batteries; http://www.visualcapitalist.com/future-battery-technology/

[35] https://cleantechnica.com/2018/08/08/the-lithium-metal-battery-is-almost-here/

[36] https://batteryuniversity.com/learn/article/experimental_rechargeable_batteries

[37] http://energystorage.org/energy-storage/storage-technology-comparisons/flow-batteries

[38] https://www.forbes.com/sites/jamesconca/2016/12/13/vanadium-flow-batteries-the-energy-storage-breakthrough-weve-needed/#71124d3f5bde. https://www.sciencedirect.com/science/article/pii/S1876610216310566 http://www.australianvanadium.com.au/vanadium-batteries/

3. battery data and projections

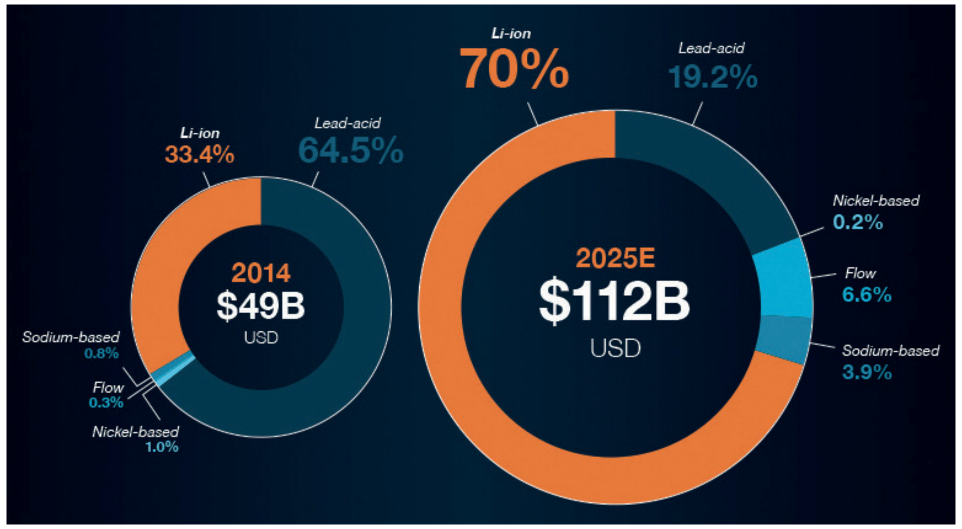
This section reviews available New Zealand and international data on the numbers and types of large batteries being produced. It also develops some projections with a view to understanding the potential scale and timeframes of what New Zealand might have to managed in terms of end of life batteries.

3.1 Battery Numbers and Trends

3.1.1 Global Trends

Production of lithium-ion batteries is set to dominate the rechargeable battery market over the next 10 years or so. Figure 9 below shows the estimated growth of lithium-ion in the rechargeable battery market.

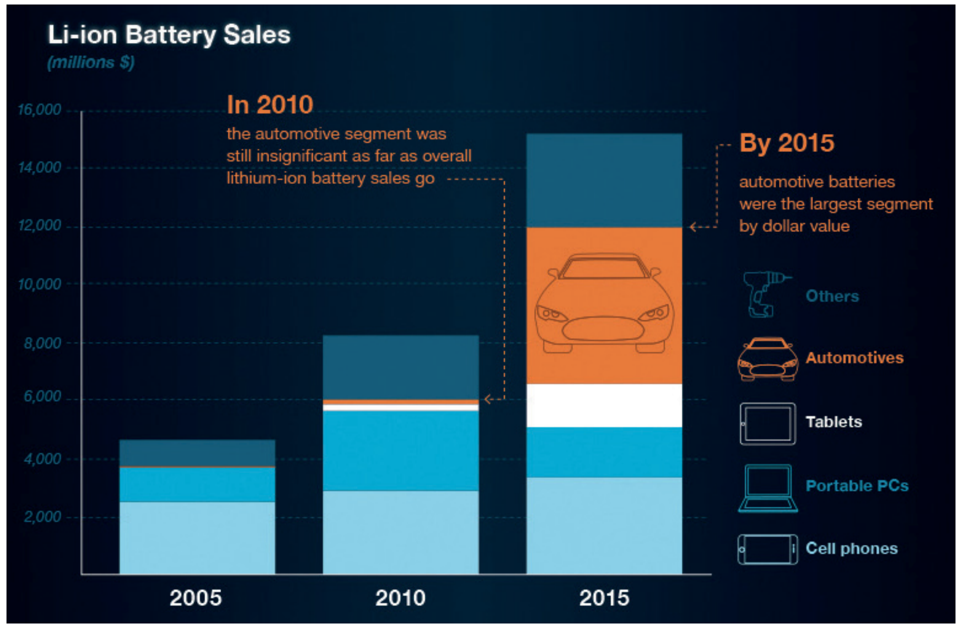
Figure 9: Estimated Size of the Rechargeable Battery Market



Source: http://www.visualcapitalist.com/explaining-surging-demand-lithium-ion-batteries/

Consumer electronics have historically been the main application for lithium-ion batteries, although by 2015 EVs had become the largest category by weight. This is shown in the chart below:

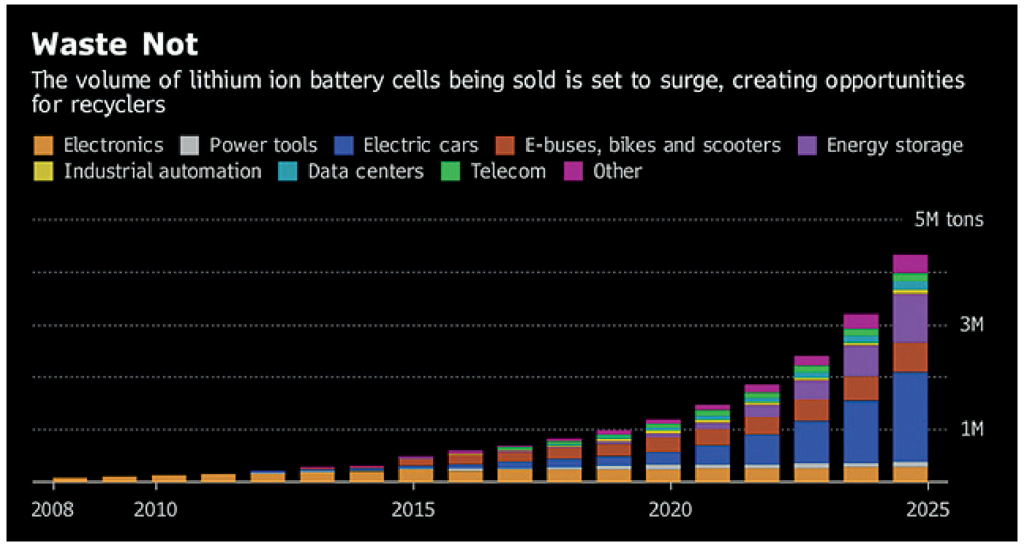
Figure 10: Evolution of the Lithium Ion Market



Source: http://www.visualcapitalist.com/explaining-surging-demand-lithium-ion-batteries/

In the future, the majority of lithium-ion batteries (by weight) are expected to be deployed in EVs (including buses), with storage applications also becoming important. This is shown in the chart below.

Figure 11: Project Use Profile for Lithium Ion Batteries to 2025



Source: https://www.li-cycle.com/blog

3.1.2 New Zealand Vehicle Fleet

There are in the order of four million vehicles in New Zealand. One of the key characteristics of New Zealand's vehicle fleet is that it has a high proportion of used vehicles and a high average age of about 14.4 years for passenger cars, 16.6 years for buses and 17.8 years for trucks.

The table below shows key characteristics of the overall fleet as of 2017:

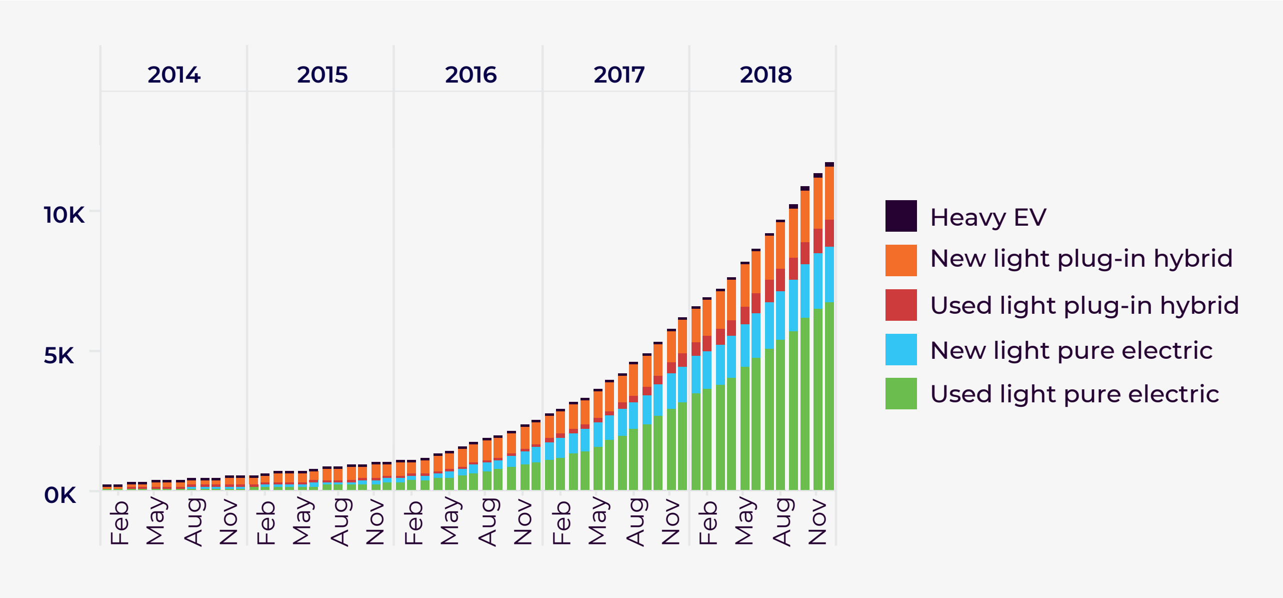
Table 6: NZ Vehicle Fleet Composition

	Total Vehicles	% Of Total	% Used Imports
Light passenger	3,218,344	77%	51%
Light commercial	580,679	14%	18%
Motor Cycle	170,547	4%	24%
Trucks	144,148	3%	35%
Bus	10,711	0%	34%
Other	30,468	1%	
Total	**4,154,897**	**100%**	**44%**

