AEMO INSIGHTS

AUGUST 2016

Electric Vehicles

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AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

EXECUTIVE SUMMARY

Key points

- The 20-year impact of electric vehicles on energy consumption is projected to be small, adding almost 4% to 2035–36 projections of electricity use in Australia.
- Despite buyer interest, public charging infrastructure remains undeveloped, electricity pricing structures for electric vehicles are not yet established, and full model ranges remain unavailable. Analysis has also shown that the transition to electric vehicles can be greatly influenced by decisions on industry policy, in particular, vehicle fleet emission standards. Australia's regulatory and policy framework for electric vehicles is yet to be resolved.

  For all these reasons, projections of uptake can vary over a wide range, and in most cases will feature a slow start.
- These uncertainties are likely to be resolved over the next 10 years, a period when AEMO expects a major transformation of the energy system due to a continuing embrace of renewable energy and new energy-efficient technologies, and a shift away from energy-intensive manufacturing.
- AEMO intends to monitor the emergence of electric vehicles in Australia, while working with industry on developing the energy system of tomorrow.

Our first *AEMO Insights* report

The transformation of Australia's energy system – driven by changes in technology, the economy, and consumer behaviour – has implications for the operation and evolution of the physical, market, and regulatory infrastructure of the energy industry.

This rapid and continuing transformation will require new ways of thinking about energy challenges, and innovative methods to accommodate a very different consumer and economy. It also has profound implications for AEMO's operational roles. The magnitude and extent of change makes it harder to project with certainty, as the past is no longer indicative of the future.

This is the first of AEMO's new *AEMO Insights* reports, which:

- Will explore a range of topical issues that have the potential to challenge the future management and operation of gas and electricity markets and infrastructure systems.
- Are intended to provide information in a timely and agile fashion to assist industry with its developing understanding of rapidly emerging challenges.

This inaugural report is about electric vehicles (EVs), and has been produced in response to keen interest on this topic. It provides a view of how this emerging technology may develop in Australia, and what this could mean for electricity consumption and demand.

The analysis has been prepared with our consultancy partner, Energeia, and expands on the work AEMO started in its *2015 Emerging Technologies Information Paper*. AEMO will use this analysis as a starting point for monitoring the emergence and use of EVs in the light vehicle fleet in Australia.

This EV projection is aligned with the scenarios and major assumptions of AEMO's recently published *2016 National Electricity Forecasting Report* (NEFR), to show how EV uptake could affect the 2016 NEFR forecasts of electricity consumption and demand in the National Electricity Market (NEM) over a 20-year outlook period to 2035–36. As well as projections for the NEM, EV uptake projections are also provided for Western Australia's Wholesale Electricity Network (WEM) based on the same scenarios.

AEMO welcomes feedback on this report, and will use it to inform the development of AEMO's forecasting and planning publications. Please email energy.forecasting@aemo.com.au by 30 September 2016 with comments.

The electric vehicle (EV) analysis

The 20-year impact of electric vehicles on electricity consumption and demand is projected to be small relative to the impact of other changes expected to take place, such as investment in renewable energy technologies, restructuring of the Australian economy, and energy efficiency improvements of major appliances.

- Electric vehicles currently (in 2015) make up 0.2% of annual vehicle sales in Australia. This is likely to increase in coming years with anticipated decline in costs, increased availability and capacity of new EV models, and assumed government and industry support.
- Growth in uptake of electric vehicles may remain constrained until a fuller product/style range is available and public charging infrastructure is developed.

In the NEM, based on the NEFR's neutral sensitivity[1], by 2035–36 Australian EV sales are forecast to reach 277,000 vehicles a year (27.1% of vehicle sales). Total EVs on the road are estimated to reach over 2.8 million (18.4% of all vehicles).

- For this projected uptake, by 2036 EVs would add 6,941 gigawatt hours (GWh) of grid-supplied electricity consumption a year. This is an increase of about 3.8% compared to 2016 NEFR forecasts of operational consumption for the NEM under the neutral sensitivity.
- Within the NEM, projected uptake varies by region. These differences are attributed to the different regional effects of market size, the relative differential between petrol prices and electricity prices, and the assumed introduction of a fleet-based greenhouse gas emissions standard[2] from 2026.

In the Western Australian WEM, based on assumptions consistent with the neutral sensitivity from the 2016 NEFR, EV sales are forecast to reach 43,000 per year by 2036, or approximately 33% of total sales. Total EVs on the road that year are estimated to reach 389,000 (approximately 20% of the light vehicle fleet).

- This uptake is estimated to add 958 GWh to annual grid-supplied consumption in the WEM by 2036.

