emission: impossible ltd

Research into the long-term trends for electric vehicle price and supply - understanding developments in the global market

Final Report

Prepared for the Ministry of Transport

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Glossary

Term	Definition
BEV	A **battery electric vehicle** uses electric motors instead of internal combustion engines (ICEs) for propulsion using power provided by rechargeable battery packs.
CO_2	**Carbon dioxide** is a greenhouse gas
EV	An **electric vehicle** in this report includes battery electric vehicles and plug-in hybrid electric vehicles.
EVI	The **Electric Vehicle Initiative** is an intergovernmental initiative working with the International Energy Agency (IEA), including the following countries: Canada, China, Denmark, France, Germany, India, Italy, Japan, Netherlands, Norway, Portugal, South Africa, Spain, Sweden, UK, and the US.
Fuel cell	**Fuel cells** in vehicles create electricity to power an electric motor, generally using oxygen from the air and compressed hydrogen.
FCEV	A **fuel cell electric vehicle** is a type of vehicle which uses a fuel cell to power its on-board electric motor.
GVM	**Gross vehicle mass** is the maximum allowed weight of the vehicle when loaded. Light vehicles have a GVM of 3.5 tonnes or less. Heavy vehicles have a GVM of more than 3.5 tonnes.
HEV	A **hybrid electric vehicle** integrates a small battery and an electric motor to enhance the energy to distance efficiency of the internal combustion engine. The battery's charge is maintained by the internal combustion engine and regenerative braking - it cannot be charged by plugging into an electrical supply. Hybrids can offer greater fuel economy than a traditional internal combustion engine but can only travel very short distances on electric power only.
ICCT	**International Council on Clean Transportation**
ICE	An **internal combustion engine** is an engine powered through the burning of fossil fuels. The term 'ICE' is often used as shorthand for any vehicle powered by an internal combustion engine, whether petrol or diesel or any other flammable medium.
IEA	**International Energy Agency**
kWh	A **kilowatt hour** is the amount of energy released if work is done at a constant rate of 1 kilowatt (kW) for one hour. Electric car battery capacity is measured in kWh.

NEV	A **neighbourhood electric vehicle** is a three- or four-wheeled vehicle with low power. This term is commonly used in the US but NEVs are typically known as quadricycles or quadrocycles in Europe. The Renault Twizy is an example of an electric quadricycle.
NRC	US **National Research Council**
OEM	When referring to auto parts, an **original equipment manufacturer** is a parts or engine manufacturer involved in the final assembly of a vehicle.
PEV	A **plug-in electric vehicle** is any motor vehicle that can be recharged from an external source of electricity and the electricity stored in the rechargeable battery drives or contributes to drive the wheels. PEV is a superset of electric vehicles that includes all-electric or battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs), and electric vehicle conversions of hybrid electric vehicles and conventional internal combustion engine vehicles.
PHEV	A **plug-in hybrid electric vehicle** is a type of vehicle that is configured like a regular hybrid, but with a larger capacity battery pack that can be charged up by plugging in to a regular electricity supply.
Range	The distance you can travel on electric power before the battery requires a recharge
REEV	A **range extended electric vehicle** is a vehicle that uses an electric motor for propulsion but also has an internal combustion engine on board to provide power for a generator, which maintains a minimum charge level on the battery. REEVs can be plugged in and charged up. Unlike PHEVs, REEVs do not use the petrol/diesel engine to directly power the wheels. However, some reports include REEVs in the PHEVs category.
TCO	**Total cost of ownership**

Executive Summary

Transportation accounts for about one fifth of global energy use and, according to the International Energy Agency (IEA), electric vehicles are seen as one of the most promising pathways to increase energy security, reduce carbon emissions, and improve air quality.

There is a general expectation that the prices of electric vehicles will reduce and that global supply of electric vehicles will be sufficient to meet ambitious international targets.

The objective of this project was to synthesise existing research on projections for electric vehicle supply, production, and price for the period 2015 to 2030 and to quantify the:

- expected level of electric vehicle **production** in New Zealand's key supply markets
- potential **supply** of new electric vehicles into New Zealand
- expected **change** in the price of new electric vehicles (including electric vehicle batteries) available to the New Zealand market.

The work included an international literature review as well as a survey of motor vehicle importers and key stakeholders to improve our understanding of the New Zealand context.

Global trends

The International Energy Agency estimates that there were 650,000 electric vehicles on the road in 2014, accounting for 0.08% of total passenger cars. The Electric Vehicles Initiative (EVI)[1] has a target of 20 million electric vehicles on the road by 2020.

Sales of electric vehicles are increasing but the future is uncertain. A recent report from the US National Research Council Committee on Overcoming Barriers to Deployment of Plug-in Electric Vehicles (PEVs) concludes that:

> **The extent to which electric vehicles are adopted over time will depend on reductions in their production costs, on the policies that governments implement to promote PEV deployment, and on the extent to which vehicle manufacturers decide to price electric vehicles attractively** (NRC, 2015)**.**

Barriers to uptake of electric vehicles are summarised in a report to the UK Committee on Climate Change (Element Energy, 2013) as follows:

- Electric vehicles have a high price premium over non electric vehicles
- Supply of electric vehicles is limited in terms of vehicle segments and brands
- Availability and consumer concerns about access to charging infrastructure
- Consumer concerns about electric vehicles short range and long charging times

[1] An intergovernmental initiative working with the International Energy Agency (IEA), that includes representation from the following countries: Canada, China, Denmark, France, Germany, India, Italy, Japan, Netherlands, Norway, Portugal, South Africa, Spain, Sweden, UK, and the US.

- Consumer concerns about:
    - reliability
    - safety
    - battery degradation
    - resale values.

A recent OECD review has found that many different kinds of policies have been implemented around the world to promote the development and deployment of electric vehicles and overcome the barriers to their adoption (OECD, 2015). Most of these policies have been fiscal in nature but market based, regulatory, informational, infrastructure creating, and innovation policy tools have also been used. Governments have also played a convening and coordinating role, particularly relating to the roll out of infrastructure for battery-charging stations.

New Zealand context

New Zealand is a very small market on a global scale. It currently has limited policies or incentives to encourage uptake of electric vehicles.

Supply of electric vehicle models to New Zealand is currently limited. As at November 2014, the number of mass production highway-capable all-electric passenger cars and utility vans available globally was around 30 models, with most of these available in the United States and Western European countries. However, fewer models are offered in Japan and there are only eight electric vehicle models currently available in New Zealand.

To better understand the relevance of global projections to New Zealand we undertook a survey of electric vehicle importers and other stakeholders.

Key findings

Our overarching conclusion for production, supply and price of electric vehicles is that the electric vehicle market is evolving quickly and is subject to significant uncertainty. The results and conclusions in this report will need to be regularly reviewed. More importantly, **policies to promote or encourage uptake of electric vehicles will need to be flexible and adaptive to change**.

The following sections summarise our key findings based on the results of our international literature review, as well as the results of the stakeholder survey.

Key findings: electric vehicle production and supply

Based on a review of international literature on electric vehicle demand and production we have concluded that, while there is considerable uncertainty in projected electric vehicle demand and production, **it is reasonable to assume that growth in electric vehicle production capacity will be adequate to meet demand** in New Zealand's key supply markets of Japan and Europe.

Supply: passenger cars

In general, the responses to the stakeholder survey suggest that supply of electric vehicles in New Zealand is limited (in terms of model variants) compared with international markets because there is limited demand.

The general consensus is that **demand** in New Zealand will lag behind other countries because:

- the price of electric vehicles is still too high without government support/subsidies/ penalties to encourage adoption and
- other countries have better charging infrastructure[2].

We conclude that **supply of electric vehicles in New Zealand will continue to be limited until costs reduce or policies are introduced to reduce cost or increase demand**.

However, motor vehicle importers consistently report that **they could respond quickly to increased demand** if sales of electric vehicles really take off.

Uptake of **neighbourhood electric vehicles** in New Zealand is likely to be limited because these vehicles **do not meet New Zealand frontal impact regulations**. However, it is reasonable to assume that supply of these vehicles is not constrained.

Supply: light commercial vehicles

Light commercial electric vans (less than 3.5 tonnes gross vehicle mass or GVM) are available in Europe and Japan but they are not currently available in New Zealand. We conclude that **supply of electric light commercial vehicles in New Zealand will be limited until costs reduce, or policies are introduced to reduce cost or increase demand.** However, it is reasonable to assume that these vehicles could become available here if and when this becomes a viable business proposition for vehicle importers.

Based on the literature reviewed, we conclude that heavier light commercial electric vehicles (above 3.5 tonnes GVM) are likely to be slower to come to the market compared to equivalent internal combustion engine vehicles. This is because the battery technology for heavier vehicles is relatively heavier and more expensive and requires more expensive charging solutions compared with lighter vehicles.

Supply: heavy commercial vehicles

Electric trucks are produced for niche markets and applications such as urban delivery and rubbish trucks. However the battery technology is still relatively heavy and expensive. Suitable fast charging infrastructure is also required for these vehicles. Heavy commercial electric vehicles currently have limited application and we conclude that production of heavy commercial electric vehicles will be **limited to a small niche market** for the next decade.

[2] However, we note that the uptake of plug-in hybrid electric vehicles is unlikely to be affected by availability of charging infrastructure.

Key findings: policy constraints

In addition to price and charging infrastructure, some specific policy constraints have been identified through the stakeholder survey, these include:

- **Neighbourhood electric vehicles** do not meet New Zealand frontal impact regulations.
- Some models of **neighbourhood electric vehicles** are designed for a maximum speed of only 45km/hour.
- Electric **bus and truck** technology is heavy and electric buses would be likely to breach limits under the Vehicle Dimensions and Mass (VDAM) Rule.
- Electric **heavy commercial** vehicle adopters would be penalised with the existing Road User Charges (RUC) regime. Even a slight increase in weight reduces the payload while also potentially moving the vehicle into another RUC cost category.

Key findings: electric vehicle price

We reviewed international literature from a wide range of sources, including government agencies, motor vehicle manufacturers, independent committees, academic papers and media reports. There is consensus from all sources that the **price** of electric vehicles will reduce over time so that they will become cost effective compared with conventional vehicles. However it is difficult to predict how quickly this will happen.

The results of the stakeholder survey are consistent with the findings of our international review. In general, motor vehicle importers expect the price of electric vehicles in New Zealand to reduce over time, but they do not know how long this will take.

Cost projections: passenger cars

The difference in price between a conventional and an electric vehicle is primarily due to the high cost of batteries. We reviewed and collated recent literature on battery cost and recommended high, medium and low projections based on the range of costs reported in literature. We used this information to develop high, medium and low estimates of the likely reduction in **manufacturing costs** to 2030 for battery electric vehicles and a plug-in hybrid electric vehicle.

The results of our analysis suggest that a typical electric vehicle[3] costs around **$11,500 more to manufacture** in 2015 than an equivalent internal combustion engine vehicle[4]. This difference is expected to drop to around **$4,500 by 2030**.

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[3] A battery electric vehicle with a 120km range such as the Nissan Leaf.

[4] These projections are estimates of the incremental manufacturing cost of electric vehicles compared with an equivalent internal combustion engine vehicle manufactured to 2010 greenhouse gas and fuel efficiency standards. The incremental cost may actually be less in future because the cost of manufacturing internal combustion engines is expected to increase. We have not attempted to determine any price trajectory for conventional internal combustion engine vehicles. However, the EPA estimates an average compliance cost of around US$1000 (NZ$1400) for the 2016 light duty fleet greenhouse gas emission and fuel economy standards (EPA, 2010) so this could be taken as an **indicative** cost increase for the average vehicle.

Price: passenger cars

The literature that we reviewed provides projections of **cost**. It is not possible to project **price** with any confidence because reductions in manufacturing costs may not necessarily translate directly into vehicle price. Battery price is generally expected to be about 50% more than the manufacturing costs. However, the price will be depend on the availability of unused battery production capacity, a manufacturer's desire to be perceived as a technology leader and the willingness of the manufacturer to set a price that will gain market share (NRC, 2015).

Price premium in New Zealand: passenger cars

Our analysis suggests that the difference between prices of new vehicles (including electric vehicles) in New Zealand and in international markets is expected to be in the order of NZ$6,000 in 2015 dollar values[5]. This estimate could be used to project future prices of vehicles that are not currently available in the New Zealand market.

Cost projections: light commercial

The extra cost of producing an electric light commercial vehicle up to approximately 2 tonnes can be estimated using the same data as passenger cars. An example is the Nissan eNV200 van, which is available in Japan and Europe. The Nissan van has the same battery and motor specifications as a Nissan Leaf so it is reasonable to assume that the difference in manufacturing costs for a passenger car is directly applicable.

Cost data for larger commercial vehicles are not available in the model that we have used to develop cost projections because the USEPA consider that electric vehicle technology is unlikely to be adopted for these vehicle classes. Based on the literature reviewed, we conclude that large (over 3.5 tonne GVM) commercial vehicles are likely to show increased cost differential compared to equivalent internal combustion engine vehicles for some time.

Cost projections: heavy commercial vehicles

Urban delivery trucks are currently produced in small numbers for a niche market. The literature predicts that the cost of the battery system relative to the total cost of truck will continue to be substantial over the next 15 years. However, [redacted] Section 9(2)(ba)(i) considers that heavy commercial electric vehicles, in particular buses, could become cost effective based on **total cost of ownership** within the next few years.

[5] Recent trends in the exchange rate between Australia and New Zealand may affect this result. However, we have analysed the price differential over a single time period and a single assumed exchange rate. We would need to undertake the analysis over a longer period to know if it was sensitive to exchange rate.

1 Introduction

According to the International Energy Agency (**IEA**), transportation accounts for about one-fifth of global energy use. Electric vehicles are seen as one of the most promising pathways to increase energy security, reduce carbon emissions, and improve air quality[6].

1.1 Objectives and scope

The Ministry of Transport is modelling the expected uptake of electric vehicles[7] in New Zealand for the period 2015 to 2030 and wants to establish a better understanding of supply side factors. This includes the expected price of **new**[8] electric vehicles, the level of global production, and the level of supply available to New Zealand.

Consequently, the Ministry is seeking a report which synthesises existing research on projections for electric vehicle supply, production, and price for the period 2015 to 2030.

The objective of this report is to quantify the:

- expected level of electric vehicle production in New Zealand's key supply markets
- potential supply of new electric vehicles into New Zealand and
- expected change in the price of new electric vehicles (including electric vehicle batteries) available to the New Zealand market.

The report has collated relevant information for the following vehicle classes:

- Neighbourhood vehicles
- Conventional passenger vehicles
- Light commercial vehicles
- Heavy commercial vehicles.

1.2 Methodology

The research comprised four parts:

1. Conduct an international literature review

   The objective of the literature review was to synthesise existing research on international projections of electric vehicle production and price.

[6] IEA (2015), press release available at http://www.cleanenergyministerial.org/News/evi-releases-the-global-ev-outlook-2015-27091

[7] Electric vehicles, for the purposes of this project, include pure electric vehicles and plug-in hybrid electric vehicles.

[8] This work is in parallel to research looking at the projected supply and price of used electric vehicles from Japan into the New Zealand market.

2. Review the New Zealand context

   Key suppliers and stakeholders were surveyed to help establish the New Zealand context and to determine whether international projections are applicable in New Zealand.

3. Analysis

   We have undertaken a primarily qualitative analysis of global production of electric vehicles and potential supply to New Zealand based on the results of the literature review and the stakeholder survey. A high, medium and low scenario for expected reduction in cost of batteries and electric vehicles has been developed based on the information reviewed.