Source: https://www.transport.govt.nz/resources/vehicle-fleet-statistics/#annual

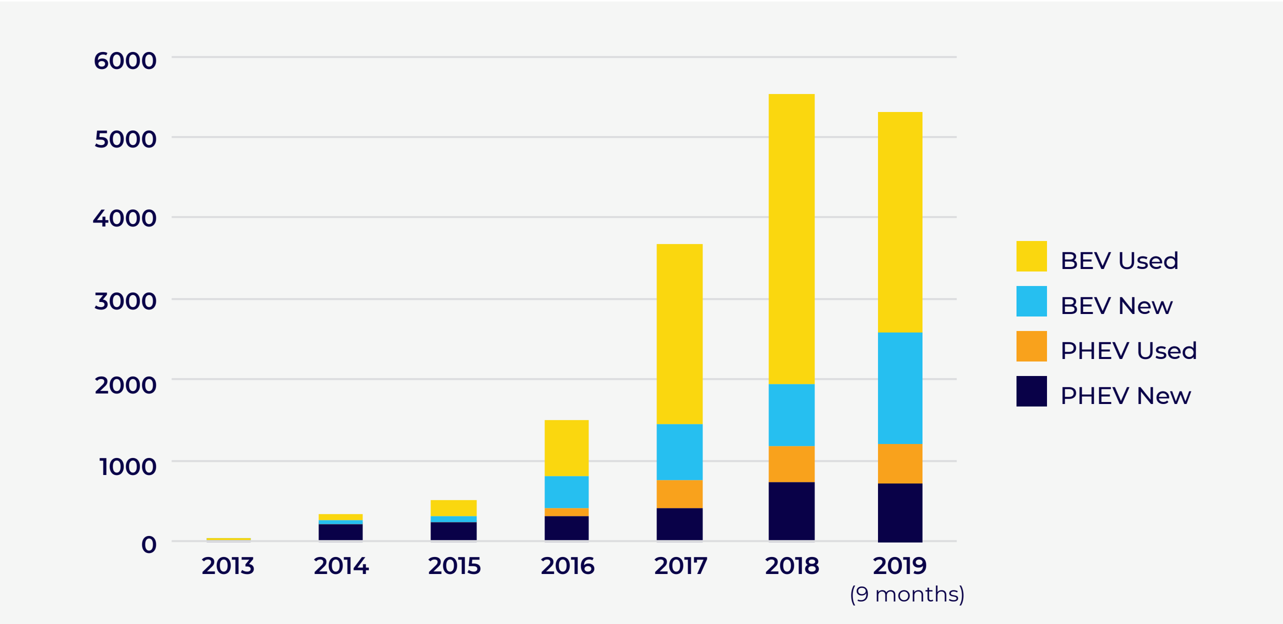
By comparison the numbers of EVs on the road in New Zealand is currently estimated to be 17,026[39], meaning that approximately 0.4% of NZ's light fleet is electric. This number is growing however, although the percentage of EVs registered is still small as a proportion of the total at at 3.67% (but this has grown from 1.44% in 2018).[40]

Figure 12: New Zealand EV Fleet Size by Year



Source: https://www.transport.govt.nz/mot-resources/vehicle-fleet-statistics/monthly-electric-and-hybrid-light-vehicle-registrations/ (updated 17/10/2019)

Figure 13: EVs Added to the Fleet by Year



Source: https://www.transport.govt.nz/mot-resources/vehicle-fleet-statistics/monthly-electric-and-hybrid-light-vehicle-registrations-2/

[39] https://www.transport.govt.nz/mot-resources/vehicle-fleet-statistics/monthly-electric-and-hybrid-light-vehicle-registrations/
[40] https://www.transport.govt.nz/resources/vehicle-fleet-statistics/monthly-electric-and-hybrid-light-vehicle-registrations-2/

Given the makeup of the NZ vehicle fleet and the large proportion of used imports, particularly from Japan, the number of EVs sold in Japan could be a constraining factor on the take up of EVs in New Zealand. The table below shows the number of Japanese EV sales.

Table 7: Japanese EV Sales

	BEV	PHEV	Total Evs Registered	Fuel Cell	Hybrids
2009/10	1,078	0	1,078	0	347,999
2010/11	2,442	0	3,520	0	481,221
2011/12	12,607	15	16,142	0	451,308
2012/13	13,469	10,968	40,579	0	887,863
2013/14	14,756	14,122	69,457	0	921,045
2014/15	16,110	16,178	101,745	7	1,016,757
2015/16	10,467	14,188	126,400	411	937,575
2016/17	15,299	9,390	151,089	1,055	1,275,560
2017/18	18,092	36,004	205,185	849	1,385,343
2018/19	26,533	23,230	254,958	612	1,431,980

Source: https://www.transport.govt.nz/resources/vehicle-fleet-statistics/monthly-electric-and-hybrid-light-vehicle-registrations-2/

The above data shows that BEV sales in Japan are relatively small and are not yet growing at the pace seen in other markets. However, although numbers of EVs are relatively small, if the NZ demand for used BEVs is strong there may still be adequate numbers to supply a large proportion of the NZ fleet – although there may be a price premium compared to other used vehicle options.

3.2 Future Projections

3.2.1 Global Electric Vehicle Projections

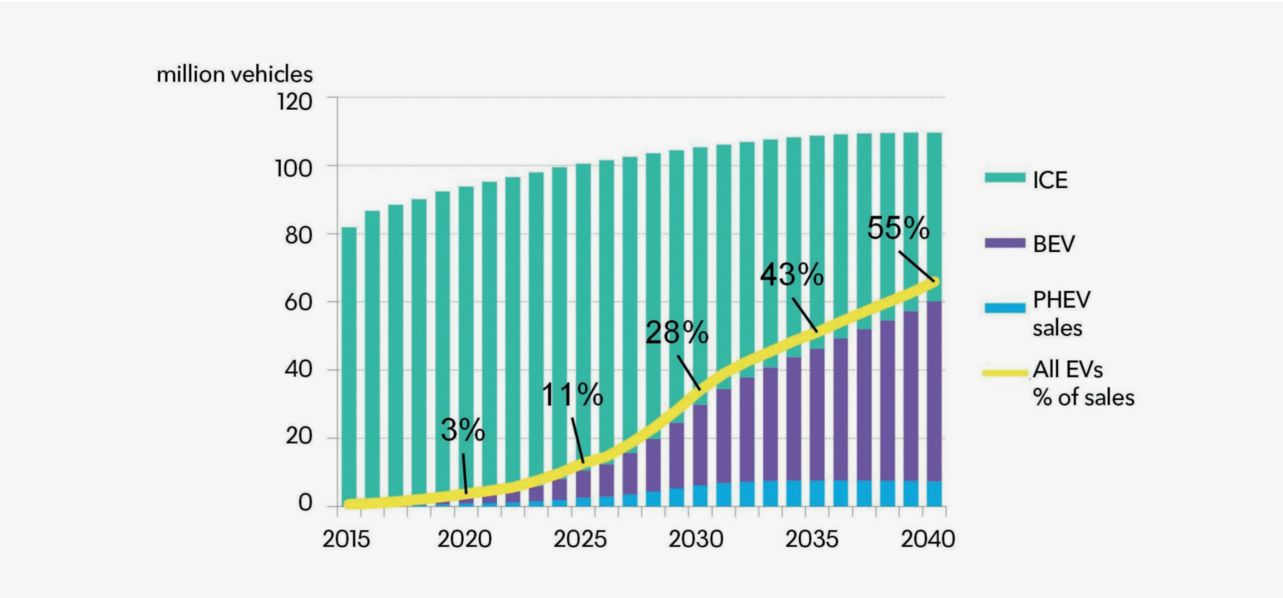
As discussed, EVs are expected to be the main user of rechargeable batteries by weight.

A recent forecast by Bloomberg New Energy Finance[41] shows sales of EVs increasing from a record 1.1 million worldwide in 2017 to 11 million in 2025 and then to 30 million in 2030 as they become cheaper to make than internal combustion engine (ICE) cars.

By 2040 Bloomberg estimates 55% of new car sales and 33% of the fleet will be EVs.

China will lead this transition, with sales there accounting for almost 50% of the global EV market in 2025 and 39% in 2030. China also leads on percentage adoption, with EVs accounting for 19% of all passenger vehicle sales in China in 2025. The trajectory for EV sales is shown in the chart below.

Figure 14: Projected EV Market Share



Source: Bloomberg New Energy Finance[41]

[41] https://bnef.turtl.co/story/evo2018?teaser=true

3.2.2 Buses and Heavy Vehicles

Led by China and motivated by a desire to reduce air pollution, EV bus sales are set to increase significantly globally. Bloomberg estimates that by 2030 84% of bus sales globally will be EV, and by 2040 80% of the world's bus fleet will be EVs.[42]

There are applications which are also likely to see increased numbers of EV trucks. For example, waste and recycling collection is viewed as highly suitable for EVs with low noise, stop start driving and low emissions. Most new urban municipal collection contracts in New Zealand for example are specifying electric trucks.