Table 1 shows the projected impact of EVs on operational consumption forecasts for both the NEM and WEM.[3]

Table 1 Operational consumption and EV uptake forecasts for the NEM and WEM

	2015–16 consumption			2025–26 consumption			2035–36 Consumption		
	Non-EV *(GWh)*	**EV** *(GWh)*	**EV impact** *(%)*	**Non-EV** *(GWh)*	**EV** *(GWh)*	**EV impact** *(%)*	**Non-EV** *(GWh)*	**EV** *(GWh)*	**EV impact** *(%)*
NEM	183,258	6	0.00%	187,129	1,620	0.87%	184,467	6,941	3.76%
WEM	18,475	0.5	0.00%	20,318	185	0.91%	n/a[3]	958	n/a[3]

[1] AEMO's forecasts explore a range of sensitivities that represent the probable pathway for Australia across weak, neutral (considered the most likely), and strong economic and consumer outlooks. All three sensitivities assume Australia achieves its commitment at the 21st Conference of the Parties for the United Nations Framework Convention on Climate Change (to reduce greenhouse gas emissions by between 26% and 28% below 2005 levels by 2030), and state governments continue to target increasing levels of renewable generation, although instruments to achieve these targets are yet to be determined.

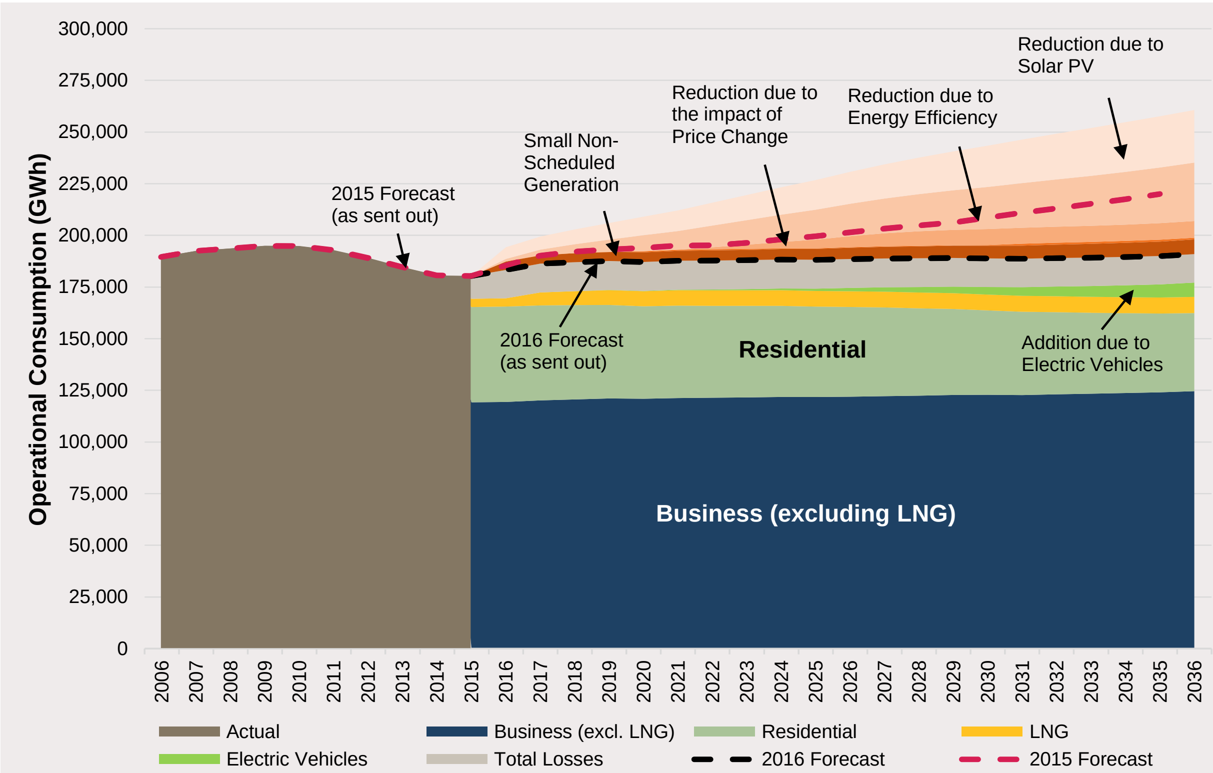
[2] As part of the National Energy Productivity Plan, implementation of vehicle emission standards will be examined. See: https://scer.govspace.gov.au/files/2015/12/NEPP-Work-Plan-version-for-release-20151203sc.pdf.