4. Reporting

   In addition to this report there is an excel spreadsheet which includes cost projection calculations. A separate confidential report has also been prepared which includes detailed responses from motor vehicle importers and other key stakeholders.

1.3 Report layout

This report is structured as follows:

- **Section 2** of summarises the results of our international literature review on production and price of new electric vehicles.
- **Section 3** provides New Zealand context, including some information on the electric vehicle market in New Zealand.
- **Section 4** summarises our analysis of electric vehicle production, supply and price.
- **Section 5** provides key conclusions.

2. Global Projections

This section of the report covers the findings from our review of existing literature on global projections for electric vehicle supply, production and price for the period 2015 to 2030.

2.1 Sources used

Electric vehicle technology is a fast moving field with new information and analysis becoming available constantly. To ensure that we considered relevant and recent information, we used a number of recent international publications as the starting point for our review. These included:

- The International Energy Agency Global EV Outlook 2013 (IEA, 2013) and the 2015 Update (IEA, 2015).
- The National Research Council (US) report from the Committee on Overcoming Barriers to Electric-Vehicle Deployment (NRC, 2015).
- A report for the European Climate Foundation, Fuelling Britain's Future (CE, 2015).

These publications generally provide high level statistics across the whole vehicle fleet. We reviewed a range of other literature and information sources to determine the applicability of global production forecasts to New Zealand supply markets and to develop detailed cost projections. The sources used are referenced throughout the report.

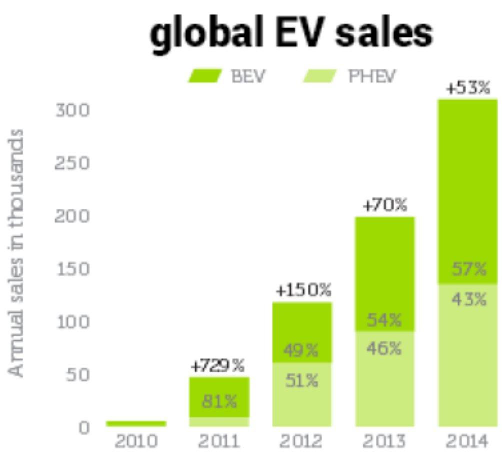
2.2 Global trends

As noted by the IEA, transportation accounts for about one-fifth of global energy use. Reduction of greenhouse gas emissions from the vehicle fleet is a high priority globally and electric vehicles are seen as one of the most promising pathways to increase energy security, reduce carbon emissions, and improve (local) air quality[9].

The IEA reports that over the past few years there has been considerable progress in the development of the electric vehicle market, as seen in Figure 1:

- Global EV stock has surged, rising from about 180,000 electric cars on the road in late 2012 to 665,000 on the road at the end of 2014.
- Battery cost has dropped by about 50% since 2011.
- Battery energy density has risen, which in turn can improve vehicle range - a key consumer concern.

Figure 1: Global electric vehicle sales



Source: (IEA, 2015)

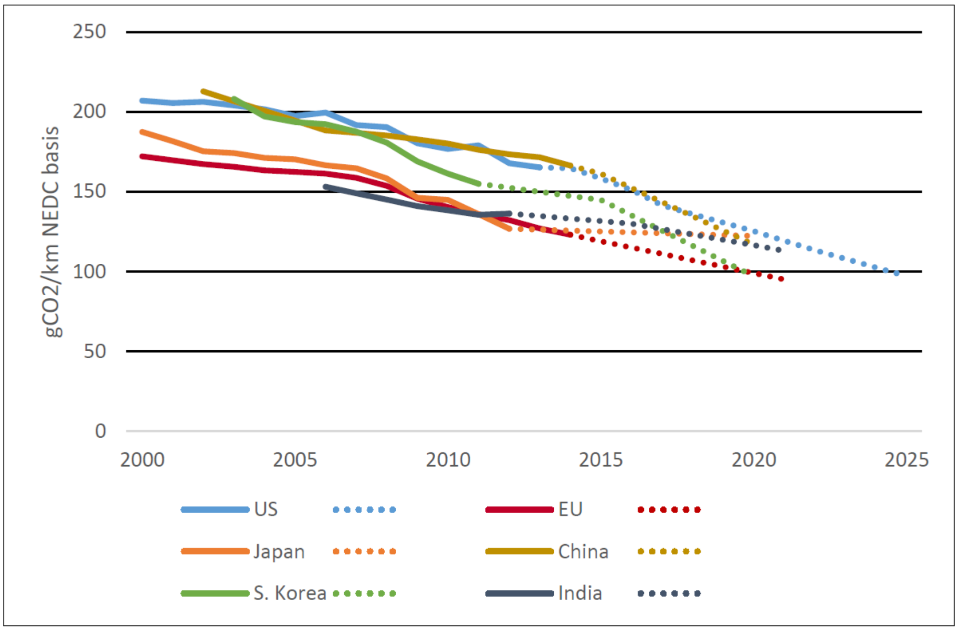
[9] IEA (2015), press release available at http://www.cleanenergyministerial.org/News/evi-releases-the-global-ev-outlook-2015-27091

Even with these advancements, significant and complex technological, financial, market and policy challenges remain (IEA, 2015).

2.2.1 Vehicle CO_2 emissions or fuel efficiency standards

One of the key mechanisms overseas to reduce carbon dioxide (**CO_2**) emissions from the vehicle fleet is through the introduction of new vehicle emission standards, which are becoming progressively more stringent. Although emission standards are different around the world they are expected to converge towards 2025 as shown in Figure 2.

Figure 2: Global vehicle CO_2 emissions performance and standards



Source: (CE, 2015), **Figure 1.1**

These legally binding standards generally require manufacturers to achieve an average CO_2 emission (directly related to fuel consumption for use of fossil fuels) standard across their fleet, which is expected to result in increased production and availability of electric vehicles. For example, in Europe most manufacturers have announced that they plan to release at least one electric version in each model series[10]. However, the standards alone are not necessarily expected to result in widespread use of battery electric vehicles or plug-in hybrid electric vehicles (OECD, 2015).

2.2.2 Barriers to uptake of electric vehicles

Barriers to uptake of electric vehicles are summarised in a report to the UK Committee on Climate Change (Element Energy, 2013) as follows:

- Electric vehicles have a high price premium over non electric vehicles
- Supply of electric vehicles is limited in terms of vehicle segments and brands

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10 [redacted] Section 9(2)(ba)(i)

- Availability and consumer concerns about access to charging infrastructure
- Consumer concerns about electric vehicles short range and long charging times
- Consumer concerns about:
    - reliability
    - safety
    - battery degradation
    - resale values.

2.2.3 International policies to promote electric vehicle uptake

A recent OECD review has found that many different kinds of policies have been implemented around the world to promote the development and deployment of electric vehicles and overcome the barriers to their adoption (OECD, 2015). Most of these policies have been fiscal in nature, but market based, regulatory, informational, infrastructure creating, and innovation policy tools have been used as well. Governments have also played a convening and coordinating role, particularly relating to the roll out of infrastructure for battery-charging stations.

The OECD review concludes that technical barriers and costs remain a primary obstacle to the more rapid deployment of electric vehicles. Most importantly, the costs of batteries have not reduced enough to make battery electric vehicles cost competitive without some sort of government incentive. Table 1 summarises the deployment incentives that have or are being implemented internationally (OECD, 2015). According to the OECD, incentive measures typically result in a reduction in the current investment for an electric passenger car of US$7,000 to $10,000 (approximately NZ$10,000 to NZ$14,000).

Table 1: Deployment incentives for battery electric and plug-in hybrid electric vehicles by country (OECD, 2015)

Type of incentive	Locations
Income tax credit or deduction for purchase of a BEV or PHEV	Austria, Belgium, Israel, Netherlands (BEV taxis or vans only), United States (federal, Colorado, Georgia, Montana, Oklahoma, South Carolina, Utah)
Grants or rebate on purchase or lease of a BEV or PHEV	Canada (Ontario, Quebec), China (paid to manufacturers), Spain (federal and several regions), Sweden, United Kingdom, United States (California, Hawaii, Illinois, Louisiana, Maryland, Tennessee, Texas)
“Fee-bate” Scheme (whereby a fee is imposed on inefficient or polluting vehicle, and rebates offered for low emission or electric vehicles)	Austria; Belgium (Walloonia); China; Estonia; France; Ireland; Japan; Luxembourg; Singapore, Spain; Sweden

Type of incentive	Locations
Reduction in, or exemption from, vehicle purchase or registration tax	Belgium (Flanders), Costa Rica, Denmark, Finland, India, Ireland, Israel, Japan, Malaysia, Netherlands, Norway, Portugal, Romania, Singapore, Sweden, United Kingdom, United States (District of Columbia, Maryland, New Jersey, Washington State)
Exemption from, or reduction in, annual circulation, road, or tonnage taxes	Austria, Australia (Victoria), Czech Republic, Denmark, Finland, Germany, Greece, India, Ireland, Italy, Japan, Latvia, Netherlands, **New Zealand,** Norway, Portugal, Romania, Sweden, Switzerland (varies by canton), United Kingdom (London), United States (New Jersey)
Discounted or free battery charging	Netherlands, Norway, United States (California, local incentives)
Privileged access to bus or high-occupancy vehicle (HOV) lanes	Korea, Netherlands, Norway, Portugal, Canada (Ontario), United States (Arizona, California, Florida, New Jersey)
Free or reduced charges for parking in public car parks	Denmark, France, Netherlands, Norway, Portugal, United Kingdom
Public procurement preferences	Belgium (Walloonia), Bulgaria, Estonia, France, Italy, Japan, Korea, Portugal, Sweden, United Kingdom, United States (federal and several states)
Government support for the deployment of battery-charging infrastructure	Austria, Canada (BC and Québec), China (in selected cities), Denmark, Estonia, France, Germany, Israel, Italy, Japan, Korea, Netherlands, Norway, Poland, Portugal, Spain, United Kingdom, United States
Income tax credit, rebate, or grant for private installation of a charger	Belgium, Canada (BC), Denmark, United States (Arizona, Georgia, Maryland, Oregon)

2.3 Light duty electric vehicle production

There is a general expectation that global production of electric vehicles will be sufficient to meet any potential increases in demand. The focus of this section of the report is to investigate the validity of this assumption for light duty vehicles.

Light duty vehicles include neighbourhood vehicles, passenger cars and light commercial vehicles.

2.3.1 Forecasts

There are a wide range of market predictions available for the light duty fleet and these are based on a range of methods and assumptions. The two key methods for prediction of market share are (Ricardo AEA, 2013):

> **Future market demand forecasts,** which are used by companies to help plan their product portfolio. They rely principally on projecting existing trends into the future. These are commonly used to make projections five to ten years into the future.
>
> **Backcasting**, which is commonly used by governments and policy makers to establish what policy measures or programmes may be necessary to achieve future targets. Backcasting techniques are often used in relation to future scenarios which may be 20 to 50 years away.

For this project, we are concerned with predictions out to 2030.

Ricardo AEA undertook a review of European and global predictions for EV uptake in 2013. The review found that most predictions use a mixture of forecasting and backcasting by attempting to forecast future market shares, but including policy levers and instruments that are expected to be put in place to achieve carbon reduction targets (Ricardo AEA, 2013). The review found widely differing future market projections and forecasts for electric vehicles. Table 2 provides 'mainstream' estimates from the Ricardo AEA report for each technology. These are intended to give an approximate range of the majority of estimates, ignoring outliers that may have resulted from more extreme assumptions.

Table 2: Mainstream estimates of predicted market share of electric vehicles

Technology	Market share in 2020	Market share in 2030
Hybrids	5-20%	20-50%
Plug-in hybrids	1-5%	15-30%
Pure battery electric cars	1-5%	5-20%
Range-extended electric cars[11]	1-2%	5-20%
Plug-in hybrid and battery electric combined	2-10%	20-50%

Source: (Ricardo AEA, 2013)

The Ricardo AEA report concludes that:

> **In the longer term, the likely mix of technologies is extremely difficult to predict. The speed with which plug-in hybrids and pure electric vehicles achieve significant market shares is highly dependent on their total cost of ownership in comparison to that of more conventional alternatives. This is, in turn, dependent on factors such as oil prices, further battery and fuel cell cost reductions, and government policies.**

[11] **Range Extended Electric Vehicle** - a vehicle that uses an electric motor and on board battery for propulsion but also has an internal combustion engine on board to provide power for a generator, which can be used to charge the battery. REEVs can be plugged in and charged up. Unlike PHEVs, REEVs do not use the petrol/diesel engine to directly power the wheels.

This is consistent with the findings from a recent report from the National Research Council Committee on Overcoming Barriers to Deployment of Plug-in Electric Vehicles (NRC, 2015), which concludes that:

> **The extent to which electric vehicles are adopted over time will depend on reductions in their production costs, on the policies that governments implement to promote PEV deployment, and on the extent to which vehicle manufacturers decide to price electric vehicles attractively.**

Figure 3 illustrates a range of market scenarios and forecasts for market share of electric vehicles including two scenarios from a report to the European Climate Foundation (CE, 2013). The two scenarios shown are:

> **Tech 2 scenario:** This scenario is based on the rate of deployment of advanced powertrain vehicles that is necessary to meet European CO_2 emission reduction goals. This scenario assumes market penetration of electric vehicles of 2.5% in 2020 and 37% in 2030.
>
> **Tech 3 scenario:** This scenario assumes a more rapid rate of introduction of electric vehicles, which could be possible with appropriate supporting measures. The scenario assumes market penetration of electric vehicles of 9.5% in 2020 and 80% in 2030.