3.2.3 NZ End of Life EV Battery Projections

We have developed projections to provide estimates of the numbers of EV batteries that may come to the end of their life between now and 2030.

3.2.3.1 Assumptions

- The Government's official target of 64,000 EVs on the roads by 2021 is assumed to be met
- Similarly, we have adopted the PC's suggestion that to have a mostly EV fleet by 2050 will require virtually all new light vehicles to be EVs by 2030.
- We have assumed a similar new/used split to the current EV fleet of 30% new and 70% used imports, rising to a 40/60 split as a higher proportion of the new vehicle fleet becomes electrified.
- We have assumed that EV batteries will last between 5 and 15 years and that this will exhibit a normal distribution curve (this means that in effect 2/3rds of EV batteries reach the end of their useful life between 9 and 11 years).
- We have assumed that used imports are on average 5 years old when they arrive in NZ, and therefore reach the end of their life 5 years sooner than NZ new.

With the above assumptions this suggests that by 2030 there could be nearly 84,000 end of life EV battery packs requiring management each year. The projection is shown in the table and chart below.

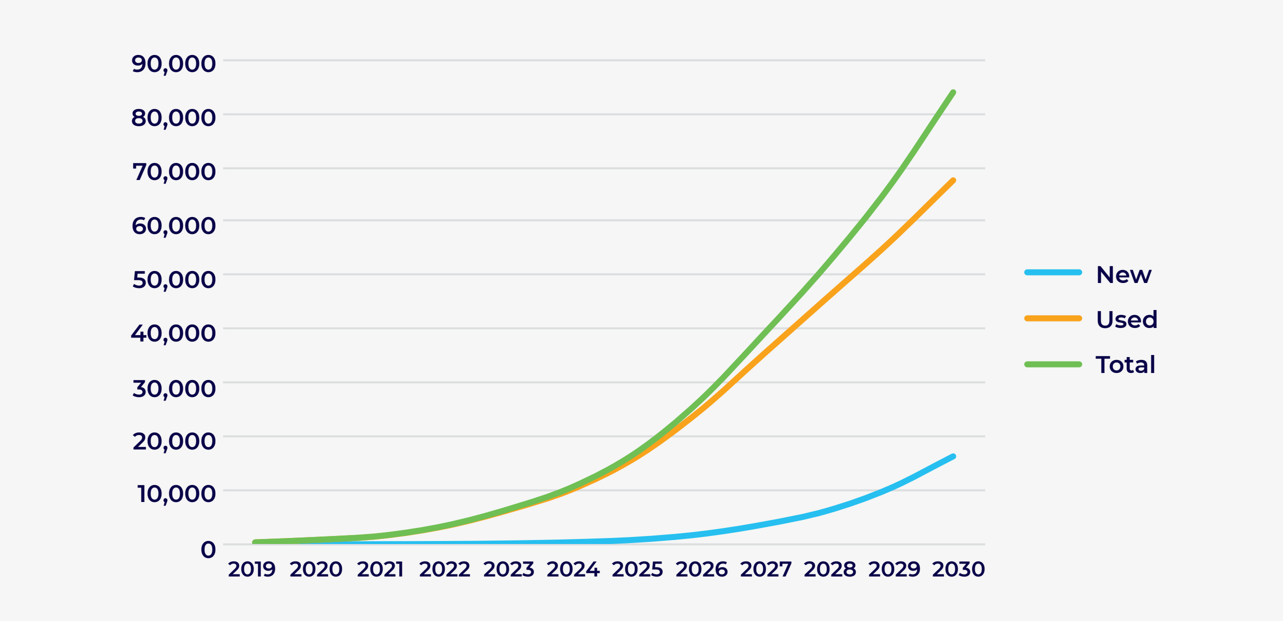
Table 8: Estimates of End of Life EV Battery Packs 2019 - 2030

	New	Used	Total
2019	34	478	512
2020	46	952	997
2021	63	1,679	1,742
2022	103	3,495	3,598
2023	205	6,478	6,683
2024	435	10,316	10,751
2025	883	16,211	17,094
2026	1,879	24,749	26,628
2027	3,667	35,202	38,869
2028	6,180	45,633	51,813
2029	10,343	56,095	66,438
2030	16,267	67,540	83,807

[42] https://bnef.turtl.co/story/evo2018?teaser=true

3. battery data and projections continued

Figure 15: Estimates of End of Life EV Battery Packs 2019 - 2030



The chart illustrates the potentially steep trajectory that is likely to be facing the industry if the adoption of EVs takes place at forecast rates. The influence of the used car market on the flow of end of life EVs is also apparent from the above projection.

In addition to the above projection we also modelled a number of alternative scenarios with some varying assumptions including the government targets not being met, a higher proportion of new vehicles and the impact of an assumed longer life for EV batteries. These projections are provided in Appendix A.3.0.

In brief, if the adoption of EVs follows a similar profile to global forecasts this would suggest between 880 batteries coming to the end of life by 2020 rising to 9,500 by 2025 and 30,000 per annum by 2030.

In the other alternative scenario, if the vehicle fleet composition targets are met, but the fleet is assumed to have a higher proportion (50%) of NZ new vehicles in its makeup, and a longer average battery life of 12 years is assumed this would reduce the total number of end of life batteries to 54,000 per annum by 2030.

3.3 Other Future Developments

There are a range of likely technological and business model developments that could influence the uptake of EVs and the way they are utilised. For example, ridesharing and autonomous cars could lead to fewer vehicles on the road as vehicles become viewed as a transport service rather than a possession. EVs could also be used as temporary storage for homes and help to balance network loads. While these types of advances could lead to fewer vehicles, they would also result in higher utilisation of the vehicles and which could accelerate the speed at which they reached end of life.[43]

[43] Research by Warwick University (https://warwick.ac.uk/newsandevents/pressreleases/clean_energy_stored/) indicates that with advanced management, battery life could actually be improved through use in temporary stationary storage applications.

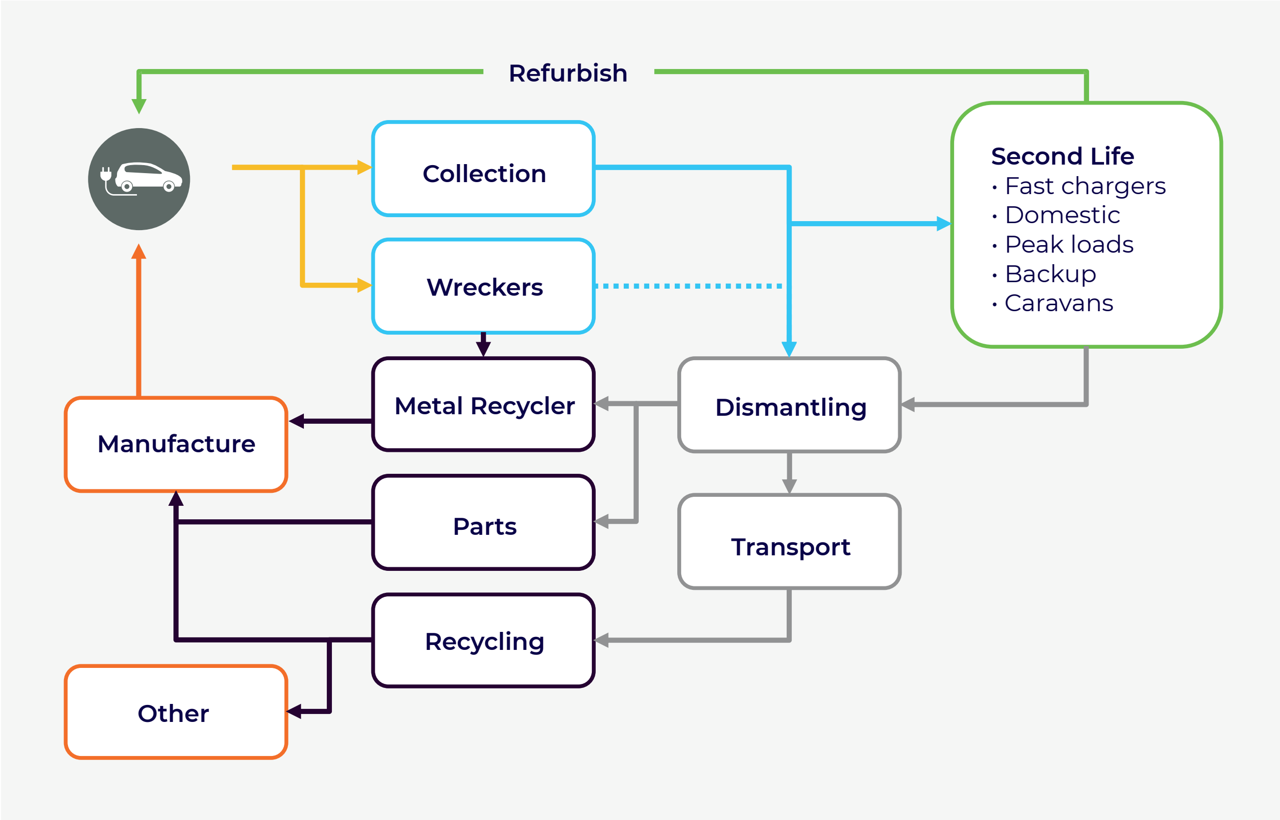
4. recovery pathways

This section outlines the key pathways for recovery of large batteries at the end of their life. It highlights the key issues in respect of recovery and provides some analysis of potential responses to these issues.