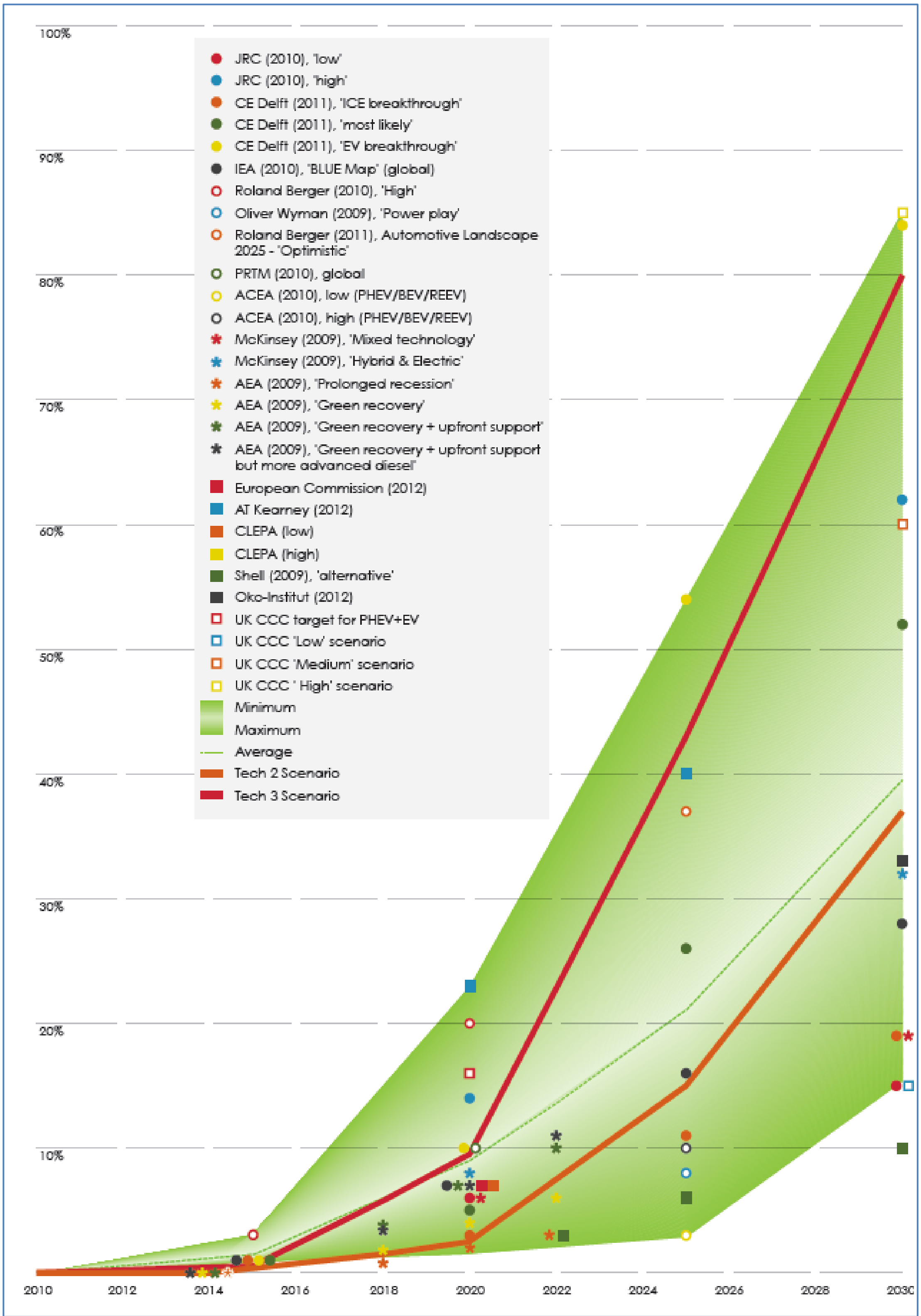
A follow-up report "Fuelling Britain's Future" (CE, 2015) considers similar scenarios for transition to low carbon vehicles in Britain:

> **Current Policies Initiative (CPI) scenario,** which is based on the latest European Commission legislation to regulate new vehicle efficiency. The CPI scenario assumes that no further policy targets are set after 2020.
>
> **Tech 2 scenario:** Consistent with the European study (CE, 2013), this scenario assumes market penetration of electric vehicles of 2.5% in 2020 and 37% in 2030.
>
> **Plug-in scenario:** is a variant on the Tech 2 scenario where plug-in hybrid vehicles are taken up in place of fuel cell vehicles.
>
> **Fuel cell scenario**: another variant on the Tech 2 scenario in which fuel cells are taken up in place of plug-in hybrid vehicles.

The projected sales mix under each scenario is illustrated in Figure 4. The current policies initiative (CPI) scenario shows that, **without government policy and interventions, electric vehicles would not be expected to achieve a significant market share**.

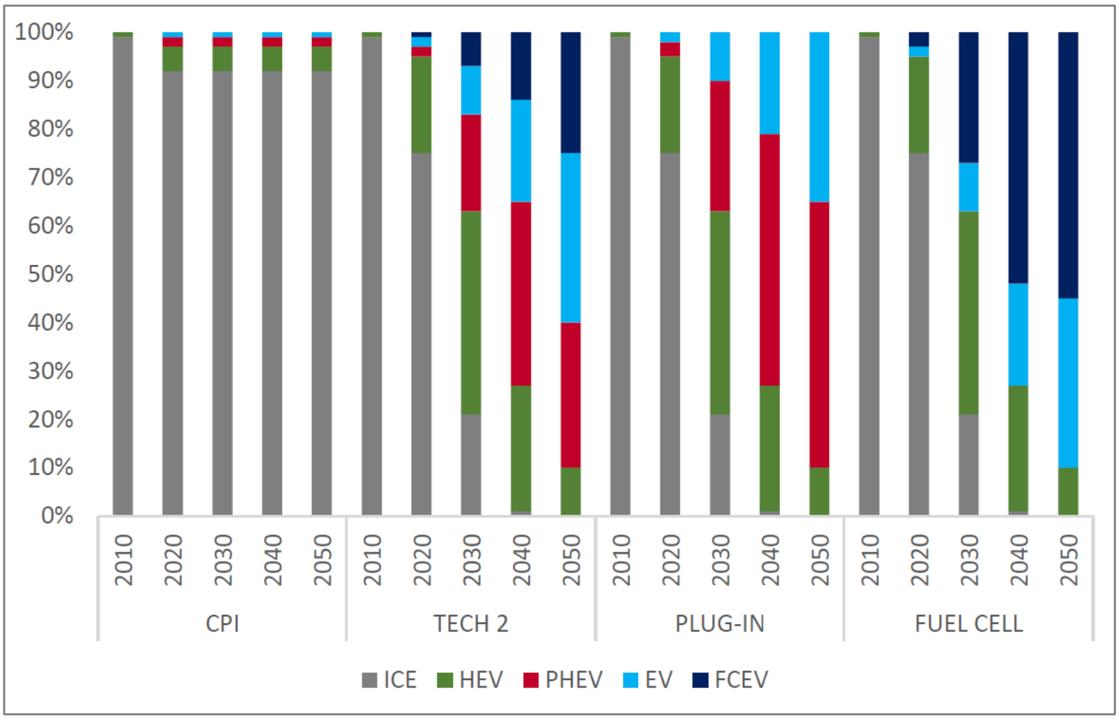
Overall, we conclude that the **future market share of electric vehicles is highly uncertain** and depends on reductions in battery cost, as well as the effectiveness of policies and interventions that are intended to address other barriers to uptake. We consider that the best data are provided by the Ricardo AEA report (Ricardo AEA, 2013), which collates a range of mainstream estimates of predicted market share (shown in Table 2). These estimates suggest that electric vehicles will represent between 20% and 50% of the light duty vehicle market globally by 2030.

Figure 3: Predicted market shares for plug-in hybrid and electric vehicles combined



Source: (CE, 2013) **Figure 2.3**

Figure 4: Projected sales mix under each scenario from the "Fuelling Britain's Future Report" (CE, 2015)

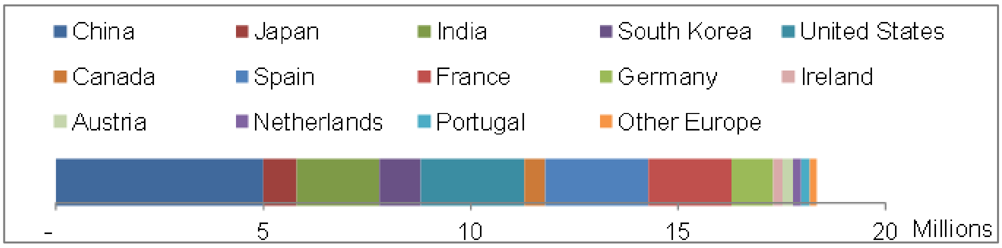


Source: (CE, 2015), Figure 2.2

2.3.2 Constraints – light duty vehicle production

The market share projections discussed in Section 2.3.1 are based on projected **demand** for electric vehicles. An assessment to determine whether global electric vehicle **production** will keep up with projected demand was undertaken as part of a study commissioned by the UK Committee for Climate Change (Element Energy, 2013). The study found that the sum of national targets for EV deployment is 18.4 million electric vehicles on the road in 2020 globally as shown in Figure 5.

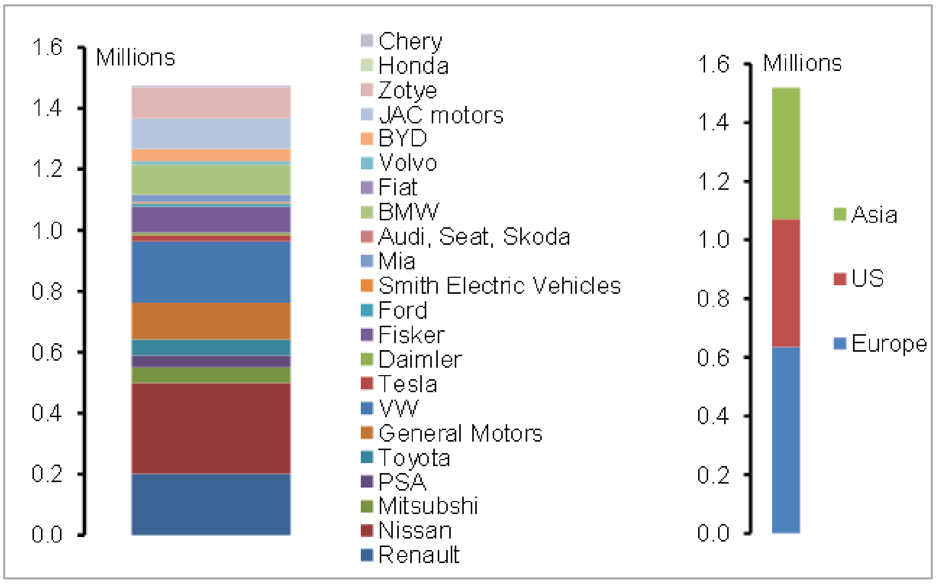
Figure 5: Targets for EV deployment by 2020 (millions, cumulative)



Source (Element Energy, 2013)**, Figure 8**

To assess the feasibility of the global target for 2020, the authors compared this target with **production capacity**. The authors estimated global capacity for 2015 based on a variety of sources including press releases, automotive news and personal communications. The estimate for 2015 is illustrated in Figure 6.

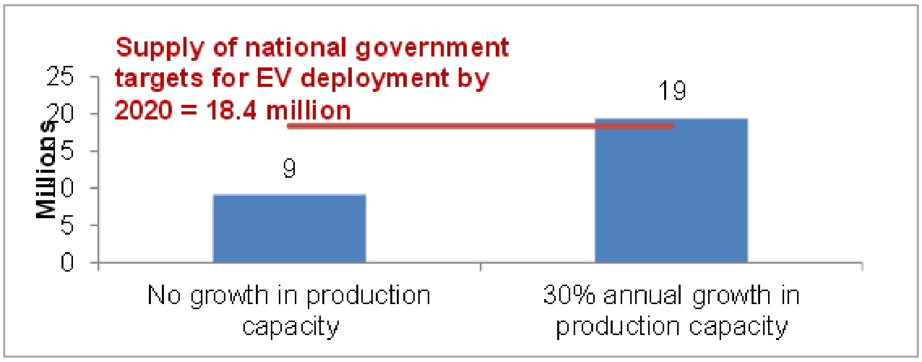
Figure 6: Global annual production capacity for 2015



Source: (Element Energy, 2013), Figure 7

The authors estimate that a 30% annual growth in production capacity would be required from 2015 to meet global targets for 2020, as shown in Figure 7.

Figure 7: Comparison of national deployment targets with cumulative production capacity



Source: (Element Energy, 2013), Figure 9

In considering whether production capacity can meet demand projections, the Element Energy report notes that:

- A 30% growth rate would result in annual production capacity of 5.6 million electric vehicles in 2020 which is less than 7% of the current total motor vehicle production.
- Manufacturers are cautious in their announced production and can be highly responsive to demand.
- Where electric vehicle models are based on existing internal combustion models (for example, the Renault Fluence), rapid scaling up is possible.
- Factories do not all run at full capacity.
- The battery supply chain has been responsive to electric vehicle demand and is not limiting the short term production.

The Element Energy report concludes that, **while there is always uncertainty with any market projection, the required growth in production capacity is feasible**.

2.3.3 Production in New Zealand's key supply markets

Key supply markets for New Zealand are Asia (primarily Japan), Europe and Australia. These markets accounted for 69%, 22% and 8% of new vehicle imports into New Zealand in 2013 respectively[12].

Global projections of electric vehicle production (in particular projections from the IEA) include Japanese and European manufacturers. These projections are directly applicable in New Zealand. According to the IEA[13], Japanese manufacturers (Nissan, Mitsubishi and Toyota) together account for 40% of global electric vehicle production projections for 2020. European manufacturers (Volkswagen, BMW and Renault) account for another 40%. These manufacturers all supply vehicles to the New Zealand market.

Based on the literature that we have reviewed, we consider that, **while there is considerable uncertainty in projected electric vehicle demand and production, it is reasonable to assume that growth in electric vehicle production capacity will be adequate to meet demand in New Zealand's key supply markets of Japan and Europe**.

2.3.4 Production of right hand drive electric vehicles

Supply of vehicles to New Zealand could potentially be constrained because we drive on the left side of the road, and drive right-hand drive vehicles (although left-hand drive vehicles are legal).

A real example of this constraint is the Holden Volt. General Motors have recently announced that the next generation Volt will not be manufactured in the right-hand drive configuration so this will no longer be available in New Zealand and Australia[14].

However several major international markets drive on the left, including Japan, Australia, the United Kingdom, Southern Africa, India, and several countries in South-East Asia (e.g. Malaysia and Indonesia). We note that:

- In Japan there is a relatively limited choice of models and, similarly to New Zealand, sales are dominated by the Nissan Leaf and the Mitsubishi Outlander (ITS, 2014).
- However, Japan is a significant market for electric vehicles. In 2014, Japan accounted for 16% of global electric vehicle stock (IEA, 2015), second only to the United States with 39%.
- Japan has played a major role in development of electric vehicles and the Japanese electric vehicle market is actively supported by incentive programmes. The Japanese Government target for electric vehicles in their fleet is 15% to 20% by 2020 and 20% to 30% by 2030.
- In the United Kingdom, there are 29 different plug-in electric vehicle models available[15], which is similar to the number of models available in the United States and European markets[16].

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[12] 2013 New Zealand Vehicle Fleet Statistics, available from www.transport.govt.nz

[13] http://www.iea.org/etp/tracking/electric-vehicles/

[14] http://www.caradvice.com.au/350518/the-holden-volt-is-dead/

In our literature review, which includes a number of reports and projections from the United Kingdom, **we have found no evidence that the availability of right hand drive electric vehicles from Japan or Europe is constrained**.

2.3.5 Neighbourhood vehicles production

Neighbourhood electric vehicles (or quadricycles), such as the Renault Twizy, are ultra-compact vehicles which generally have a maximum speed of 45km/hour and range of 100km.

The literature that we have reviewed does not include separate forecasts for market share or production of neighbourhood vehicles. Neighbourhood vehicles are included in the light duty passenger vehicle statistics and forecasts discussed in the previous sections.

Source: renault.co.uk

2.3.6 Light commercial vehicles production

Most of the literature that we have reviewed does not include separate forecasts for market share of light commercial vehicles.

In the recent EPA analysis of light duty vehicle greenhouse gas emission standards, the costs of electric vehicles were not estimated for vehicles[17] equivalent to light commercial vehicles above 2 tonnes because the agencies considered that EV technology would be unlikely to be adopted for these vehicle classes (EPA, NHTSA, 2012). Costs for electric vehicles equivalent to light commercial vehicles up to about 2 tonnes gross vehicle mass (**GVM**)[18] were included in the modelling.

A review for the UK Committee for Climate Change (Element Energy, 2013) specifically considers vans. The report found that, as of April 2013, there were nine electric van models available and eligible for a “plug-in van grant”. The authors describe the electric van market in the UK as nascent. However, the report includes model projections suggesting that the market share of electric and plug-in electric vans in the UK could be higher than the market share for electric passenger vehicles by 2030. This applies to the panel van segment[19] only. The report notes that other van segments may be slower to come to the market, and might show an increased cost differential to internal combustion engine (**ICE**) vehicles, particularly large panel vans and pickups which will also require more expensive charging solutions (typically 400V three-phase).

The Nissan eNV200 van is an example of an electric light commercial vehicle currently in mass production. The eNV200 is a small 2.2 tonne GVM van with a 160km range.

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[15] http://www.nextgreencar.com/electric-cars/statistics/

[16] http://evobsession.com/

[17] Vehicles classed as large MPV or Truck in the USEPA vehicle classification system.

[18] Classed as small MPV by the USEPA and includes small pickups and small SUVs with Curb Weight Range of 3600-4200 lbs (approximately 2 metric tonnes). Examples are given as Saturn Vue, Ford Escape, Honda CRV.

[19] Less than 3.5 tonnes GVM.

2.4 Heavy commercial vehicles production

A review of state of the art technologies (CE Delft, 2013) concludes that battery electric long haul trucks are not feasible in the foreseeable future because, even with significant improvements in energy density, batteries will be too heavy for long haul applications. The report concludes that battery electric drive trains will not be used in long haul trucks unless alternative charging infrastructures, such as inductive charging or overhead catenary technology shown in Figure 8 (used by the Wellington trolley bus system), are widely developed and deployed. These solutions are unlikely to be feasible in New Zealand (at least in the near future) due to the high infrastructure costs.

Figure 8: Hybrid electric truck under a catenary in a Siemens pilot project

Source: (CE Delft, 2013)**, Figure 22.**

Battery electric trucks are feasible for city goods distribution because these vehicles travel limited distances and can be charged at a depot overnight. According to the CE Delft report, Smith trucks (see Figure 9) are the largest electric truck manufacturer in the world with around 1000 delivery trucks on the road worldwide.

Figure 9: Smith "Newton" electric truck

Source: www.smithelectric.com

Smith has recently announced that they are considering opening an assembly plant in Brisbane, Australia with a production capacity of up to 200 trucks per year[20]. Smith produces 7.5 tonne, 10 tonne and 12 tonne GVM trucks with a range of between 50 and 160km[21].

[20] http://www.couriermail.com.au/business/electric-trucks-set-to-power-up-in-brisbane-as-diesel-becomes-costly/story-fnihsps3-1227310829608

[21] Range depends on a number of factors including battery size (customisation is available), driving style, GVM and payload. Details are available at www.smithelectric.com.

2.5 Global electric vehicle price projections

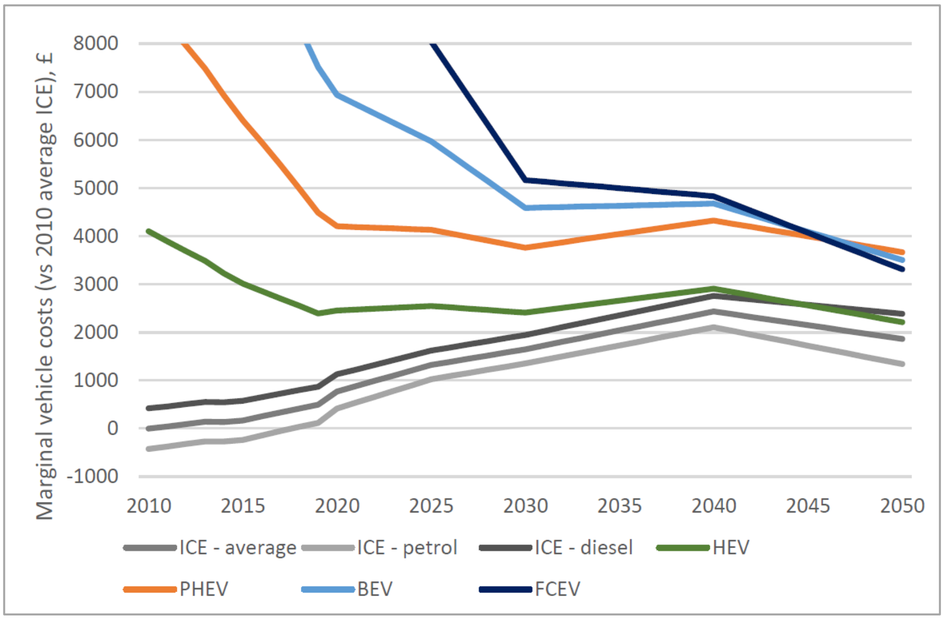
2.5.1 Global cost trends

The motor vehicle market is global in that there is widespread international trade in vehicles and models are available in many different countries.

This means that the results of international research and projections for vehicle costs are applicable in New Zealand.

In general, there is an expectation that the cost of electric vehicles will reduce over time. Vehicle capital cost projections from a recent study in the UK are illustrated in Figure 10. As well as the expected reduction in electric vehicle costs, this illustrates that the cost of internal combustion engine vehicles is expected to increase due to increasingly stringent fuel efficiency requirements.

Figure 10: Additional capital cost of cars under a low carbon technology[22] scenario



Source: (CE, 2015), **Figure 3.1**

The UK study (CE, 2015) shows that the total cost of ownership (**TCO**) of advanced power train vehicles are expected to converge with internal combustion engine vehicles over the next two decades. Figure 11 shows the estimated TCO[23] in the UK of various vehicle types including fuel and maintenance costs. Total ownership costs will be different in New Zealand. In particular, the cost of electricity is lower in New Zealand compared with the UK, so TCO for an electric vehicle may converge with TCO for an internal combustion engine vehicle earlier than expected in the UK.

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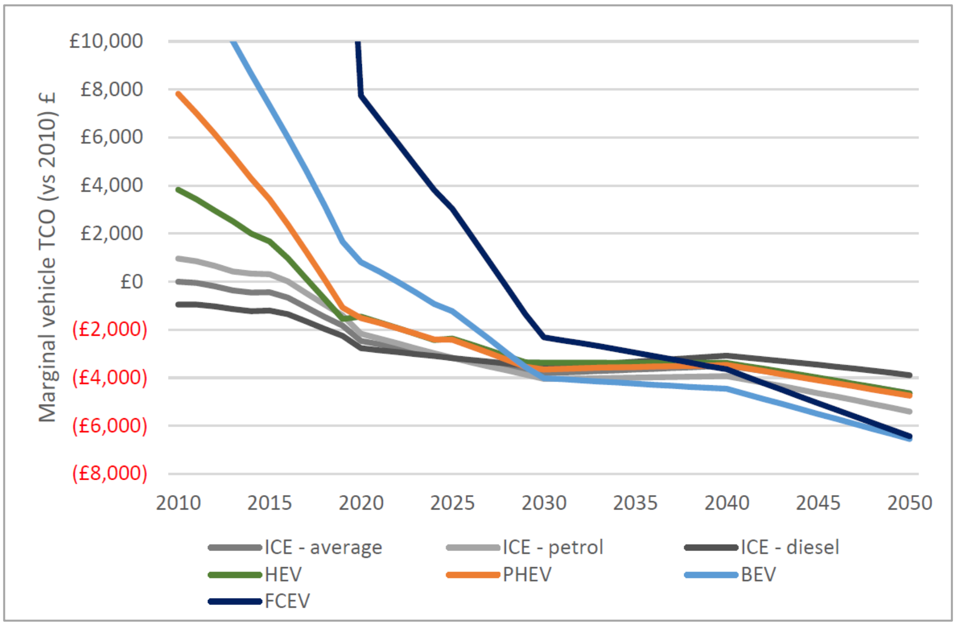
[22] These projected costs are based on a low carbon technology scenario where advanced power trains (plug-in hybrid electric vehicle, battery electric vehicle and fuel cell electric vehicles) account for 37% of sales and hybrid electric vehicles account for 42% of sales in 2030.

[23] The estimated total cost of ownership (excluding insurance) for a new vehicle bought in each year, relative to the total cost of ownership of a 2010 internal combustion engine vehicle under 10% discount rates.

Figure 11: Marginal car total cost of ownership in the UK (10% discount rate)



Source: (CE, 2015), **Figure 3.6**

2.5.2 Disruptive technology projections

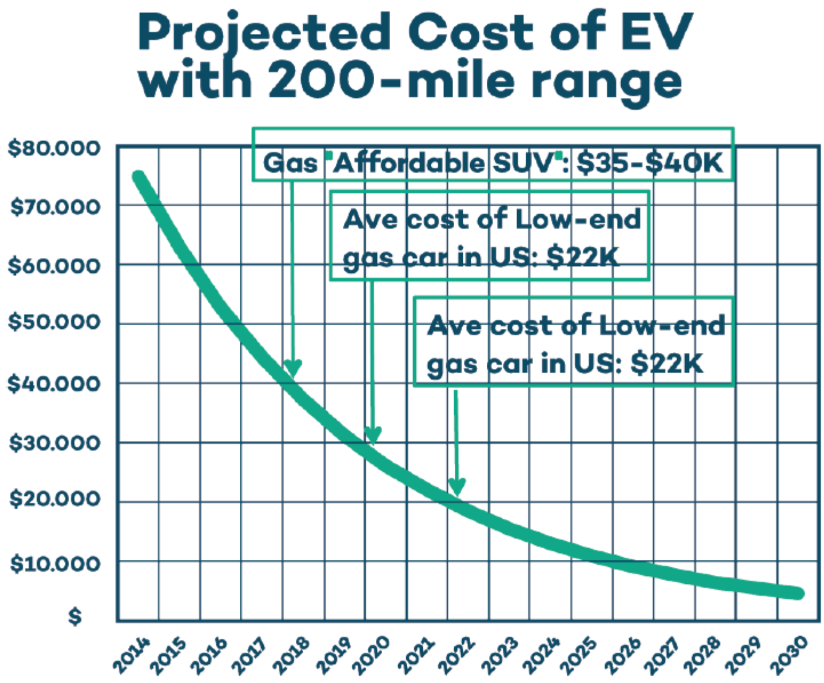
To develop cost projections we have adopted a similar method to the UK study described in the previous section. This method quantifies the difference in manufacturing costs between an electric vehicle and an equivalent internal combustion engine vehicle, taking into consideration differences in costs of the battery, electric motor, inverter, wiring, transmission, etc. The assumption is that the residual costs associated with manufacturing a vehicle (chassis, body, wheels, air conditioning, electronics, etc.) will be comparable for both types. This means that over time (as the cost of producing batteries for electric vehicles reduces) the manufacturing costs of electric vehicles and internal combustion engine vehicles will converge.

The results of these mainstream estimates differ relative to projections from Tony Seba shown in Figure 12 (Seba, 2014). The assumptions behind his projections are not explicit, but he predicts that the cost of an electric vehicle will fall well below the average cost of low-end conventional vehicle excluding the cost of a motor and transmission[24]. For the cost of an electric vehicle to fall significantly below the cost of a current internal combustion engine vehicle, the projections would need to assume a fundamental shift in vehicle specifications, or in the concept of vehicle ownership. This type of "disruptive" shift is possible, but is difficult to quantify or predict with any confidence.

To ensure we are not being unrealistically conservative, we have used battery cost projections from Tony Seba in our incremental cost projections as described in Section 4.2. Seba's battery projection is consistent with the US Department of Energy's projection (DOE, 2014) to 2022. Beyond 2022, Seba's projection is based on consideration of trends in other "disruptive" technology. The projection does not necessarily consider the potential limits of the technology.

[24] For example, the EPA/NHTSA estimate the manufacturing cost of an internal combustion engine and associated transmission for a standard car as US$2,490.

Figure 12: Electric vehicle cost projections from Tony Seba (Seba, 2014)



2.5.3 Sources used for cost projections

The electric vehicle market is global, so projections of cost are directly applicable in New Zealand. To determine whether price projections could be made for each vehicle class, we reviewed some detailed models and projections. These included:

- A 2012 report to the UK committee on Climate Change (AEA, 2012)
- United States LAVE-Trans model and reports (NRC, 2013)
- Detailed modelling undertaken by the USEPA in support of light-duty vehicle greenhouse gas emission standards (EPA, NHTSA, 2012).

Battery technology and costs have progressed since the development of these models, so we also considered the latest available information on battery prices. Sources included:

- The US Department of Energy EV Everywhere Progress Report 2014 (DOE, 2014)
- A peer reviewed journal article on rapidly falling costs of battery packs for electric vehicles (Nykvist & Nilsson, 2015).

2.5.4 Cost projections for batteries

The difference between the costs of producing electric vehicles and comparative conventional vehicles can be largely attributed to the high cost of high energy batteries (NRC, 2015).

Battery costs are reviewed in the recent report from the US Committee on Overcoming Barriers to Deployment of Plug-in Electric Vehicles (NRC, 2015). The Committee relied on detailed analysis undertaken by the USEPA (EPA, NHTSA, 2012) as well as on presentations from vehicle manufacturers, suppliers, and market analysts.

The Committee report notes that:

- The range of cost projections from studies of current and future battery costs is considerable.
- There are no definitive studies of battery costs from battery manufacturers given their need to protect proprietary information.
- Estimates of current costs are difficult to obtain with future projections even more difficult, requiring for example estimates of how many EVs will be purchased.
- Large price fluctuations must be expected until battery supply and demand for PEVs becomes more predictable. Until then, the price will likely depend strongly on the availability of unused battery production capacity and a manufacturer's desire to be perceived as a technology leader. It may also depend on the willingness of the manufacturer to set a price that allows it to gain a market share for its vehicles.

The Committee concluded that:

> **It is not possible to determine a completely reliable projection of future battery cost.** However, given the available data, the committee assume for this report a battery pack cost of **$500 per kWh in 2013 and a 50% lower cost in about 10 years.**

A range of estimates for a 25 kWh battery is given in the Committee's report as shown in Table 3.

Table 3: Estimates of US dollars per kWh for a 25 kWh battery[25]

Year	Manufacturing volume	Pack price ($US/kWh)
2013	25,000	**400-500**
2016	50,000	**275-350**
2020	100,000	**225-275**

Source: Anderman, as provided in (NRC, 2015) **page 37**

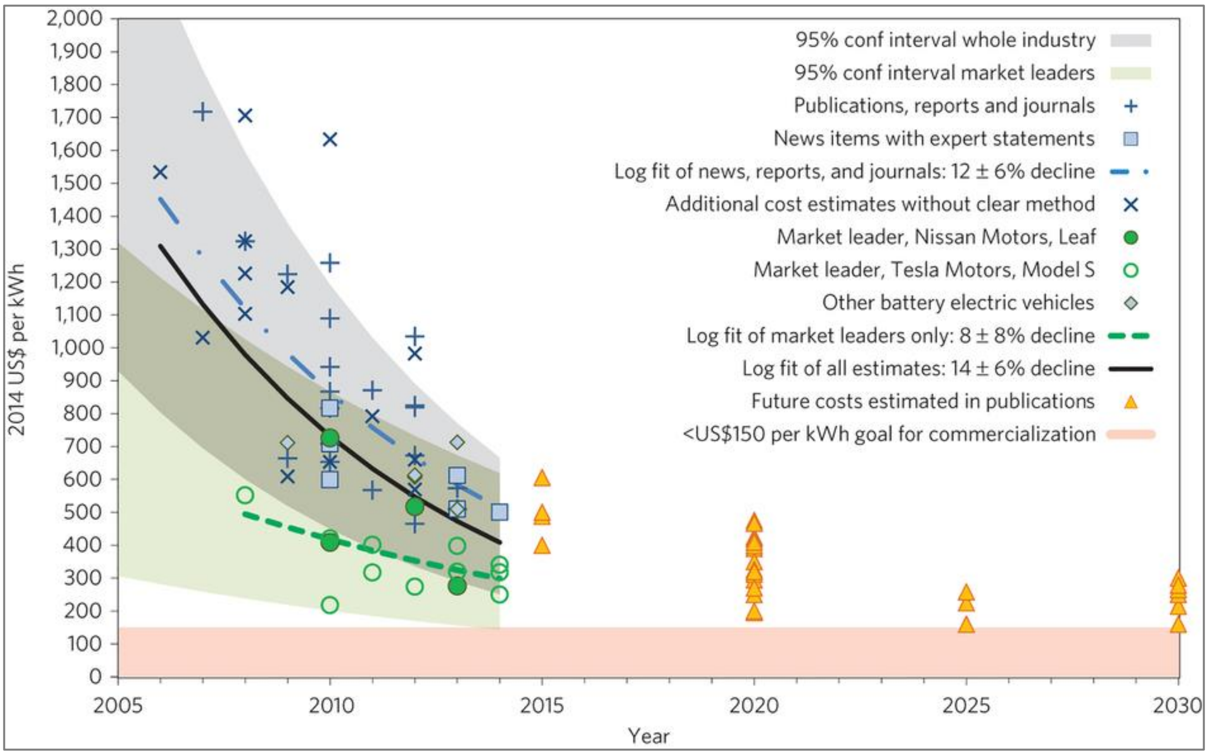
According to the EV Everywhere progress report (DOE, 2014), the cost of plug-in electric vehicle batteries has reduced approximately 50% in the last four years from US$625 per kWh of useable energy in 2010 to **US$325 per kWh in 2014**. The DOE has a goal of **$125 per kWh by 2022** and has committed US$20 million in funding for further development of battery technology. Tony Seba (Seba, 2014) provides an optimistic projection beyond 2022, predicting that battery costs will reduce to **US$73 per kWh in 2025.**

Recent research published in Nature Climate Change Letters (Nykvist & Nilsson, 2015) analysed 80 different cost estimates from a range of sources and estimates that industry wide costs are around **US$410 per kWh in 2014** and market leading manufacturers are around **US$300 per kWh in 2014**. The results are illustrated in Figure 13.