4.1 Current Pathways

The current pathways for recovery are summarised in the diagram below:

Figure 16: Summary of Recovery Pathways



Key elements of the pathway diagram are discussed in the following sections.

4.1.1 Collection

The first step for recovery is for there to be infrastructure in place to safely receive, store and transport batteries to where they may be further processed. This requires that facilities are appropriately designed, and staff trained to ensure safe handling.

Batteries present a number of hazards including electric shock, the potential for corrosive material to leak, and for combustion, or gasses to be given off. Transporting and storage of lithium-ion batteries for example requires the terminals to be insulated to avoid accidental discharge and the potential for fires. The hazards involved in transporting of lithium-ion batteries may place constraints on logistics.[44] Appendix A.4.0 provide some further information about transporting of waste lithium-ion batteries.

There are not yet many established pathways for the collection of large batteries. Some manufacturers have processes to take batteries back, but batteries can also end up in car wreckers and scrapyards.

To ensure that batteries are returned to the correct places for end of life management, recovery needs to ideally be free to the consumer, or there needs to be some form of incentive such as a bounty.[45]

[44] https://www.packsend.co.nz/clarifying-lithium-battery-sending/ https://www.dhl.co.nz/en/express/shipping/shipping_advice/lithium_batteries.html#overviewAnecdotally there is currently only one shipping company willing to transport used lithium-ion batteries.

[45] International examples include BEBAT (Belgium), INOBAT (Switzerland) Call2Recycle (North America). Refer to: MS2 (2013) Business and Public Policy Case for Battery Stewardship – BACKGROUND PAPER AND REPORT Prepared for Sustainability Victoria

There also needs to be a good level of consumer and industry information about how batteries should be returned at end of use.[46]

With regard to large batteries the pathways are likely to be different than for small consumer batteries. Most large batteries will be from vehicles and these will enter the return system either via car wreckers, mechanics, or brand dealerships and service centres. Devising return systems to accommodate industry players is likely to be less complex than for consumers directly.

There may be greater challenges in respect of some other battery applications which may require consumer level programmes to address.

4.1.2 Reuse/Repurposing

Large EV batteries may have in the order of 70% - 80% of their capacity remaining when they reach the end of their useful life in a vehicle.[47] This presents a significant opportunity to repurpose EV batteries in other applications that do not require such high levels of capacity, such as stationary storage. They could still have a further 5-10 years of life in a stationary storage application. Some batteries may have reduced performance due to a small number of weak or faulty cells, rather than the whole battery being degraded.

A further option is to refurbish EV battery packs by rebalancing or replacing cells or modules.

This is being done in NZ and can reportedly extend the life of existing packs for 2-4 years.[48] Nissan for example has just announced that it will offer refurbished battery packs for Nissan Leafs at approximately half the cost of a new battery pack.[49] It is expected that, particularly with the large number of second hand EVs that make up the New Zealand EV fleet, the demand for refurbishing and replacement battery packs will increase.[50]

There is rising demand for energy storage systems as there is a shift to renewables which only supply power at certain times (and not necessarily when it is needed). Repurposing is one way in which demand for these systems could be met as well as finding a home for a potential growing stockpile of end of life EV batteries. Examples include:[51]

- Buffer for multi-unit fast charging stations
- Domestic energy storage (e.g. for solar energy)
- Management of network and peak loads
- Emergency back-up power
- Mobile applications such as caravans and forklift trucks

Table 9: Summary of Global Lithium Battery Recyclers

Company	Process classification	Product	Annual capacity
ARetriev	Hydrometallurgy	Cobalt cake, Li2CO3, Cu/Al foil	3,500 tonnes
Umicore	Pyrometallurgy and hydrometallurgy	Co-Ni-Cu alloy, cathode slag for construction materials, Fe	7,000 tonnes
Recupyl /TES-AMM	Hydrometallurgy	Co(III)OH3, Li2CO3, steel	110 tonnes
Xstrata Nickel	Pyrometallurgy	Ni, Co, Cu alloys	3,000 tonnes
Batrec	Mechanical treatment and hydrometallurgy	Co, Ni scrap, non-ferrous metals, Mn oxides, plastic	1,000 tonnes
Accuree	Pyrometallurgy	Co alloy, Li2CO3	1,000 tonnes
Kobar[52]	Pyrometallurgy and hydrometallurgy	Li, Na, Co, Al, Cu, Fe	+1,000 tonnes

Source: King S, Boxall NJ, Bhatt AI (2018) Australian Status and Opportunities for Lithium Battery Recycling. CSIRO, Australia.

[46] https://www.productstewardship.us/page/Batteries
[47] https://www.energywise.govt.nz/assets/Resources-Energywise/on-the-road/ev-battery-report.pdf
[48] http://evtalk.co.nz/where-do-dead-batteries-go/
[49] https://www.youtube.com/watch?v=w93QF1ZCoiU
[50] Communication with Carl Barlev, Blue Cars
[51] Natkunarajah et al, Scenarios for the return of lithium-ion batteries out of electric cars for recycling. Procedia CIRP 29 (2015), 740-745
[52] http://www.kobar.co.kr/?module=Html&action=SiteEnglish&sSubNo=8

4.1.3 Global Recycling Capacity

The following table shows the main battery re-processors and their annual recycling capacity.

In New Zealand local recyclers are investigating options for processing or pre-processing International Commodity Markets

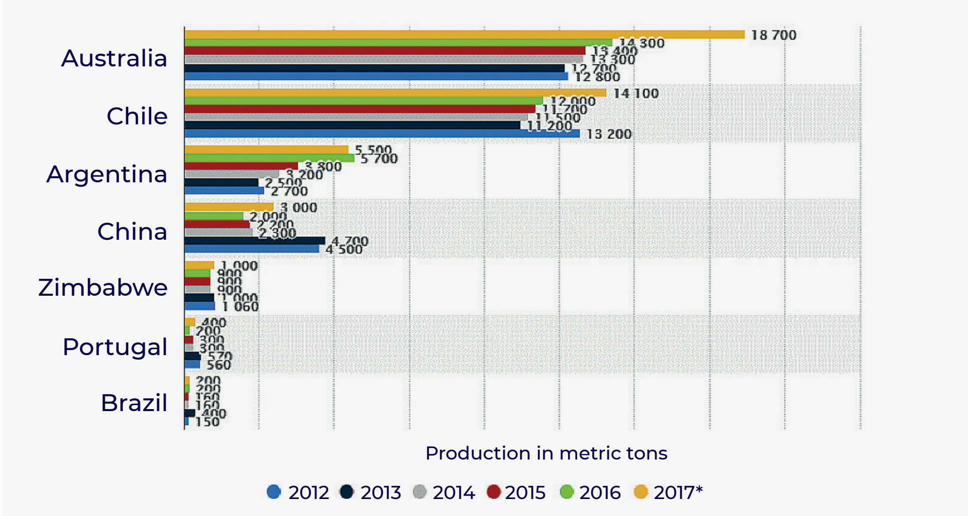
Although there are a range of different materials in large batteries, the three most strategic elements are lithium, cobalt and graphite.

4.1.4 Lithium

The main method of obtaining lithium is extraction from the brine of salt flats. Holes are drilled into the salt flats and the brine is pumped to the surface, leaving it to evaporate in ponds. This allows lithium carbonate to be extracted through a chemical process.[53] Lithium is also extracted from mineral ore sources, but this is a more costly and energy intensive process.[54]

The current largest producer is Australia which produced nearly 19,000 tonnes in 2017. Major producers and the quantities are shown in Figure 17 below. Global production was in the order of 43,000 tonnes of lithium metal in 2017, but this rate is climbing as can be seen from the chart below.

Figure 17: Major Lithium Production Countries 2012 to 2017 (tonnes)



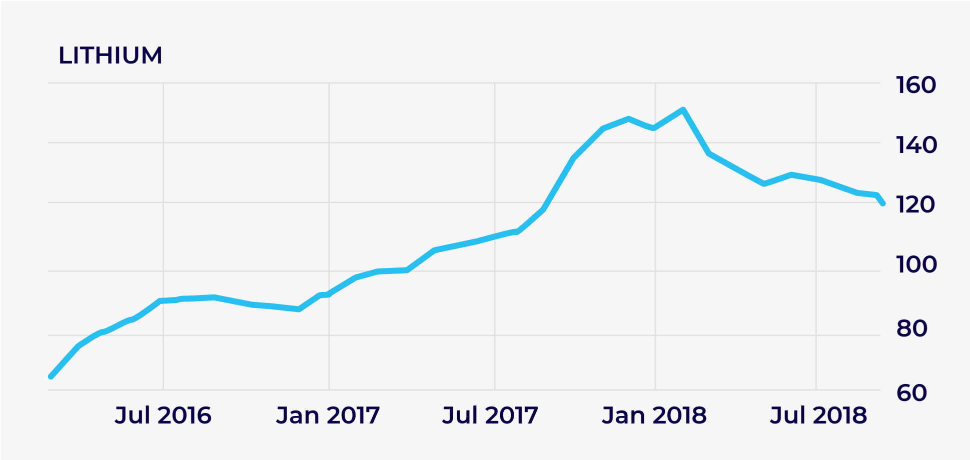
Source: https://www.statista.com/statistics/268789/countries-with-the-largest-production-output-of-lithium/

Bolivia is not currently a major producer but is estimated to have the largest reserves.[55]

[53] There are a range of environmental and ethical concerns with Lithium extraction. This includes water pollution and depletion and the risk of leaching and spills from chemicals used in the production processes. Countries where there have been environmental an ethical issues reported include Chile, and Argentina (http://www.foeeurope.org/sites/default/files/publications/13_factsheet-lithium-gb.pdf), and China (https://www.wired.co.uk/article/lithium-batteries-environment-impact)
[54] https://www.thebalance.com/lithium-production-2340123
[55] http://www.foeeurope.org/sites/default/files/publications/13_factsheet-lithium-gb.pdf

The price of lithium has been climbing and is currently over $12,000 per tonne. This is shown in the chart below.