Nykvist & Nilsson estimate that costs of the whole industry and market leaders will converge at around **US$230 per kWh in 2017-2018**. However, they note that their results come with large uncertainties.

[25] Based on estimates provided to the Committee by Anderman (a battery market analyst) in 2014.

Figure 13: Range of costs for Li-ion battery packs in battery electric vehicles. Data are from multiple sources.



Source: (Nykvist & Nilsson, 2015), **Figure 1**

In response to the Nykvist & Nilsson paper, Luis Munuera (an energy analyst for the IEA) and Pierpaolo Cazzola (a transport policy analyst also for the IES) caution in an e-mail to *MIT Technology Review* that the cost reductions implied in the new analysis "*should be taken with care*" since battery costs taken from disparate sources are often not directly comparable. Further, they point out the degree to which cost decline trends for energy technologies can be extrapolated into the future is unclear. Still, they admit, "*we have seen events moving quicker than expected in lithium-ion battery technology*." [26]

Reducing battery costs depend on technological advances and economies of scale. These variables cannot be predicted with any certainty so we have used the range of projections discussed in this section to develop cost projections for electric vehicles. High, medium and low estimates of future battery costs are collated in Section 4.2.1 of this report.

2.5.5 Neighbourhood vehicles

The literature that we reviewed did not include specific price projections for neighbourhood vehicles (quadricycles). However, the future cost of these vehicles could be estimated based on battery cost projections provided in Section 4.2.1 of this report. The batteries in these vehicles are relatively small[27], so reductions in battery manufacturing costs will have a relatively small effect on future costs. [redacted] Section 9(2)(ba)(i)
the price of neighbourhood vehicles is "*pretty flat*" because the units are bespoke and engineered for the purpose.

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[26] MIT Technology Review April 2015

[27] For example, the Renault Twizy battery is 6.1kWh, compared to the Nissan Leaf battery which is 24kWh.

2.5.6 Passenger cars

The extra cost of producing an electric car compared with a conventional vehicle depends on a number of factors including the size of the battery and the type of vehicle (pure electric, plug-in hybrid etc.).

After reviewing the recent literature and the available models, we decided to base our cost projections on the modelling undertaken by USEPA (EPA, NHTSA, 2012) because:

- The model is based on detailed cost tear down analysis undertaken by external consultants.
- The cost analysis is robust and has been used to support regulation in the US.
- The US model and supporting technical documentation are readily available on the internet.

Source: nissan.co.uk

- The model provides costs for different vehicle sizes and types.

We also used up to date information on battery prices as described in Section 2.5.4. Our analysis and cost projections are provided in Section 4.2.2.

2.5.7 Light commercial vehicles

The extra cost of producing an electric light commercial vehicle up to approximately 2 tonnes can be estimated using the same data as passenger cars. An example is the Nissan eNV200 van, which is available in Japan and Europe. The Nissan van has the same battery and motor specifications as a Nissan Leaf so it is reasonable to assume that the difference in manufacturing costs for a passenger car is directly applicable.

Cost data for larger commercial vehicles is not available in the EPA/NHTSA model that we have used to develop cost projections because the EPA/NHTSA consider that electric vehicle technology is unlikely to be adopted for these vehicle classes.

2.5.8 Heavy commercial vehicles

Urban distribution trucks

Production costs for a battery electric urban distribution truck are estimated in the Zero Emissions Trucks report (CE Delft, 2013) as shown in Table 4.

Urban delivery trucks are currently produced in small numbers for a niche market. The cost projections shown in Table 4 suggest that the cost of the battery system relative to the total cost of the truck will continue to be substantial out to 2030.

Table 4: Production costs for a battery electric urban distribution truck

Year	Production Costs in € (as at 2010)	
	Total Vehicle	Battery System
2012	159,250	112,500
2020	100,975	55,200
2030	78,208	33,408

Source: CE Delft, 2013 (table 16)

[redacted] Section 9(2)(ba)(i) They estimate for 2016 that an electric cab and chassis truck equivalent to a Hino 500 (12 to 14 tonnes GVM) will cost around NZ$100,000 more than its ICE equivalent here.

Long haul trucks

The CE Delft report does not assess costs for battery electric long haul trucks because these are considered infeasible based on current and foreseeable battery technology.

Buses

Section 9(2)(ba)(i) [redacted] estimate that if an urban super low floor bus costs in the low NZ$400,000s, then by 2016 they will be able to supply an equivalent battery electric bus with fast charge capability and 150km range per single charge for around NZ$500,000.

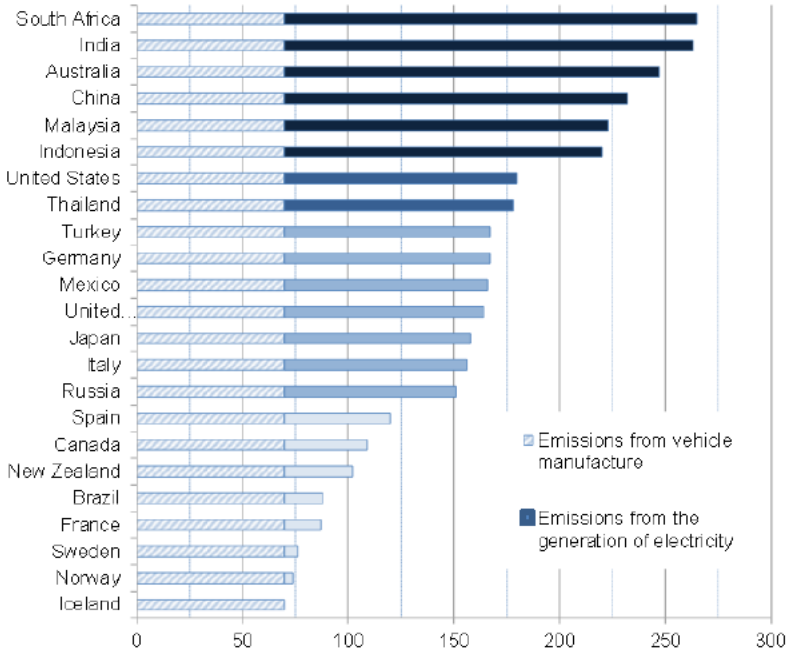
3. New Zealand Context

This section of the report describes the New Zealand context for electric vehicles including policy and current sales and supply. The price premium for new vehicles in New Zealand is also examined.

3.1 Policy context

As shown in Figure 14, New Zealand is well placed to benefit from electric vehicles because a relatively high percentage of New Zealand's electricity is generated from renewable sources.

Figure 14: Total GHG emissions in selected countries from using a grid powered electric vehicle, 2013



Note: Assumes for each country that manufacturing emissions average 70 gCO_2e/km over the lifetime of the vehicle (compared with 40 gCO_2e/km for a vehicle powered by an internal-combustion engine only), and that the vehicle's wall-to-wheels energy use is 211 Watt-hours per kilometre — i.e., similar to that of a Nissan Leaf.

Source: (OECD, 2015)

As discussed in Section 2.2.3, there are a wide range of policies and incentives that have been adopted overseas to encourage adoption of electric vehicles.

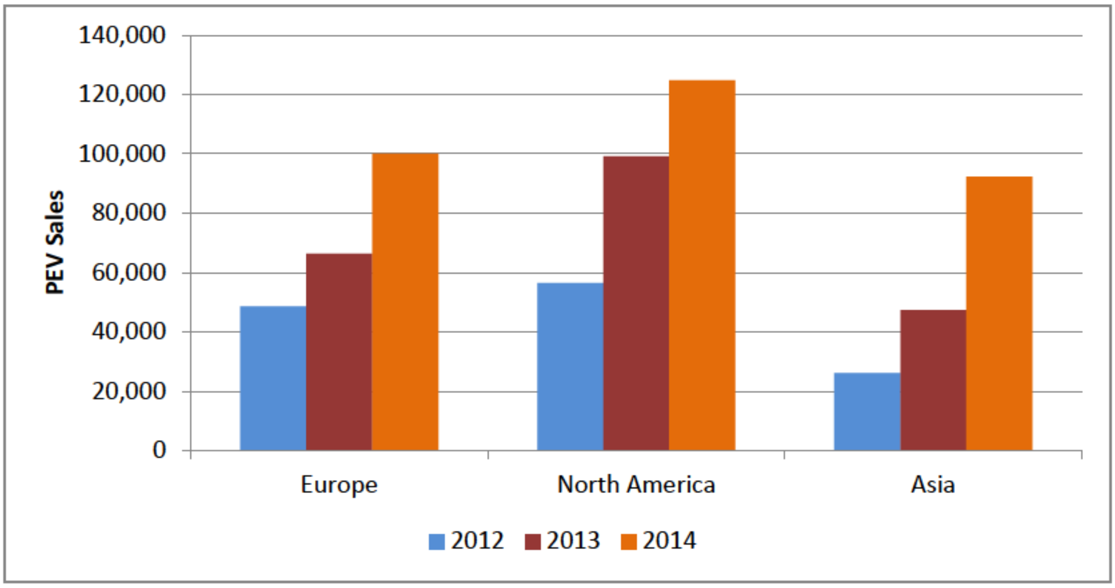
In New Zealand, electric vehicles are currently exempt from road user charges but there are no other fiscal incentives to encourage electric vehicle uptake. Some awareness and facilitation initiatives include:

- Drive Electric, a leadership organisation at the core of the emerging electric vehicle industry in New Zealand
- Vehicle Fuel Economy Labelling scheme
- Fuelsaver website which provides advice on fuel economy for light vehicles
- Consumer information on the EECA websites relating to electric vehicles
- Sponsorship of electric vehicle events.

3.2 Historical sales data

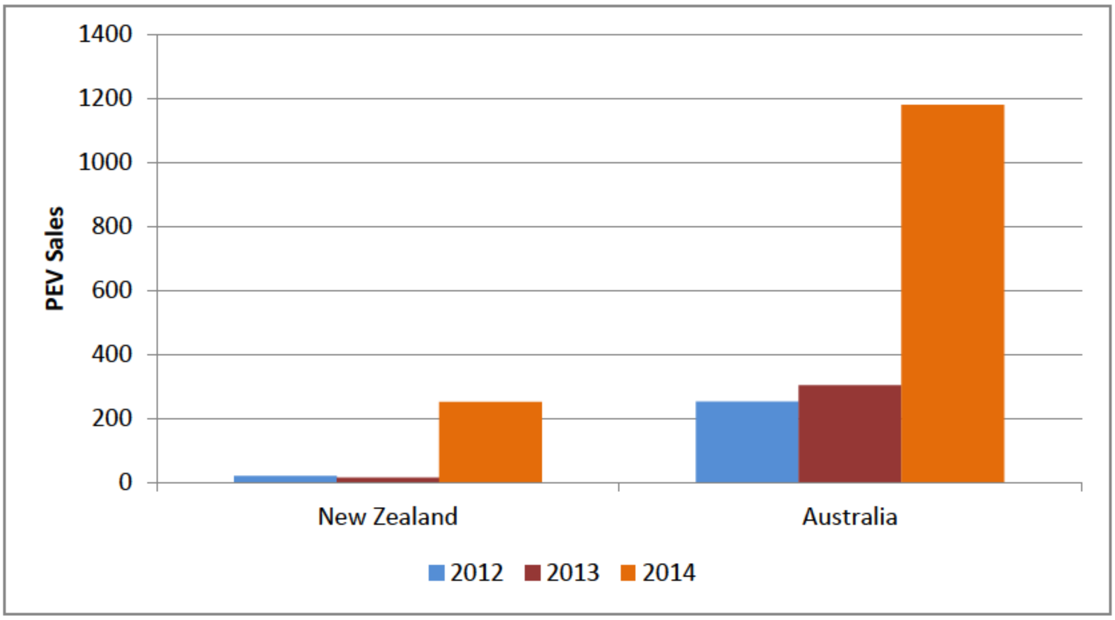
As shown by Figures 15 and 16, the New Zealand electric vehicle market is very small on a global scale.

Figure 15: Global trends in plug-in electric vehicle sales



Data source: (NRC, 2015)

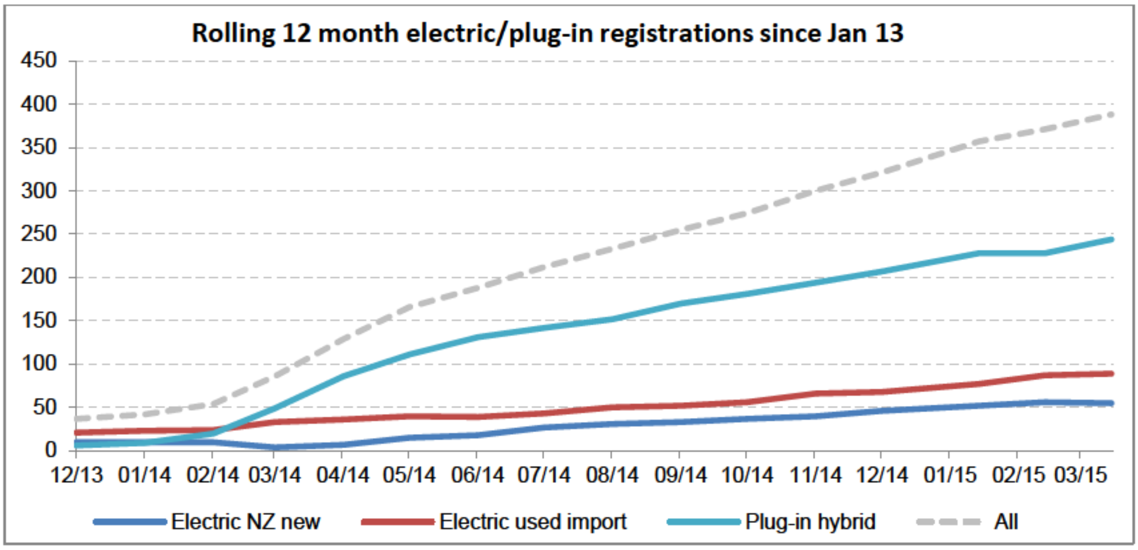
Figure 16: Australia and New Zealand trends in plug-in electric vehicle sales



Data source: Australia (NRC, 2015). New Zealand data provided by Ministry of Transport.

However, sales of electric vehicles in New Zealand have increased markedly in recent years, as shown in Figures 16 and 17.

Figure 17: Electric vehicle registrations in New Zealand



Source: Ministry of Transport

3.3 Current supply of electric vehicles to New Zealand

The vehicle market is global. This means that the results of international research and projections are generally transferrable to New Zealand. However, New Zealand is a very small market on a global scale so is it possible that supply of electric vehicles could be constrained by vehicle importers. This could be influenced by factors such as government subsidies and availability of charging infrastructure.

The two top-selling electric vehicles in New Zealand are the Mitsubishi Outlander plug-in hybrid, and the Nissan Leaf BEV. These vehicles accounted for approximately 61% and 31% respectively of total electric vehicle sales in New Zealand in 2014.

There are currently eight different electric car models available in New Zealand[28]. This is a very limited choice compared with the UK and US markets, where 29[29] and 30[30] different EV models are available respectively. However, Japan also has a much limited range of models with only nine models[31].

The choice of electric vehicle models could reduce further in the near future because, as discussed in Section 2.3.4, GM has announced that the next generation Holden Volt will not be produced in right-hand drive. However, Volvo has announced sale of T8 in NZ and Audi expect to increase range by at least one new e-model each year.

To better understand the relevance of global projections to New Zealand and to quantify the potential supply and price of new electric vehicles in New Zealand, we undertook a survey of key importers of new motor vehicles and other key stakeholders. Appendix 1 lists the survey respondents. The results of the survey are discussed briefly in Section 4 of this report and are reported in full in a separate report.

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[28] http://driveelectric.org.nz/

[29] http://www.nextgreencar.com/electric-cars/statistics/, accessed 24 May 2015.

[30] http://cleantechnica.com/car-answers/, accessed 24 May 2015.

[31] http://en.wikipedia.org/wiki/Plug-in_electric_vehicles_in_Japan, based on sales up to September 2014.

Motor vehicle importers and other stakeholders identified some potential technical and policy barriers that may restrict supply or uptake of electric vehicles in New Zealand. These are summarised in Section 4.1.

3.4 Comparison with global prices

Projections of vehicle prices in international markets need to be translated into price estimates in New Zealand. In a fully-competitive market, prices would be expected to reflect prices in international markets plus any differences in transport costs. However, New Zealand is a small market with small numbers of new vehicle sales (approximately 10% of those in Australia, for example), and motor industry representatives suggest that overhead costs for distributors need to be recovered over this smaller total income.

The extent to which prices for new vehicles can be increased in New Zealand relative to those in other markets (aside from the transport cost differential) depend on competitive pressure that might come from prices of second-hand vehicle imports or of "grey-market" imports (new vehicles imported by parties other than the official distributors).

Second-hand vehicle imports will provide competition for some potential purchasers, but some will be in the market only for a new vehicle. This will reflect a number of factors, including reliability, high specifications and so on. Grey-market imports of new vehicles purchased at retail price in another country might be landed in New Zealand for approximately $3,000 in import costs (Table 5). However, this does not take account of the costs that result from the lack of distributor warranty and benefits such as free servicing that would otherwise apply. Actual costs will be considerably higher than this such that grey-market imports provide little competitive pressure and very few occur, apart from for specialist conventional vehicles.

Table 5: Vehicle import costs (2015 NZ$)

	¥	US$	NZ$
Japan-side fees[1]			
Supplier fees	¥65,000 - ¥1000,000		$720-$1,100
Auction house fees	¥15,000-¥25,000		$167-$275
Domestic transport	¥5,000 - ¥30,000		$55-$333
Customs clearance	¥12,000-¥20,000		$133-$222
Bank fees	¥2,500		$30
Total FOB Japan	¥75,000-¥175,000		$830-$1940
Shipping costs[2]		$1,000-$1750	$1,300-$2,300
Port service charges			$95
Total			**$2,200-$4,300**

Sources: [1] www.Japancardirect.com; www.Getcarsjapanauction.com
[2] www.tradecarview.com; www.japan-partner.com/car-shipping-cost.php; www.hashimoto-trading.com/shippingfreight.html

We compared vehicle manufacturers' list prices between Australia and New Zealand, after correcting for GST differences and exchange rates[32]. Prices are higher in New Zealand across all of the vehicles examined (Table 6). The differences ranged from approximately $2,400 to $9,500 (6% to 38% higher), with an average of $6,100 (19%). This likely reflects market power in New Zealand enabling distributors to recover fixed costs across fewer vehicles and the slightly reduced variety of vehicles available compared with Australia, which means some of the vehicles here are of a higher specification than those available in Australia.

Table 6: Vehicle price differences - Australia and New Zealand

Vehicle	Australia inc GST(A$)	NZ inc GST (NZ$)	Difference excl GST(NZ$)
Ford Focus Ambiente hatch (1.6L)	$23,975	$33,340	$5,988
Ford Mondeo Ambiente Wagon 2.0L	$38,757	$45,490	$2,371
Ford Territory TX 4WD Diesel	$50,246	$59,990	$3,956
Mazda 3 Neo hatch (2.0L) (GLX in NZ)	$25,956	$32,795	$3,614
Mazda 6 Wagon (2.5L Sport)	$37,790	$46,745	$4,390
Mazda CX-9 Luxury FWD, 3.7L Petrol	$48,890	$58,490	$3,953
Mitsubishi Outlander ZK LS MY16 2WD 2.0L	$28,490	$39,990	$7,439
Mitsubishi Outlander ZK LS MY16 4WD 2.4L	$33,490	$43,990	$6,120
Nissan Pathfinder 3.5L petrol ST 2WD	$39,990	$54,990	$9,448
Nissan Pathfinder 3.5L petrol ST 4WD	$44,490	$59,990	$9,479
Nissan Pulsar SSS hatch	$29,216	$39,990	$6,742
Nissan Pulsar ST hatch	$23,036	$29,990	$3,976
Toyota Corolla Ascent hatch (1.8L) (GLX in NZ)	$21,490	$29,990	$5,459
Toyota Corolla Levin SX hatch (1.8L)	$25,490	$38,890	$9,361
Toyota Corolla Levin ZR hatch (1.8L)	$29,990	$43,690	$9,217

Note: converted to NZ$ using exchange rate of 0.9475; GST = 10% in Australia, 15% in NZ

Source: Dealer websites

The Australian Federal Chamber of Automotive Industries has undertaken a benchmarking project which compares the price and specifications of various new vehicles available in the Australian market with equivalent models in other markets. The project demonstrated that Australian-market vehicles are price competitive versus their international counterparts.

Consequently, we suggest that **the difference between prices of EVs in New Zealand international markets is expected to be in the order of NZ$6,000 in 2015 dollar values.** Note this is not a differential that is unique to EVs but would apply to all vehicle imports. This finding is not directly relevant to cost projections presented in this report because, as discussed in Section 4.2.3, changes in the cost of vehicle manufacturing do not necessarily translate directly into price. However, this estimated price differential could be used to estimate and project future prices of vehicles that are not currently available in the New Zealand market.

[32] A$ converted to NZ$ using exchange rate of 0.9475. Recent trends in the exchange rate between Australia and New Zealand may affect this result. However, we have analysed the price differential over a single time period and a single assumed exchange rate. We would need to undertake the analysis over a longer period to know if it was sensitive to exchange rate.

4. Analysis

4.1 Production and supply projections

Our review has found that projections for the future market share of electric vehicles are highly uncertain and depend on the success of policies that are intended to overcome barriers to uptake as well as reductions in the total cost of ownership of electric vehicles. Cost reductions in turn depend on factors including reductions in battery cost, international government policies and fuel prices.

This conclusion has been confirmed by Michael Walsh (International Council on Clean Transportation - ICCT) who states, with respect to electric vehicle market projections:

> **I think the situation is very uncertain in the next decade with the global oil price being just one major variable**[33]

4.1.1 Neighbourhood electric vehicles (Quadricycles)

Production

Neighbourhood vehicles are included in the overall projections of production of light duty passenger vehicles discussed in the next section. The literature that we reviewed did not include separate projections for these vehicles.

Supply

[redacted] provides excellent information about the status of neighbourhood vehicles in New Zealand. [redacted] has identified a number of constraints to supply. However, these constraints are primarily due to low volumes, and issues with New Zealand regulations and policy (as opposed to limited supply). Specific issues include: Section 9(2)(ba)(i)

- Quadricycles do not meet New Zealand frontal impact regulations.
- Quadricycles need exemptions from NZTA under the current Vehicle Classifications process.
- In some parts of Europe, quadricycles are speed limited to 45km/hour.

Section 9(2)(ba)(i) [redacted]**, there is potential for these vehicles to be manufactured locally** if there was adequate demand.

4.1.2 Passenger cars

Production

Table 7 shows the range of mainstream estimates of electric vehicle production collated in a review of global and European projections (Ricardo AEA, 2013) as discussed in Section 2.2.1.

[33] Personal communication, 23 April 2015.

Table 7: Mainstream estimates of new electric vehicle production (as a percentage of total production) for light duty vehicles

Technology	Market share in 2020			Market share in 2030		
	high	medium	low	high	medium	low
Plug-in hybrid and battery electric combined	10%	4%	2%	50%	30%	20%

Source: (Ricardo AEA, 2013)

The responses from our stakeholder survey are consistent with these (uncertain) market share projections. For example:

- [redacted] expect huge growth in electric passenger and SUV – they say that the future is electric and we are on the cusp of change.
- [redacted] anticipates that production of electric vehicles will grow, but perhaps more slowly than many expect.
- [redacted] plug-in hybrids as a stop gap measure for the real end game which will be hydrogen in 30 to 40 years.
- [redacted] expect to see a significant increase in the number of vehicles available for sale, more government subsidies globally and reducing costs of production. These factors will make EVs more widely accepted. [redacted] anticipate total volume becoming 20% of sales by 2020.

Section 9(2)(ba)(i)

Supply

Based on the literature discussed in Section 2.3, we consider that it is reasonable to assume production will keep up with demand in New Zealand's key supply markets. We also consider that it is reasonable to assume that the availability of right hand drive vehicles from Europe and Japan is unconstrained.

However, as discussed in Section 3.3, the number of model variants supplied to New Zealand is currently limited. There are eight electric vehicle models available here compared with 29 in the United Kingdom and 30 in the United States.

Responses to the stakeholder survey are generally qualitative, but these can help to understand the applicability of global production projections in New Zealand. For example:

- According to one importer, a key issue is that if vehicles do not sell NZ importers need to discount to clear aged stock. This means that vehicle importers need to have reasonable confidence in consumer demand to ensure that importation of vehicles is a viable business proposition.
- Two importers state that there is limited supply of EVs globally and one suggests that these are more likely to go to markets with subsidies etc.
- One importer says that the launch phase of EV adoption in NZ will be longer and slower (compared with other countries) without positive Government strategy and/or financial incentives or tax relief.

In general, the responses to the stakeholder survey suggest that supply of electric vehicles in New Zealand is currently limited compared with international markets because there is limited demand. The general consensus is that **demand** in New Zealand will lag behind other countries because:

- the price of electric vehicles is still too high without government support/subsidies/ penalties to encourage adoption and
- other countries have better charging infrastructure[34].

According to Nissan Australia CEO, Richard Emery, the situation is similar in Australia where sales of the Nissan Leaf, the world's best-selling electric car, have been relatively slow. He states that:

> The two barriers to its local acceptance are the same two it has faced everywhere else in the world, and they aren't marketing or so-called 'range anxiety'. **They are the lack of publicly available battery recharging infrastructure and the absence of government-driven incentives for consumers to buy a zero-emissions car**. These two facilities are behind the success of electric vehicles in Europe, the USA and Japan and we need them here[35].

In New Zealand and Australia, pricing of the Nissan Leaf has recently fallen significantly to $39,990. Richard Emery has stated that this price is "*not economical for us long-term*."[36]

Overall, we conclude that **supply of electric vehicles in New Zealand will continue to be limited until costs reduce, or policies are introduced to reduce cost or increase demand**.

Although supply is currently limited in New Zealand, motor vehicle importers consistently report that **they could respond quickly to increased demand** if sales of electric vehicles really take off. To some extent this is a chicken and egg problem. Consumers are unlikely to adopt electric vehicles widely until there is supply of vehicles across brands and vehicle types. However, New Zealand vehicle importers need to have a viable business case to bring new models into the country.

In addition to price and charging infrastructure, some additional potential constraints to supply were identified in the stakeholder survey:

Section 9(2)(ba)(i)

- [redacted] a number of New Zealand vehicle importers report to an Australian head office and these companies are unlikely to import EVs before Australia.
- Servicing support may be limited, especially for European vehicles which don't have a comprehensive servicing network across New Zealand.

4.1.3 Light duty commercial vehicles

Production

Small vans (less than 3.5 tonnes GVM) are currently available in Japan and Europe. It is likely that the market share of these light commercial vehicles will lag behind the market share of

[34] However, we note that the uptake of plug-in hybrid electric vehicles is unlikely to be affected by availability of charging infrastructure.

[35] http://www.motoring.com.au/news/2015/nissan/leaf/nissan-ceo-comes-out-swinging-50555

[36] http://www.caradvice.com.au/296549/nissan-leaf-a-loss-maker-in-australia-but-brand-remains-committed-to-electric-hatch/

light duty passenger cars on a global scale. However, it is not possible to predict the extent of this lag with any confidence.

Heavier commercial vehicles may be slower to come to the market, and may show increased cost differential compared to equivalent internal combustion engine vehicles.

Supply

Light commercial electric vehicles are not currently available in New Zealand. Nissan are using the e-NV200 electric vans on a trial basis with some Australian companies. However, the van is unlikely to be launched in Australia in the near future. The CEO of Nissan Australia has stated that electric car sales in Australia are not economic, and with respect to the e-NV200 van states that "*I wouldn't be rushing to launch another electric car*". He cites the extremely cost-sensitive nature of the commercial van segment as yet another hurdle for a battery-powered van.[37]

Overall, we conclude that **supply of electric light commercial vehicles in New Zealand will be limited until costs reduce, or policies are introduced to reduce cost or increase demand.** However, light commercial vans are in production and it reasonable to assume that these could become available here, if and when this becomes a viable business proposition.

4.1.4 Heavy commercial vehicles

Production

Overall, we consider that production will be limited and electric trucks and buses will remain as a small niche market for the next decade.

Supply

Comprehensive responses to the stakeholder survey were received from [redacted] Section 9(2)(ba)(i) there is potential for heavy electric vehicles to be manufactured locally. However, responses to the survey identify a number of technical and policy issues that will need to be resolved before supply of electric buses or heavy commercial vehicles becomes commercially viable in New Zealand. These include:

- Lack of emissions compliance requirements or monetary incentives for change.
- Bus services are ultimately paid for by central and local government via competitive tender processes. Operators will only be able to adopt expensive technology if government is willing to pay the cost.
- Electric commercial vehicle adopters are currently penalised with the existing Road User Charges (**RUC**) regime. Even a slight increase in weight reduces the payload while also potentially moving the vehicle into another RUC cost category.
- Electric buses are expensive, not only for the batteries but for the charging infrastructure. Costs may also be affected by higher ongoing maintenance costs and lower resale values.
- There is a lack of fast charging infrastructure suitable for heavy vehicles.

[37] http://www.caradvice.com.au/296549/nissan-leaf-a-loss-maker-in-australia-but-brand-remains-committed-to-electric-hatch/

- Electric bus technology is heavy and electric buses would be likely to breach limits under the Vehicle Dimensions and Mass (**VDAM**) Rule.
- The technology is new and untested.
- Organisations face unknown risks changing energy technology. This process must be supported for those early adopter organisations that are prepared to provide leadership in this sector.