Figure 18: Lithium International Market Price (US$ per 100kg)



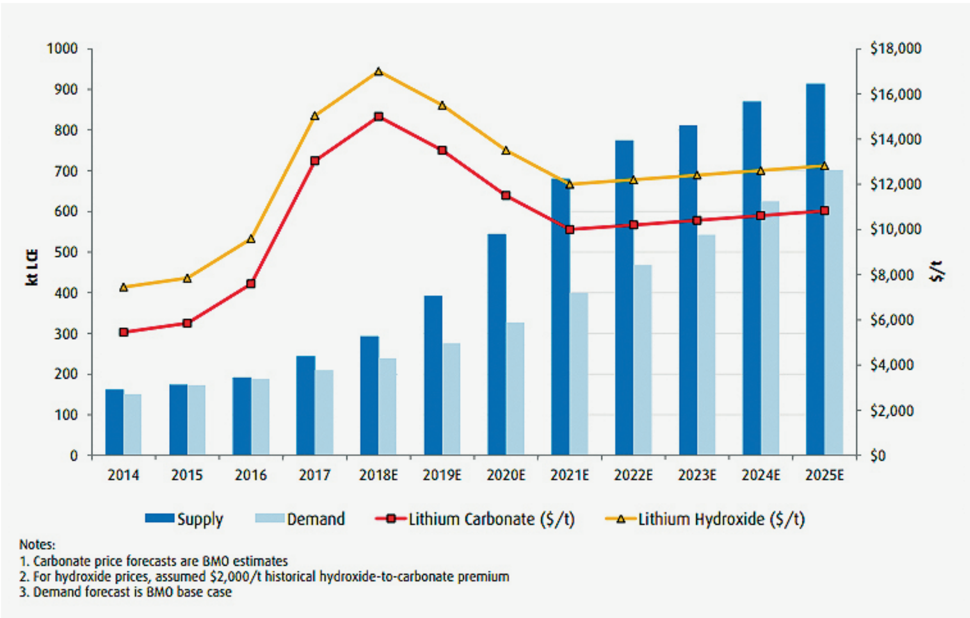
Source: https://tradingeconomics.com/commodity/lithium

However, because lithium is a small fraction of the makeup of a lithium-ion battery (1-2%) the high price of lithium is not expected to significantly impact battery prices.

4.1.4.1 Projected Lithium Supply against Projected Demand (2005 – 2030)

Although production is projected to increase ahead of demand, lithium supply is expected to remain tight as demand continues to grow. Price forecasts suggest that the cost of lithium will drop from recent peaks but is expected to remain high. This is shown in the chart below:

Figure 19: Lithium International Supply and Demand



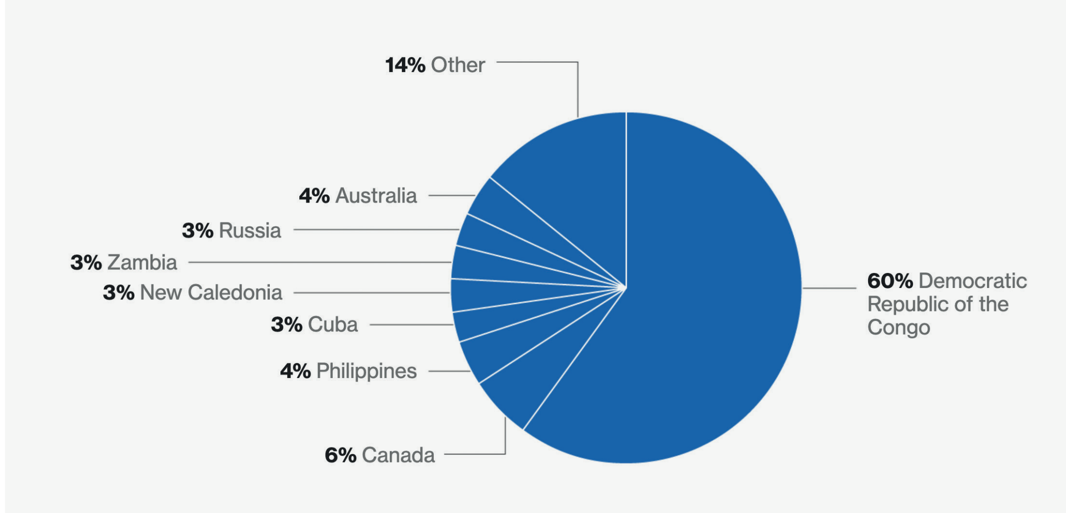
Source: http://www.mining.com/lithium-demand-battery-makers-almost-double-2027/
Note: The intermediate stage of lithium extraction is production of lithium carbonate or lithium hydroxide, which is how lithium is usually sold by the producing countries. The supply and demand quantities shown in the chart above are for lithium carbonate which is extracted at a rate of 5.3 units of lithium carbonate to 1 unit of lithium metal.[56]

[56] https://www.thebalance.com/lithium-production-2340123

4.1.5 Cobalt

Cobalt is regarded as the most strategic material in the makeup of batteries. The global market consumes in the order of 110,000 tonnes annually.[57] Supplies of cobalt are dominated internationally by the Democratic Republic of Congo. Long term security of supply and ethical issues are noted as concerns.[58]

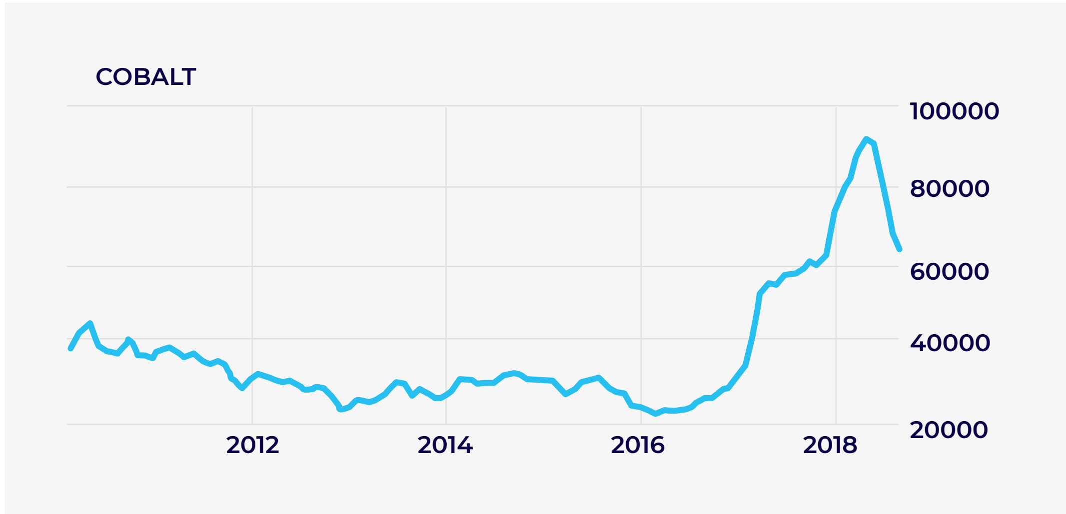
Figure 20: Mined Cobalt Output 2016



https://www.bloomberg.com/graphics/2018-cobalt-batteries/

The price of cobalt has also climbed very steeply over the last 2 years and is currently trading in the order of US$65,000 per tonne. This is shown in the chart below.

Figure 21: Cobalt International Market Price (US$ per Tonne)



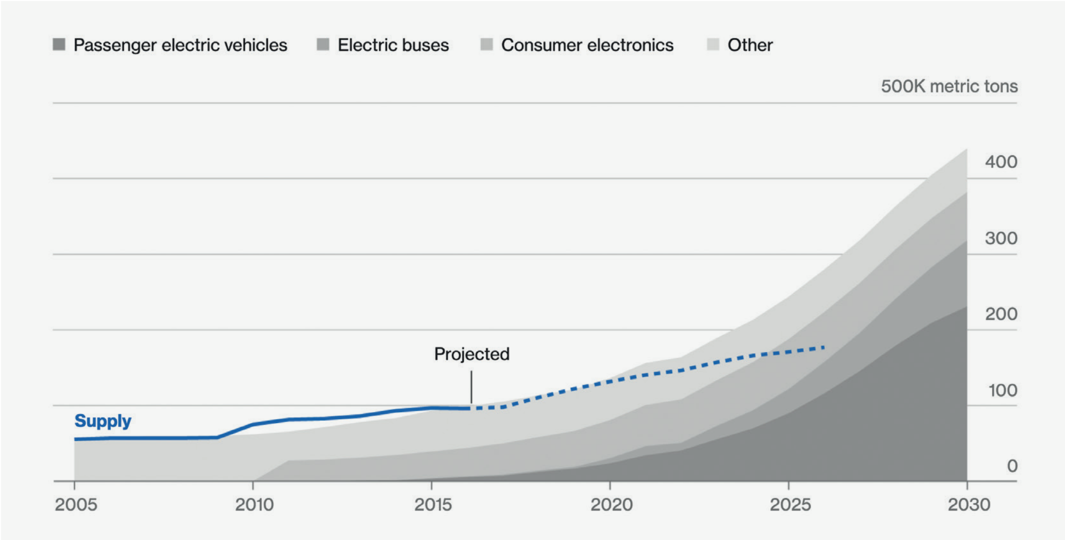
Source: https://tradingeconomics.com/commodity/cobalt

[57] https://investingnews.com/daily/resource-investing/critical-metals-investing/cobalt-investing/top-cobalt-producing-countries-congo-china-canada-russia-australia/
[58] https://www.bloomberg.com/graphics/2018-cobalt-batteries/

4. recovery pathways continued

Furthermore, as demand for batteries takes off, the supply of cobalt is forecast to struggle to keep up. This is shown in the chart below.