4.2 Price projections

4.2.1 Cost projections for batteries

To provide high, medium and low estimates of likely battery costs we have collated the estimates provided in recent literature as discussed in Section 2.4.2. We have interpolated the numbers to arrive at high and low estimates for battery cost for each year to 2025 as shown in Table 8. The literature that we have reviewed does not include projections for battery cost beyond 2025 so our high and low battery cost projections do not change from 2025 to 2030.

Table 8: High, medium and low battery cost projections based on recent literature

Year	Anderman[1]	NRC (2015)	Nykvist & Nilsson (2015)	Tony Seba (2014)	DOE (2014)	Low[2]	Medium[3]	High[4]
	$US/kWh					$US/kWh		
2013	400-500	500				400	450	500
2014			300-410	500	325	300	416	475
2015				420		280	347	450
2016	275-350			353		265	313	425
2017				296		248	297	400
2018			230	249		225	281	375
2019				209		200	266	350
2020	225-275			176		175	250	325
2021				148		150	238	300
2022				124	125	125	225	275
2023		250[5]		104		104	213	250
2024				87		87	200	250
2025				73		73	188	250
2026				73		73	175	250
2027				73		73	163	250
2028				73		73	150	250
2029				73		73	138	250
2030				73		73	**125**	250

[1] Data presented by M Anderman to the NRC Committee as shown on p37 of the NRC (2015) report.

[2] The low projection is based on the US Department of Energy target of US$125 in 2022, followed by Tony Seba's values. We do not have a clear explanation of their derivation but one possible reason would be cheaper alternative battery technology.

[3] The medium projection is the midpoint of the Anderman projections until 2020. From 2021, it is a linear projection down to US$125 in 2030 (the US Department of Energy target for 2022, if delayed).

[4] The high projection is based on the NRC (2015) Committee estimates taking a starting point of US$500 in 2013 and linearly reducing it to US$250 by 2023 then holding it at $250 out to 2030.

[5] Based on the NRC (2015) Committee estimate of 50% reduction in 10 years.

For the medium projection, we have assumed that battery cost reaches US$125/kWh by 2030. This is the US Department of Energy target for 2022 (DOE, 2014), which is more optimistic than other estimates that we have reviewed but is technologically feasible according to the DOE.

4.2.2 Cost projections for passenger cars

Method

To provide cost projections for this project we used data from the USEPA analysis of greenhouse gas standards (EPA, NHTSA, 2012). This analysis included vehicle-simulation modelling and detailed component cost analysis (cost tear down studies) to determine the cost and effectiveness of a wide range of technologies across all light fleet categories.

The EPA/NHTSA study provides estimated battery and non-battery costs for hybrids, plug-in hybrids and battery electric vehicles through to 2025. The non-battery costs include the electric motor, inverter, high-voltage wiring, etc. Savings from the elimination of the ICE, transmission, etc., are included in the non-battery costs. The EPA/NHTSA model includes projected reductions in the non-battery costs (electronics etc.) for each vehicle type. These projected costs are incorporated into our cost projections so that the results include estimated cost reductions for electronics and other non-battery costs. However, the non-battery costs have not been adjusted for the high, medium and low scenarios.

The battery costs shown in Table 8 are for a typical battery electric vehicle with a range of 120 to 150km (such as the Nissan Leaf).

To estimate high, medium and low cost scenarios for other vehicle types, we adjusted the battery costs based on the assumptions in the EPA/NHTSA model. The adjustment factors are shown in Table 9.

Table 9: Battery cost and size for different vehicle types

	Range for all electric mode	Adjustment factor for battery cost $/kWh	Battery size kWh
Battery electric vehicle – compact car	120km	100%	24
Battery electric vehicle – compact car	160km	90%	32
Battery electric vehicle – compact car	240km	80%	47
Plug-in hybrid electric vehicle	50km	150%	11

For example, to calculate costs for a plug-in hybrid electric vehicle we used EPA/NHTSA data for a **small SUV[38] plug-in hybrid electric vehicle.** Key steps were as follows:

1. Extract battery and non-battery costs (direct manufacturing costs) from the EPA/NHTSA spreadsheet (for a “small LT” with 30 mile (50km) range)
2. Convert cost to NZ$2015[39]
3. Convert high medium and low battery costs (Table 8) to NZ$

[38] In the EPA/NHTSA model, this is specified as a Small LT.

[39] Using the consumer price index for transportation equipment.

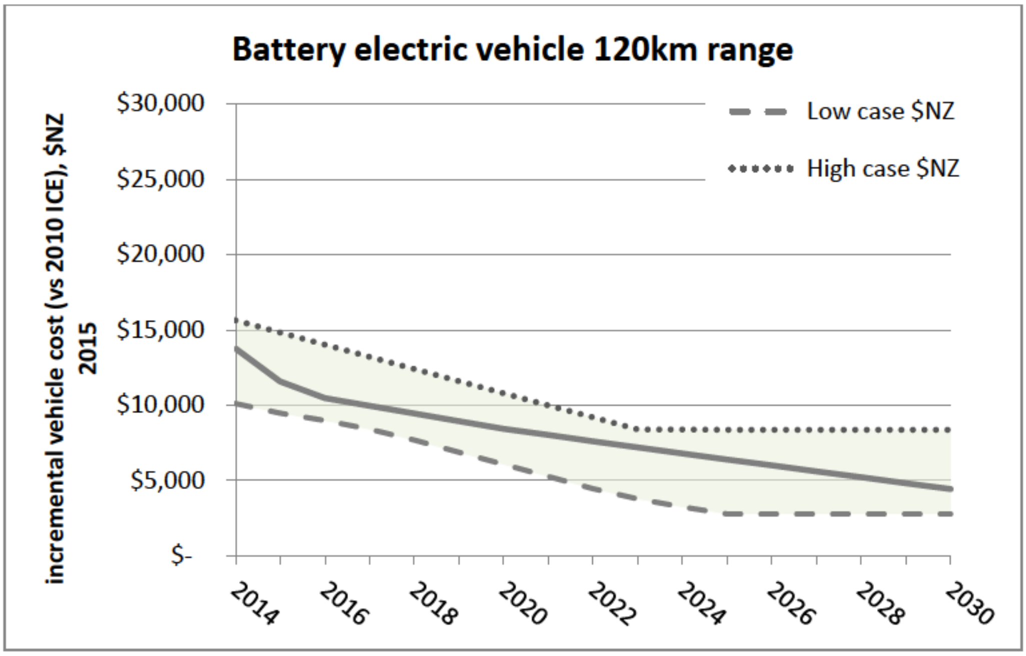
4. Adjust high medium and low battery cost with the factor shown in Table 10 (150% for a plug-in hybrid electric vehicle with a 50km range)
5. Calculate high medium and low battery costs based on battery size as shown in Table 10 (11kWh for plug-in hybrid electric vehicle with a range of 50km in all electric mode)
6. Add battery costs and non-battery costs to calculate total direct manufacturing costs[40].

Results

The results of this analysis are illustrated in Figures 18 to 20[41] and are summarised in Table 10. Full results for each analysis year are provided in Appendix 2.

The results are the **estimated incremental cost of manufacturing a battery electric vehicle** compared with an internal combustion engine vehicle constructed in accordance with 2010 fuel efficiency requirements. The incremental cost may actually be less in future because the cost of manufacturing ICEs is expected to increase. We have not attempted to determine any price trajectory for conventional internal combustion engine vehicles, however the EPA estimates an average compliance cost of around US$1000 (NZ$1400) for the 2016 light duty fleet greenhouse gas emission standards (EPA, 2010) so this could be taken as an **indicative** cost increase for the average vehicle.

Figure 18: High, medium and low projections of the incremental[42] manufacturing cost for a battery electric vehicle with a 120km range



[40] The non-battery costs provided in the EPA/NHTSA spreadsheet were not adjusted for the high, medium and low scenario.

[41] The EPA/NHTSA model provides estimated costs to 2025. We have assumed that the high, medium and low estimates remain constant out to 2030.

[42] The cost shows the incremental cost of a battery electric vehicle **with a 24kWh battery and 120km range** compared with an internal combustion engine vehicle constructed in accordance with 2010 fuel efficiency requirements.

Figure 19: High, medium and low projections of the incremental[43] manufacturing cost for a battery electric vehicle with a 240km range

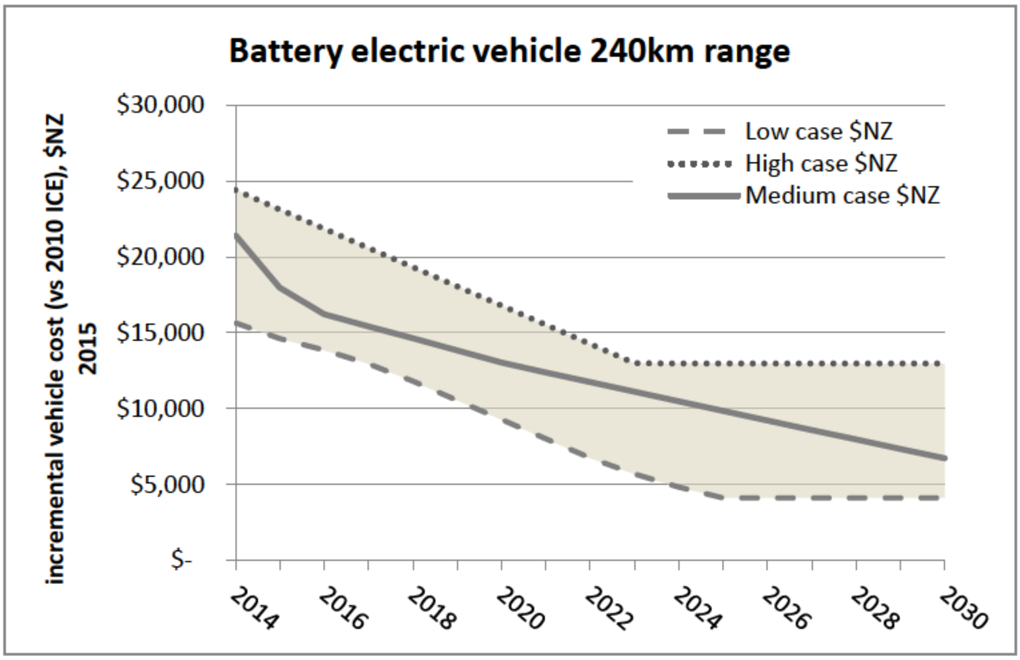
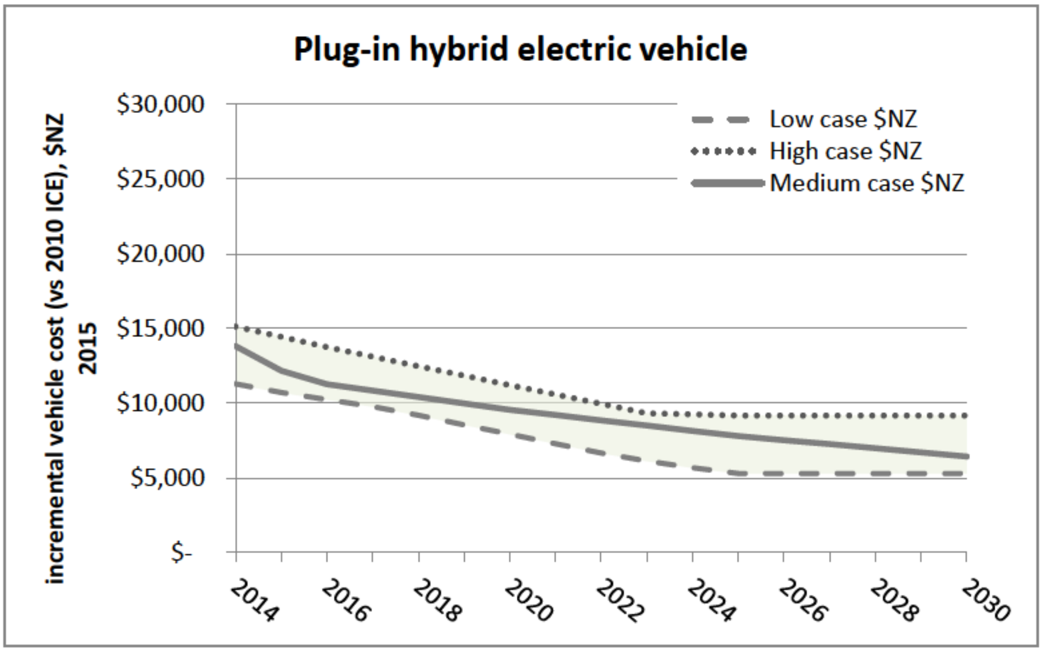


Figure 20: High, medium and low projections of the incremental manufacturing cost for a plug-in hybrid electric vehicle with a 50km all electric range



[43] The cost shows the incremental cost of a battery electric vehicle **with a 47kWh battery and 240km range** compared with an internal combustion engine vehicle constructed in accordance with 2010 fuel efficiency requirements.

Table 10: Summary of cost projections showing the incremental cost of an electric vehicle compared with an internal combustion engine vehicle constructed in accordance with 2010 fuel efficiency requirements

		2015	2020	2025	2030
		NZ$ 2015			
BEV - 120km range	low	9,461	6,060	2,782	2,782
	medium	11,569	8,425	6,393	4,422
	high	14,821	10,790	8,363	8,363
BEV - 160km range	low	11,186	7,139	3,232	3,232
	medium	13,707	9,966	7,548	5,192
	high	17,595	12,793	9,904	9,904
BEV 240km range	low	14,631	9,292	4,130	4,130
	medium	17,975	13,042	9,855	6,730
	high	23,131	16,792	12,980	12,980
PHEV 50km range	low	10,707	7,922	5,292	5,292
	medium	12,175	9,568	7,805	6,433
	high	14,438	11,214	9,176	9,176

The results suggest that the current cost of manufacturing a battery electric vehicle with a 120km range (e.g. the Nissan Leaf or the Ford Focus) is between **NZ$9,500 and NZ$15,000** more than the cost of manufacturing an equivalent internal combustion engine vehicle. This differential is expected to drop to somewhere between **NZ$3,000 and NZ$8,000 by 2025**.

To determine whether the current estimates of incremental cost are realistic, we have compared the current price of two electric vehicles with an equivalent internal combustion engine vehicle. The price of a Nissan Leaf in the UK with and without a battery (the battery can be leased) is also compared because the Leaf is not available in an internal combustion engine equivalent model.

The price differential for these vehicles is within the range of the incremental costs shown in Table 11. This is a very limited sample, but it provides some confidence that the estimates of current incremental costs are realistic.

Table 11: Price differential between electric vehicles and an equivalent internal combustion engine vehicle

Vehicle type	Model	Price ($NZ)	Differential between EV and equivalent ($NZ)
120km range EV petrol ICE	Ford Focus (US) Ford Focus SE Hatch (US)	$38,796[1] $25,217[2]	13,579
135km range EV 135km range EV	Nissan Leaf VISIA (UK) Nissan Leaf VISIA battery lease option (UK)	$46,259[3] $37,728[4]	$8,531
plug-in hybrid petrol ICE	Mitsubishi Outlander XLS Mitsubishi Outlander 2.4 MIVEC CVT XLS	$59,990 $47,490	$12,500

[1] Price in $US = $29,170 (Ford.com, accessed 9 May 2015)

[2] Price in $US = $18,960 (*ibid*)

[3] Price in UK = £22,029.17 (Nissan.co.uk, accessed on 9 May 2015)

[4] Price in UK = £17,862.50 (*ibid*)

4.2.3 Price projections

The literature that we have reviewed provides projections of **cost**. It is not possible to project **price** with any confidence because reductions in manufacturing costs may not necessarily translate directly into vehicle price. Factors influencing **price** might include the availability of unused battery production capacity, a manufacturers desire to be perceived as a technology leader and the willingness of the manufacturer to set a price that will gain market share (NRC, 2015). However, there is a general expectation that electric vehicle prices will reduce over time and will eventually be competitive with conventional vehicles.

The Committee on Overcoming Barriers to Deployment of Electric Vehicles suggests that battery price is expected to be about 50% more than the manufacturing costs. To provide an indication of the possible range in price difference between electric vehicles and an equivalent conventional vehicle we have estimated high, medium and low incremental prices as follows:

- Low price scenario = low cost
- Medium price scenario = medium cost x 125%
- High price scenario = high cost x 150%

The results are shown in Table 12.

Table 12: Indicative projections of the incremental *price* of an electric vehicle compared with an internal combustion engine vehicle constructed in accordance with 2010 fuel efficiency requirements

		2015	2020	2025	2030
		NZ$ 2015			
BEV - 120km range	low	9,461	6,060	2,782	2,782
	medium	14,462	10,532	7,991	5,527
	high	22,232	16,186	12,545	12,545
BEV - 160km range	low	11,186	7,139	3,232	3,232
	medium	17,134	12,458	9,435	6,490
	high	26,392	19,190	14,856	14,856
BEV - 240km range	low	14,631	9,292	4,130	4,130
	medium	22,469	16,303	12,319	8,413
	high	34,697	25,188	19,470	19,470
PHEV - 50km range	low	10,707	7,922	5,292	5,292
	medium	15,219	11,960	9,756	8,041
	high	21,657	16,822	13,764	13,764

If we assume that the reduction in manufacturing costs translates directly into price reductions, then we can expect the price of a battery electric vehicle (such as the Nissan Leaf) to fall by at least $7,000 over the next 15 years. We can expect the price of a plug-in hybrid electric vehicle to fall by at least $5,000. The price drop could be higher depending on how manufacturing costs translate into prices.

It is important to note that the cost of manufacturing internal combustion engine vehicles is expected to increase over the same time frame due to increasingly stringent fuel efficiency requirements. However, this may not necessarily translate into price increases.

4.2.4 Price premium in New Zealand

The stakeholder survey provided no quantitative data on how price is set in New Zealand.

Our analysis suggests that the difference between prices of EVs in New Zealand international markets is expected to be in the order of NZ$6,000 in 2015 dollar values. This estimate could be used to project future prices of vehicles that are not currently available in the New Zealand market.

4.2.5 Battery leasing

In overseas markets, electric vehicles are increasingly being offered with an option to lease the battery based on a monthly fee. This reduces up-front costs for consumers and ensures that batteries are recycled at the end of their useful life. For example, the Renault Twizy retails in the UK from £6,895 (NZ$14,650) excluding the battery, which is leased for between £45 (NZ$95) and £67 (NZ$142) per month depending on contract term and mileage.

5. Conclusions

There is consensus in the international literature and amongst key stakeholders in New Zealand that, over time, the cost of electric vehicles will become competitive with the cost of conventional vehicles and that they will become more widely available across more models.

However, there is significant uncertainty about how quickly this will happen.

Our overarching conclusion for production, supply and price of electric vehicles is that the electric vehicle market is evolving quickly and is subject to significant uncertainty. The results and conclusions in this report will need to be regularly reviewed. More importantly, **policies to promote or encourage uptake of electric vehicles will need to be flexible and adaptive to change**.

Key conclusions for each vehicle category are summarised in the following sections.

Production and supply: light duty vehicles

Based on a review of international literature on electric vehicle demand and production we have concluded that, while there is considerable uncertainty in projected electric vehicle demand and production, **it is reasonable to assume that growth in electric vehicle production capacity will be adequate to meet demand** in New Zealand's key supply markets of Japan and Europe.

Supply: passenger cars

Supply of electric vehicle models to New Zealand is currently limited. There are eight electric vehicle models available here compared with 29 in the United Kingdom and 30 in the United States. **Light commercial** electric vehicles are not currently available in New Zealand.

In general, the responses to the stakeholder survey suggest that supply of electric vehicles in New Zealand is limited compared with international markets because there is limited demand. The general consensus is that **demand** in New Zealand will lag behind other countries because:

- the price of electric vehicles is still too high without government support/subsidies/ penalties to encourage adoption and
- other countries have better charging infrastructure[44].

We conclude that **supply of electric vehicles in New Zealand will continue to be limited until costs reduce, or policies are introduced to reduce cost or increase demand**.

However, motor vehicle importers consistently report that **they could respond quickly to increased demand** if sales of electric vehicles really take off.

[44] However, we note that the uptake of plug-in hybrid electric vehicles is unlikely to be affected by availability of charging infrastructure.

Supply: light commercial vehicles

Light commercial electric vans (less than 3.5 tonnes GVM) are available in Europe and Japan but they are not currently available in New Zealand. We conclude that **supply of electric light commercial vehicle models in New Zealand will be limited until costs reduce, or policies are introduced to reduce cost or increase demand.** However, it is reasonable to assume that these vehicles could become available here, if and when this becomes a viable business proposition for vehicle importers.

Heavier light commercial electric vehicles (above 3.5 tonnes GVM) may be slower to come to the market compared to equivalent internal combustion engine vehicles. This is because the battery technology for heavier vehicles is relatively heavier and more expensive and requires more expensive charging solutions compared with lighter vehicles.

Supply: heavy commercial vehicles

Electric trucks are produced for niche markets and applications such as urban delivery and rubbish trucks. However the battery technology is still relatively heavy and expensive. Suitable fast charging infrastructure is also required for these vehicles.

Heavy commercial electric vehicles currently have limited application and we conclude that production of heavy commercial electric vehicles will be **limited to a small niche market** for the next decade.

Policy constraints

In addition to price and charging infrastructure, some specific policy constraints have been identified through the stakeholder survey, these include:

- **Neighbourhood electric vehicles** do not meet New Zealand frontal impact regulations.
- Some models of **neighbourhood electric vehicles** are designed for a maximum speed for 45km/hour.
- Electric **bus and truck** technology is heavy and electric buses would be likely to breach limits under the Vehicle Dimensions and Mass (VDAM) Rule.
- Electric **heavy commercial** vehicle adopters would be penalised with the existing Road User Charges (RUC) regime. Even a slight increase in weight reduces the payload while also potentially moving the vehicle into another RUC cost category.

Cost projections

Cost projections: neighbourhood vehicles

The literature that we reviewed did not include specific price projections for neighbourhood vehicles. However, the future cost of these vehicles could be estimated based on battery cost projections provided in Section 4.2.1 of this report.

Cost projections: passenger cars

We have developed a high, medium and low **cost** projections based on a range of recently published battery cost forecasts including an optimistic prediction from Tony Seba (Seba, 2014). These projections are estimates of the incremental manufacturing cost of electric vehicles compared with an equivalent internal combustion engine vehicle manufactured to 2010 fuel efficiency standards. The incremental cost may actually be less in future because the cost of manufacturing internal combustion engines is expected to increase[45].

Table 13: Summary of cost projections showing the incremental cost of an electric vehicle compared with an internal combustion engine vehicle constructed in accordance with 2010 fuel efficiency requirements

		2015	2020	2025	2030
		NZ$ 2015			
BEV - 120km range	low	9,461	6,060	2,782	2,782
	medium	11,569	8,425	6,393	4,422
	high	14,821	10,790	8,363	8,363
BEV - 160km range	low	11,186	7,139	3,232	3,232
	medium	13,707	9,966	7,548	5,192
	high	17,595	12,793	9,904	9,904
BEV 240km range	low	14,631	9,292	4,130	4,130
	medium	17,975	13,042	9,855	6,730
	high	23,131	16,792	12,980	12,980
PHEV 50km range	low	10,707	7,922	5,292	5,292
	medium	12,175	9,568	7,805	6,433
	high	14,438	11,214	9,176	9,176

The literature that we have reviewed provides projections of **cost**. It is not possible to project **price** with any confidence because reductions in manufacturing costs may not necessarily translate directly into vehicle price. Battery price is generally expected to be about 50% more than the manufacturing costs, however, the price will be depend on the availability of unused battery production capacity, a manufacturer's desire to be perceived as a technology leader and the willingness of the manufacturer to set a price that will gain market share (NRC, 2015).

Price premium in New Zealand: passenger cars

Our analysis suggests that the difference between prices of EVs in New Zealand international markets is expected to be in the order of NZ$6,000 in 2015 dollar values. This estimate could be used to project future prices of vehicles that are not currently available in the New Zealand market.

[45] We have not attempted to determine any price trajectory for conventional internal combustion engine vehicles. However, the EPA estimates an average compliance cost of around US$1000 (NZ$1400) for the 2016 light duty fleet greenhouse gas emission standards (EPA, 2010) so this could be taken as an **indicative** cost increase for the average vehicle.

Cost projections: light commercial vehicles

The extra cost of producing an electric light commercial vehicle up to approximately 2 tonnes can be estimated using the same data as passenger cars. An example is the Nissan eNV200 van, which is available in Japan and Europe. The Nissan van has the same battery and motor specifications as a Nissan Leaf so it is reasonable to assume that the difference in manufacturing costs for a passenger car is directly applicable.

Cost data for larger commercial vehicles is not available in the model that we have used to develop cost projections because the USEPA consider that electric vehicle technology is unlikely to be adopted for these vehicle classes. Based on the literature reviewed we conclude that large (over 3.5 tonne GVM) commercial vehicles are likely to show increased cost differential compared to equivalent internal combustion engine vehicles for some time.

Cost projections: heavy commercial vehicles

Urban delivery trucks are currently produced in small numbers for a niche market. Cost projections in the literature suggest that the cost of the battery system relative to the total cost of truck will continue to be substantial out to 2030. However, [redacted] suggests that heavy electric vehicles, in particular buses, could become cost effective based on total costs of ownership within the next few years. Section 9(2)(ba)(i)

References

AEA. (2012). *A review of the efficiency and cost assumptions for road vehicles to 2050, Report to the Committee on Climate Change.* Didcot: AEA Technology plc.

CE. (2013). *Fuelling Europe's Future, a report for the European Climate Foundation.* Cambridge: Cambridge Econometrics.

CE. (2015). *Fuelling Britains Future, A report for the European Climate Foundation.* Cambridge: Cambridge Econometrics.

CE Delft. (2013). *Zero emission trucks: An overview of state of the art technologies and their potential.* Delft: CE Delft.

DOE. (2014). *EV Everywhere Progress Report 2014.* US Department of Energy.

Element Energy. (2013). *Pathways to high penetration of electric vehicles, Final report for The Committee on Climate Change.* Cambridge: Element Energy.

EPA. (2010). *Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Agerage Fuel Economy Standards, Regulatory Impact Analysis.* United States Environmental Protection Agency.

EPA, NHTSA. (2012). *Joint Technical Support Document: Final Rulemaking for 2017 to 2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards.* U.S. Environmental Protection Agency and National Highway Traffic Safety Administration.

IEA. (2013). *Global EV Outlook, Understanding the Electric Vehicle Landscape to 2020.* Paris: International Energy Agency.

IEA. (2014). *Tracking Clean Energy Progress 2014.* Paris: International Energy Agency.

IEA. (2015). *Global EV Outlook 2015 Update.* Paris: International Energy Agency.

ITS. (2014). *Plug-In Electric Vehicles: A Case Study of Seven Markets.* Davis: Institute of Transportation Studies, University of California.

NRC. (2013). *Transitions to Alternative Vehicles and Fuels.* Washington: National Academies Press.

NRC. (2015). *Overcoming Barriers to Deployment of Plug-in Electric Vehicles.* Washington, D.C.: National Research Council.

Nykvist, B., & Nilsson, M. (2015, March). Rapidly falling costs of battery packs for electric vehicles. *Nature and Climate Change*, pp. 329-332.

OECD. (2015). *Domestic Incentive Measures for Environmental Goods with Possible Trade Implcations: Electric Vehicles and Batteries.* Organisation for Economic Co-operation and Development.

Ricardo AEA. (2013). *Powering Ahead: The future of low carbon cars and fuels.* London: RAC Foundation and UK Petroleum Industry Association.

Seba, T. (2014). *Clean Disruption of Energy and Transportation.* Silicon Valley: Clean Planet Ventures.

Appendix 1: List of Respondents to the Stakeholder Survey

The following stakeholders responded to the survey on trends in the price and supply of new electric vehicles in New Zealand.

Sector Covered	Stakeholder
General	[redacted]
	[redacted]
Motorcycles/Scooters	[redacted]
Neighbourhood Vehicles	[redacted]
Passenger Cars	[redacted]
	[redacted]
	[redacted]
	[redacted]
	[redacted]
Heavy Vehicles **e.g. buses and trucks**	[redacted]
	[redacted]
	[redacted]

Section 9(2)(ba)(i)

Appendix 2: Cost Projections

Table A1: Incremental cost of manufacturing a battery electric vehicle compared with an internal combustion engine vehicle constructed in accordance with 2010 fuel efficiency requirements (estimated using the method outlined in Section 4.2.2).

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
		NZ$2015																	
BEV - 120km range	low	13,284	10,111	9,461	8,969	8,399	7,671	6,866	6,060	5,256	4,452	3,779	3,233	2,782	2,782	2,782	2,782	2,782	2,782
	medium	14,861	13,757	11,569	10,467	9,955	9,445	8,935	8,425	7,621	6,817	6,081	5,803	5,573	5,573	5,998	5,604	5,210	4,816
	high	16,438	15,629	14,821	14,014	13,207	12,401	11,596	10,790	9,986	9,182	8,383	8,373	8,363	8,363	8,363	8,363	8,363	8,363
BEV - 160km range	low	15,749	11,960	11,186	10,602	9,924	9,058	8,098	7,139	6,180	5,222	4,420	3,769	3,232	3,232	3,232	3,232	3,232	3,232
	medium	17,634	16,318	13,707	12,392	11,785	11,178	10,572	9,966	9,008	8,049	7,172	6,842	6,568	6,568	7,077	6,606	6,135	5,663
	high	19,519	18,557	17,595	16,633	15,672	14,712	13,753	12,793	11,835	10,877	9,924	9,914	9,904	9,904	9,904	9,904	9,904	9,904
BEV - 240km range	low	20,671	15,651	14,631	13,862	12,969	11,826	10,559	9,292	8,026	6,760	5,700	4,840	4,130	4,130	4,130	4,130	4,130	4,130
	medium	23,171	21,432	17,975	16,237	15,438	14,639	13,840	13,042	11,776	10,510	9,350	8,915	8,555	8,555	9,230	8,605	7,980	7,355
	high	25,671	24,401	23,131	21,862	20,594	19,326	18,059	16,792	15,526	14,260	13,000	12,990	12,980	12,980	12,980	12,980	12,980	12,980
PHEV - 50km range	low	13,627	11,287	10,707	10,241	9,768	9,188	8,554	7,922	7,292	6,663	6,124	5,674	5,292	5,292	5,292	5,292	5,292	5,292
	medium	14,725	13,825	12,175	11,284	10,852	10,422	9,995	9,568	8,938	8,309	7,726	7,463	7,234	7,234	7,530	7,256	6,982	6,707
	high	15,822	15,128	14,438	13,753	13,115	12,480	11,846	11,214	10,584	9,955	9,328	9,251	9,176	9,176	9,176	9,176	9,176	9,176