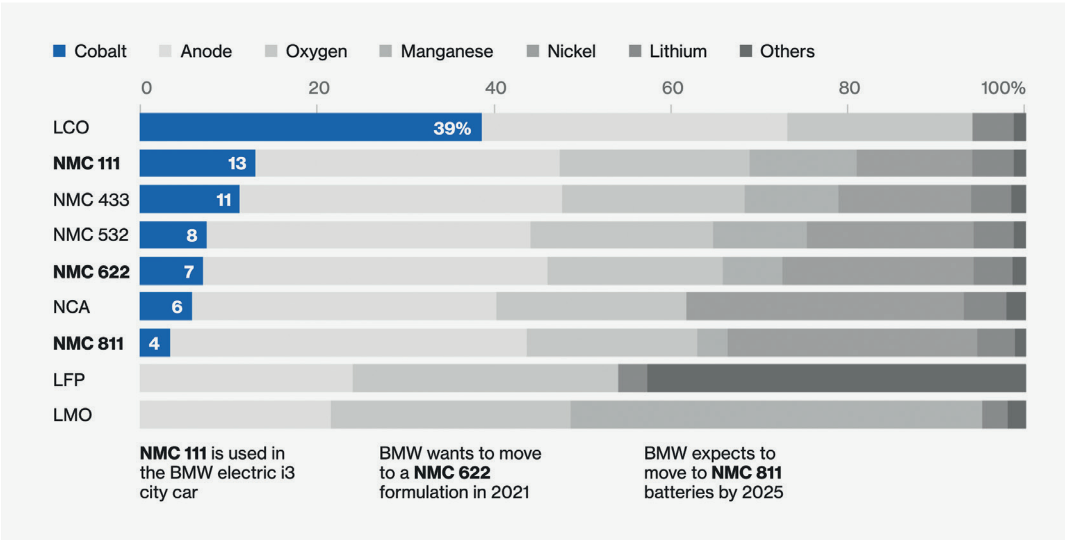
Figure 22: Projected Cobalt Supply against Projected Demand (2005 – 2030)



Source: https://www.bloomberg.com/graphics/2018-cobalt-batteries/

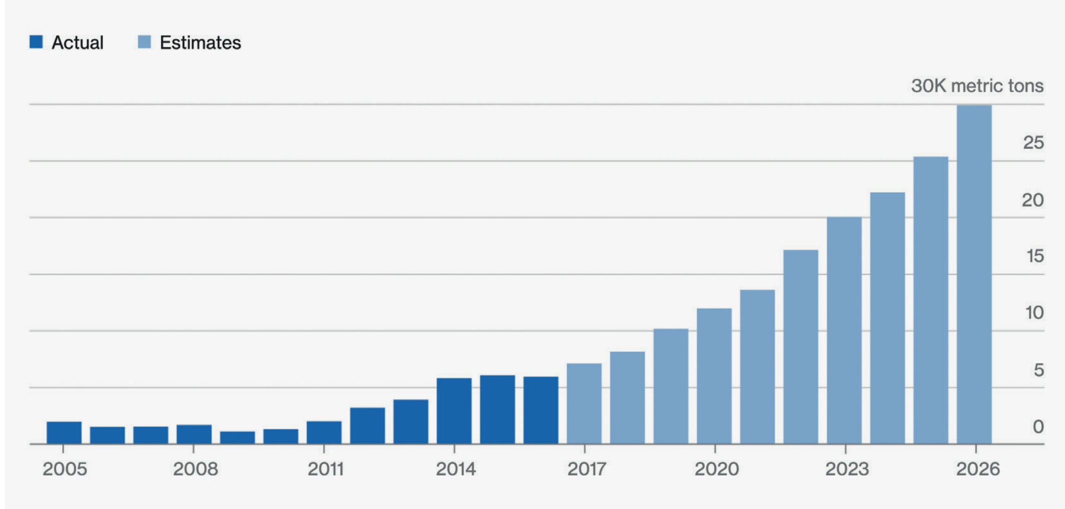
The impact of the high price of cobalt and uncertainties about its supply have led to two key responses by the industry: Moving to battery designs that use less cobalt (as shown in Figure 23) and looking to recover cobalt from used batteries (Figure 24).

Figure 23: Cobalt Content of EV Batteries



Source: https://www.bloomberg.com/graphics/2018-cobalt-batteries/

Figure 24: Estimates of Cobalt Recovery from Used Batteries



Source: https://www.bloomberg.com/graphics/2018-cobalt-batteries/

4.1.6 Graphite:

Graphite is the main material for the anode in lithium-ion batteries. EVs can have in the order of 50kg of graphite in each battery pack. 75% of flake graphite is mined in China. There are concerns over environmental and labour practices, which has China's graphite industry under scrutiny – and some mines have even been shut down by the Chinese Government.

The US, Europe, Japan and South Korea are almost entirely dependent on imported graphite; therefore, the US and the EU have declared graphite a supply-critical mineral. Very little recycling of graphite takes place, and there are almost no substitutes for the material. This has led to an increase in the price of graphite of over 40% in the last 6 months.[59]

One forecast is that the battery anode market for graphite (natural and synthetic) will at least triple in size from 80,000 tonnes in 2015 to at least 250,000 tonnes by the end of 2020.[60]

[59] https://investorintel.com/sectors/technology-metals/technology-metals-intel/northern-graphite-becoming-an-important-market-player/
[60] http://www.visualcapitalist.com/critical-ingredients-fuel-battery-boom/

5. summary and conclusions

5.1 Legislation and Policy

1. Legislation and policy have two key functions in this context: how they may (or may not) encourage battery demand and setting a framework for how end-of-life batteries are managed. New Zealand has historically had a relatively 'light touch' approach to legislation and regulation. The philosophy has generally been to make small adjustments to the way that markets work and then to let the markets solve the issues. For example, there are not yet significant subsidies for purchase of electric vehicles or distributed power systems. There is an EV target, but it is self-imposed, and there are no direct consequences for anyone if the target is not achieved. There are currently no mandatory product stewardship schemes, although the current government is consulting on the introduction of regulated schemes including for E-waste. Note: As discussed in the New Energy Futures Paper on Batteries and a Circular Economy, Vector has convened the Battery Industry Group (B.I.G.) with the aim to develop a product stewardship scheme for large batteries.

2. New Zealand's charging network has been developed by a wide range of players from supermarkets, petrol stations, city councils to utilities and vehicle manufacturers. The network already has reasonably good national coverage and is growing fast. It does not appear that charging infrastructure will be a notable impediment to uptake of EVs.

3. Overall, while there are no substantial legislative or policy drivers for fast adoption of EVs there are no substantial impediments either. Future policy initiatives (such as those suggested in the productivity commission report, or the feebate scheme recently proposed by Ministers), could see faster adoption of EVs.

4. The use of battery storage has the potential to become a more important feature of electricity networks.

5.2 Battery Types and Technology

1. The main types of large battery technology in use in NZ are NiMH and lithium-ion.

2. The main driver for battery development has been EVs. This has focused on lithium-ion. It appears likely that, for the foreseeable future, the majority of batteries that will power EVs will be some form of lithium-ion or be lithium based. In addition to seeking performance improvements, changes to the chemistry of batteries will be partly driven by the cost and security of supply of raw materials.

3. Other technologies such as flow batteries[61], including vanadium flow batteries[62] may have a share of the market in the future for large stationary storage applications.

4. Adapting dedicated EV battery designs for secondary applications may create challenges in the future unless they are designed with secondary uses in mind, and manufacturers may also have reputational concerns with the use of battery packs or components by third parties.

5. The high price of raw materials may drive the recycling market and incentivise EV manufacturers to keep the batteries within their supply chains.

6. Second life applications will have to compete with dedicated storage technologies and designs. It will come down to the economics of the options. It is likely that repurposed batteries will find a niche in certain applications, although whether there will be a match between the supply of end of use batteries and the demand for them in second life applications is uncertain.

7. There may be a divergence of approaches by different manufacturers depending on the corporate philosophy globally.

[61] http://energystorage.org/energy-storage/storage-technology-comparisons/flow-batteries
[62] The vanadium flow battery (VFB), also known as the vanadium redox battery (VRB) or vanadium redox flow battery (VRFB), is a type of rechargeable flow battery that employs vanadium ions in different oxidation states to store chemical potential energy. https://www.bbc.com/news/magazine-27829874

5.3 Future Projections

1. The number of end-of-life batteries which will have to be managed is driven primarily by the adoption of EVs. Although stationary storage applications are also growing in NZ the likely lesser scale and longer life of batteries in these applications means that stationary storage will not be a major source of end of life batteries in the next 10-15 years.

2. Globally the number of EVs being sold is growing exponentially and is projected to continue and to reach about a third of the vehicle fleet by 2040.

3. Although there are aspirations to move to net zero carbon emission in New Zealand by 2050[63] which would imply a virtually all EV fleet, it is more likely that the adoption of EVs will follow a similar trajectory to global adoption (unless there are really significant incentives by Government).

4. New Zealand's vehicle fleet has a different profile to other first world nations. The average age of our light fleet is 14 years. This is the same profile for EVs. Over half of EVs are imported as used vehicles primarily from Japan. Any improvements or lack thereof in technology / efficiency are thus also imported. In Japan cars undergo stringent Warrant of Fitness testing (the Shaken) and it is common for the vehicles to not pass the 7 year test. These vehicles are the most common source of used vehicles imports in NZ. Japan has however been slow in the take up of EVs, instead focussing on hydrogen, and this could be a constraining factor on supply of used EVs.

5. Because we have a relatively old EV fleet, New Zealand will have a high proportion of EVs coming to the end of life sooner than most other countries.

6. If the profile of our vehicle fleet (high proportion of used) remains the same, the adoption of EVs will reflect to a large extent the adoption profile of countries like Japan but with a 5-7 year delay.

7. Modelling suggests between 500 and 1,000 EV batteries coming to the end of life by 2020 rising to between 9,000 and 17,000 by 2025 and 30,000 to 84,000 by 2030. Because stationary storage applications are still a small (but growing) part of the market and have longer lifespans, the numbers of batteries reaching end of life from such uses is expected to remain relatively small between now and 2030.

5.4 Recovery Pathways

1. The recycling of lithium-ion batteries reclaims the metals such as cobalt, nickel, aluminium and copper. Lithium is not able to be reclaimed economically using the most common current thermal processes.

2. The supplies of the raw materials for battery construction represent a potential future constraint; in particular cobalt, graphite, and lithium. While reserves are not yet an issue the demand for materials such as cobalt may outstrip supply after 2020 unless supply is increased.

3. This may create market demand for recycling of batteries in order to access valuable materials for new EV batteries.

4. Given potential issues with repurposing and the likely value of accessing materials for their own production, EV manufacturers may be incentivised to bring batteries back into their supply chains for de-construction and recycling as opposed to enabling secondary uses. This may vary according to the philosophy adopted by the manufacturer globally.

5. New Zealand's remote location and small market size may make it unattractive for some manufacturers to absorb end of life batteries into their supply chains and they may be more open to local solutions.

6. The rise of technologies designed for large scale storage such as vanadium flow, may limit the market for repurposing in those applications.

7. If the level of demand for stationary storage is in line with the number of end-of-use EV batteries coming on stream, and the cost per kWh over their remaining life is competitive with dedicated designs, then there could be pull through of EV batteries into stationary storage applications.

[63] As indicated in the Government's Zero Carbon Bill

5.5 Key Conclusions

There is likely to be a substantial increase in the numbers of large batteries coming to end of life in New Zealand over the next 10-15 years. The increase in numbers is driven by the accelerating adoption of EVs in particular, with stationary storage applications also becoming important. Projections in respect of the expected future uptake of EVs and stationary storage applications are uncertain however. There are currently no strong incentives or impediments to their uptake, but the Government has signalled potential future incentives to encourage EV use.

The numbers of large batteries reaching end of life is currently small, and so this has not created issues to date, but numbers are growing rapidly and so there is a limited window for getting formal schemes in place that will be able to adequately manage end of life batteries. There are no product stewardship schemes in place at present although the Government has identified lithium-ion batteries as one of four candidates for developing a regulated product stewardship scheme over the next two years. Each brand owner has different drivers and different approaches and there will need to be flexibility to accommodate these different approaches within a product stewardship regime.

There is potential to extend the life of EV batteries through refurbishing and second-life uses. The extent to which these second life uses are taken up will depend on whether there is a match between the supply of second life batteries and the demand for them (at particular price points) in second life applications. Second life uses may also have to compete with recycling if the supplies of raw materials (in particular cobalt), are constrained and manufacturers seek to use reclaimed batteries as a source of raw materials. Finally, the increasing complexity of battery design (particularly battery and thermal management systems) may, in the future, make it more difficult to adopt EV batteries for second life uses unless this is considered during battery design.

The development of onshore processing or pre-processing for recycling end of life batteries will depend on the economics. Overseas facilities are likely to have lower processing costs due to economies of scale. However, because there are high costs involved in making batteries safe for transport, being able to avoid these costs could make local pre-processing economic.

appendices

A.1.0 electric vehicles and battery capacity

A.1.1 Full-electric

Addax MT: 10-15 kWh
BMW i3: 22–33 kWh
BYD e6: 60–82 kWh
Chevrolet Bolt / Opel Ampera-e: 60 kWh
Citroen C-Zero / Peugeot iOn (i.MIEV): 14 kWh (2011) / 16 kWh (2012-)
Fiat 500e: 24 kWh
Ford Focus Electric: 23 kWh (2012), 33.5 kWh (2018)
Honda Clarity (2018): 25.5 kWh
Hyundai Kona Electric: 64 kWh
Hyundai Ioniq Electric: 28 kWh
Kia Soul EV: 27 kWh
Luxgen S3 EV+: 33kWh
Nissan Leaf I: 24–30 kWh
Nissan Leaf II: 40 kWh (60 kWh in future option)
Mitsubishi i-MIEV: 16 kWh
Renault Fluence Z.E.: 22 kWh
Renault Twizy: 6 kWh
Renault Zoe: 22 kWh (2012), 41 kWh (2016)
Smart electric drive II: 16.5 kWh
Smart electric drive III: 17.6 kWh
Tesla Model S: 60–100 kWh
Tesla Model X: 60–100 kWh
Tesla Model 3: 50–70 kWh
Toyota RAV4 EV: 27.4 kWh (1997), 41.8 kWh (2012)
Volkswagen e-Golf Mk7: 24–36 kWh

A.1.2 Plugin hybrids

Audi A3 e-tron: 8.8 kWh
Audi Q7 e-tron: 17 kWh
BMW i8: 7 kWh
BMW 2 Series Active Tourer 225xe: 6.0 kWh
BMW 330e iPerformance: 7.6 kWh
BMW 530e iPerformance: 9.2 kWh
BMW X5 xDrive40e: 9.0 kWh
Chevrolet Volt: 16–18 kWh
Ford Fusion II / Ford C-Max II Energi: 7.6 kWh
Fisker Karma: 20 kWh
Honda Accord PHEV (2013): 6.7 kWh
Honda Clarity PHEV (2018): 17 kWh
Hyundai Ioniq Plug-in: 8.9 kWh
Koenigsegg Regera: 4.5 kWh[18]
Mitusbishi Outlander PHEV: 12 kWh
Porsche 918 Spyder: 6.8 kWh
Toyota Prius III Plug-in: 4.4 kWh
Toyota Prius IV Plug-in: 8.8 kWh
Volkswagen Golf GTE: 8.8 kWh
Volkswagen Passat GTE: 9.9 kWh
Volkswagen XL1: 5.5 kWh
Volvo V60: 11.2 kWh

A.1.3 Non–plug-in hybrids

Chevrolet Malibu (2016): 1.5 kWh
Ford Fusion II / Ford C-Max II: 1.4 kWh
Hyundai Ioniq Hybrid: 1.56 kWh
Kia Niro: 1.56 kWh
Lexus CT 200h: 1.3 kWh
Lexus NX 300h: 1.6 kWh
Toyota Prius II: 1.3 kWh
Toyota Prius III: 1.3 kWh
Toyota Prius C / Toyota Yaris Hybrid: 0.9 kWh
Toyota Camry Hybrid (2012): 1.6 kWh

Source: https://en.wikipedia.org/wiki/Electric_vehicle_battery

A.2.0 alternative end of life ev projections

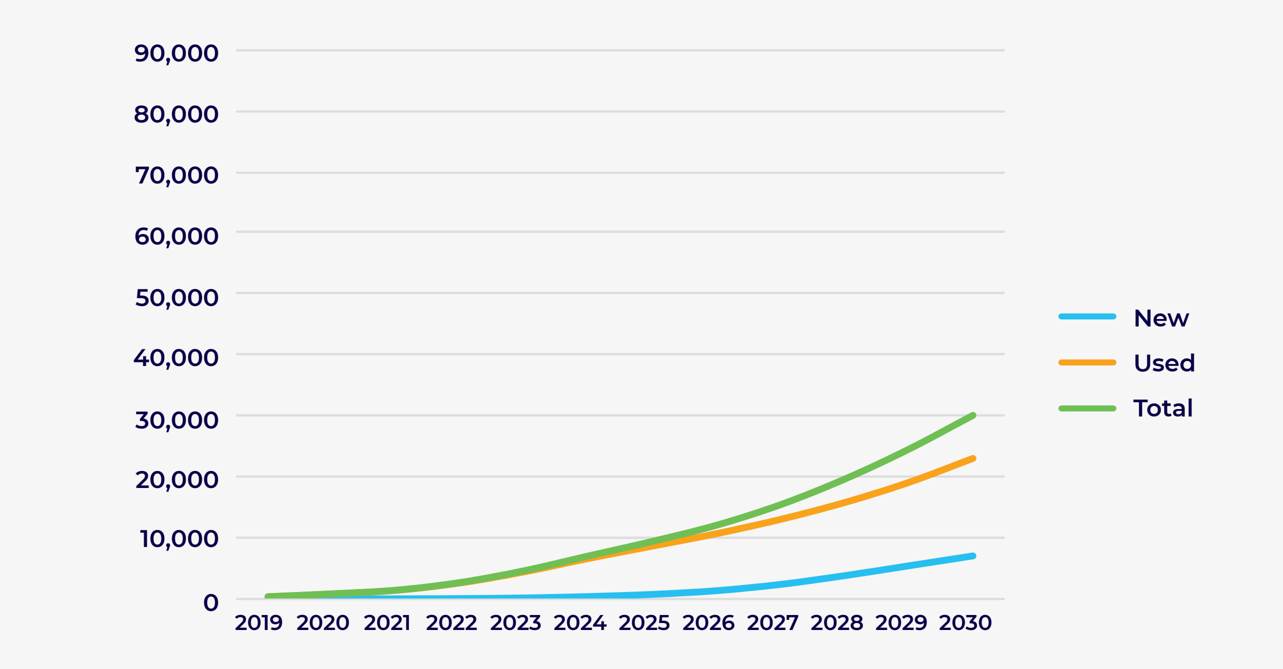
A.2.1 Sensitivity 1

Under this sensitivity EV use does not meet Government targets but instead is projected to be approximately in line with global fleet projections (about 30% by 2030) and reaches 100,000 by 2030.

Table A - 1: Used EV Battery Projections Assuming EV Uptake is in Line with Global Projections

	New	Used	Total
2019	34	478	512
2020	46	939	984
2021	63	1,520	1,583
2022	103	2,732	2,835
2023	205	4,554	4,759
2024	426	6,740	7,166
2025	777	8,774	9,550
2026	1,370	10,816	12,186
2027	2,385	13,158	15,543
2028	3,796	15,919	19,715
2029	5,384	19,210	24,594
2030	6,979	23,143	30,121

Figure A - 1: Used EV Battery Projections Assuming EV Uptake is in Line with Global Projections



Even with this more conservative scenario there will still be substantial quantities of EV batteries reaching the end of life by 2030.

A.2.0 alternative end of life ev projections continued

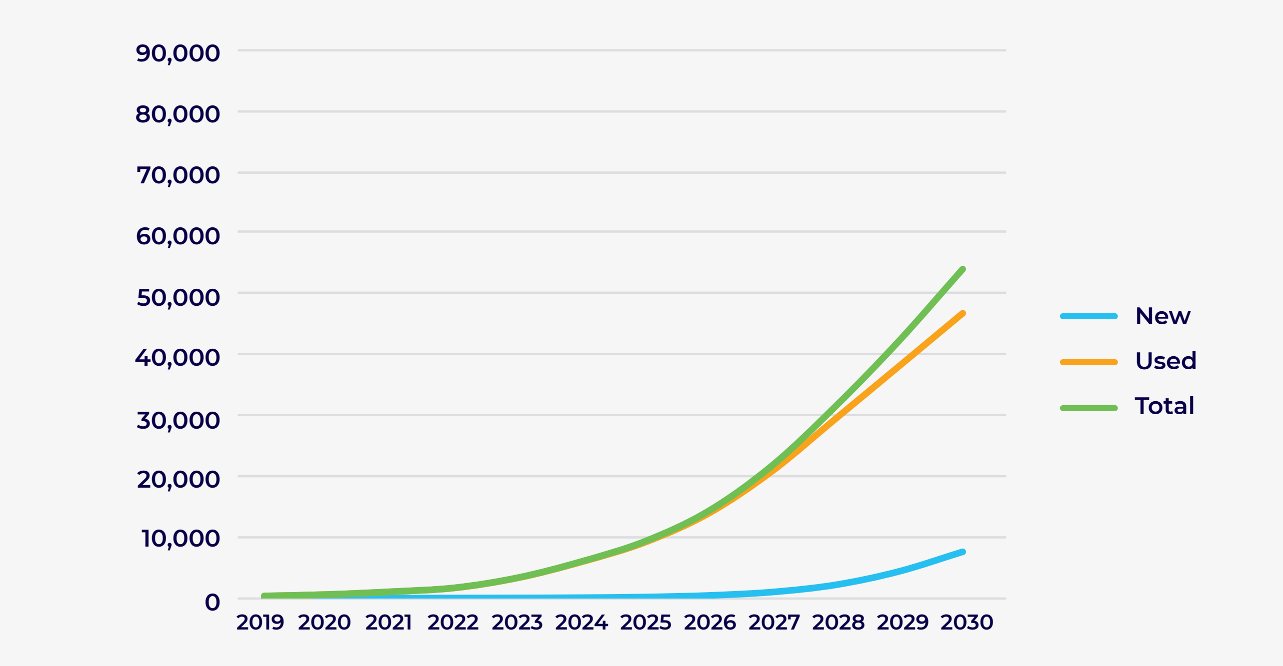
A.2.2 Sensitivity 2

Under this set of assumptions Government targets are met, but average EV life is slightly extended to 12 years, and a slightly higher proportion (50%) of the EV fleet is assumed to be new.

Table A - 2: Used EV Battery Projections Assuming Extended Average Battery Life

	New	Used	Total
2019	20	240	261
2020	27	478	505
2021	34	933	967
2022	46	1,565	1,610
2023	63	3,228	3,292
2024	103	5,854	5,957
2025	205	9,085	9,290
2026	454	13,835	14,289
2027	997	20,787	21,784
2028	2,145	29,415	31,561
2029	4,291	38,067	42,358
2030	7,411	46,762	54,174

Figure A - 2: Used EV Battery Projections Assuming Extended Average Battery Life



A.3.0 transporting of waste lithium ion batteries

There are a number of issues associated with transporting of waste and defective lithium-ion batteries.

The packaging must protect the battery from short circuiting (to avoid fires), and it must be protected from damage which could lead to thermal runaway and fires. The battery should not be able to move in the packaging (as this could lead to damage). The heavier a battery is the more protective packaging will need to be used. With heavier batteries packaging multiple batteries in the same package or crate is generally not possible.

There are generally different requirements for shipping via road and rail, sea, and air. The following table summarises key requirements and regulations:

Shipping method	Considerations	Regulations
Road and Rail	Li-ion batteries (as opposed to individual cells) generally have recessed terminals as well as output over current control and protection making them safe for transportation. The exception is batteries that are recalled that have a high likelihood of causing a fire. Cells must be wrapped in a manner that prevents them from damage while in transit. At least one layer of bubble wrap per cell is recommended.	Land Transport Rule Dangerous Goods 2005 Rule 45001/1[64] NZS 5433.1:2012 Transport of dangerous goods on land
Shipping	Special packaging may be required to transport large batteries by sea. They may be classified as dangerous goods.	Packaging must comply with the International Maritime Dangerous Goods (IMDG) Code. This code is updated every even year, so the current version is the 2016 Edition Amendment 38-16.
Air freight	Damaged batteries and those believed to be defective cannot be transported by air.	Packaging must meet the Dangerous Goods Regulations. These regulations are governed by the International Air Transport Association and the International Civil Aviation Organisation.[65]

Sources: https://www.ecotechservices.co.nz/services/recycling/batteries/battery-shipment/, https://www.nefab.com/en/insights/what-packaging-should-i-use-to-ship-lithium-ion-batteries/, https://www.nzta.govt.nz/resources/rules/dangerous-goods-2005/

A.3.1 Courier and freighting company policies

- **Courierit** – depends on the carrier used.
- CourierPost – batteries and appliances containing batteries are prohibited.
- **DHL** – batteries are transported but conditions apply.
- **Fastway** – no explicit mention of batteries in their conditions of carriage but they have stated that they do not transport batteries or only transport batteries under certain conditions.
- **FedEx** – batteries are transported but conditions apply. They give specific instructions for how to package lithium batteries for shipping.
- **NZ Couriers** – not to exceed 5 kg and lithium-based batteries require pre-approval.
- **New Zealand Post** – batteries are prohibited unless they are with equipment and are not lithium metal types.
- **Post Haste** – no explicit mention of batteries in their conditions of carriage.
- **UPS** – batteries are transported but special requirements may be stipulated for lithium metal types.

Source: https://www.ecotechservices.co.nz/services/recycling/batteries/battery-shipment/

[64] http://nzta.thomsonreuters.co.nz/DLEG-NZL-LTSA-T.LTR-45001_1.pdf
[65] https://www.iata.org/whatwedo/cargo/dgr/Pages/lithium-batteries.aspx

A.4.0 vector functional specifications for trialling battery energy storage systems

Vector is willing to pilot new or second-life batteries on the Auckland electricity network if the battery trial:

i. Aligns with Vector project planning
ii. Meets Vector functional specifications below

Functionality available	Peak Load Shaving, Voltage Control, Phase Balancing, Islanding (optional)
Protocols	DNP3, Modbus TCP/IP , IEC 61850
Max noise	55 dB normal operation, 45 dB restricted operation[66]
Size	Specific to project
Rated continuous AC power	Specific to project
Short time continuous AC Power	160% for 30 sec, 25% for 10 Min (% of rated power)[67]
10 yrs. EOL energy	Specific to project
AC Voltage	415 V 3 phase
Frequency	Specific to project
Power Factor	0 - 1.0 leading and lagging
Minimum AC Round trip efficiency (BOL/ EOL)	87% BOL, 79% EOL (10 yrs)
Capacity Warranty	Min 70% of nameplate energy available at 10 years (EOL)
Enclosure rating	IP 65 (suitable for outdoor NZ climate)
Ambient operating temperatures	0 - 45 degrees C
Minimum Certifications	IEC 62619, IEC 6100-6-4, UN 38.3, NZS 4777.2 (2015)
Product availability	Specific to project
Installation	Specific to project
Metering	Internal metering and Protection for BESS protection
Connection to network	3ph 4 wire
Protection	over/under voltage, over/under frequency, over current
Earthing system	3ph, 4 wire OK for TN-CS
Voltage control	Specific to project
Frequency response time for load step changes	Min 20ms from issuing a signal
HVAC	Included, rated for NZ climate (N.B. low noise)

[66] Zone specific. This limit can vary depending on where the BESS is deployed.
Example shown is for zones within roads: Noise from Substations and electricity storage facilities must not exceed the following noise limits when measured at the residential boundary of a residential zone site within the notional boundary of a rural zone site: 55dBLAeq between Monday to Saturday 7am to 10pm, and Sundays 9am to 6pm. 45dBLAeq for all other times. **Note:** Council are proposing to reduce these by 5 dBLAeq each for battery systems specifically. Vector are responding to these proposed changes (30/01/2019).

[67] These specs can vary depending on the project's requirements. All BESS's must be able to provide short time continuous AC power above its rated power.

notes

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