[3] For the WEM, AEMO only has a 10-year operational consumption forecast as published in the deferred 2015 *WEM Electricity Statement of Opportunities*. See: http://www.aemo.com.au/Electricity/Wholesale-Electricity-Market-WEM/Planning-and-forecasting/WEM-Electricity-Statement-of-Opportunities.

AEMO has considered these EV projections in the context of AEMO's broader forecasting and planning role:

- The introduction and growth of EVs signals yet another consumer-driven technological shift in a wider process of transformational change, risk, and uncertainty for the electricity industry.
- The approximate 3.8% forecast increase in operational consumption from EV uptake by 2035–36 appears relatively small compared to other projected drivers, as shown in Figure 1 (with the projected addition to operational consumption from EVs highlighted in bright green). By contrast, for example, AEMO forecasts that trends in rooftop photovoltaic (PV) and energy efficiency uptake are likely to reduce electricity consumption from the grid in 20 years by 18% and 15% respectively.

Figure 1 NEM operational consumption 2005–06 to 2035–36 (from 2016 NEFR, neutral sensitivity, with EV forecast impact added)



More importantly, there are major uncertainties affecting the emergence of EVs that need to be investigated to better appreciate their likely impact on the energy system. These include:

- The design, technology, and commercialisation of future public charging infrastructure.
- Potential development of government policies affecting transport, such as transportation fleet energy efficiency standards or local policy measures that further support EV uptake.
- Price and tariff structures to accommodate electric vehicles.
- Heavy transport, which was outside the scope of the study.
- The role of electric vehicles in the future power grid, in particular their contribution of energy storage to households and the grid, and their contribution of network support services to address the management of frequency, energy, and voltage.

Over a 20-year projection, differences between actual and assumed incentives could shift operational consumption projections by more than the 3.8% total EV impact now forecast. These EV projections factor in the assumptions in the 2016 NEFR's strong and weak sensitivities to explore some of this uncertainty, resulting in variations in the projections of 20-year forecast growth in operational consumption from EVs of 6.2% and 2.4% respectively.

The impact of uncertainty is particularly high when it comes to forecasting maximum and minimum demand.

- In this study, EV charging has been modelled to occur mainly overnight. This assumption results in negligible impact of EVs on projected regional maximum demands, because EVs were assumed to charge in the lower overnight demand period. (The same slight impact is seen on longer-term forecasts of minimum demand, which by the mid-2020s is forecast to shift to midday in all NEM regions when the sun is strongest and rooftop PV generates at its highest levels.)
- Different pricing incentives and consumer behaviours could result in different usage and charge profiles, potentially with greater effects on daily demand patterns, particularly at the local level.

This level of uncertainty further signals the need for AEMO to increase its focus on the potential implications for power system operation beyond technology to looking into the influences of alternative tariff structures, pricing incentives, and shifts in consumers' attitude and behaviours.

Next steps

Given the relatively small forecast impact of EVs highlighted in this report, and the level of uncertainty in drivers for EV uptake, AEMO intends to:

- Continue to closely monitor the emergence of EVs.
- Investigate and inform stakeholders about the impact of potential future energy services and pricing structures for operational consumption, demand profiles, and any implications for secure and reliable power system operation.

Greater knowledge about these areas of uncertainty is key to projecting how consumer behaviour and the economy may change in Australia, and therefore how the uptake and use of emerging technologies, including EVs, may develop and impact electricity consumption.

Electric Vehicles Insights

Prepared by ENERGEIA for the Australian Energy Market Operator's 2016 National Electricity Forecasting Paper

August 2016

Executive Summary

The National Electricity Forecasting Report (NEFR) provides electricity consumption forecasts over a 20-year forecast period for the National Electricity Market (NEM), and for each NEM region. While electric vehicle uptake in Australia is still very low (approximately 0.3% of annual vehicle sales), the combined impact of price declines in battery technology, the increasing introduction of new EV models into the market and both government and industry support will drive increased uptake over the next 20 years.

AEMO has commissioned Energeia to prepare an Electric Vehicles Insights paper, adopting the forecasts of AEMO's recently published 2016 NEFR as the basis for an impact assessment of the introduction of electric vehicles to Australia's electricity supply system.

Over the course of 2016, AEMO will monitor feedback on this report, and continue a work-program to enable the inclusion of electric vehicles in AEMO's major Forecasting and Planning publications in 2017.

Scope and Approach

The Electric Vehicle Insights paper provides forecasts of EV uptake for each region of the NEM and the corresponding impact on annual electricity consumption and maximum and minimum demand because of charging of EVs from the grid.

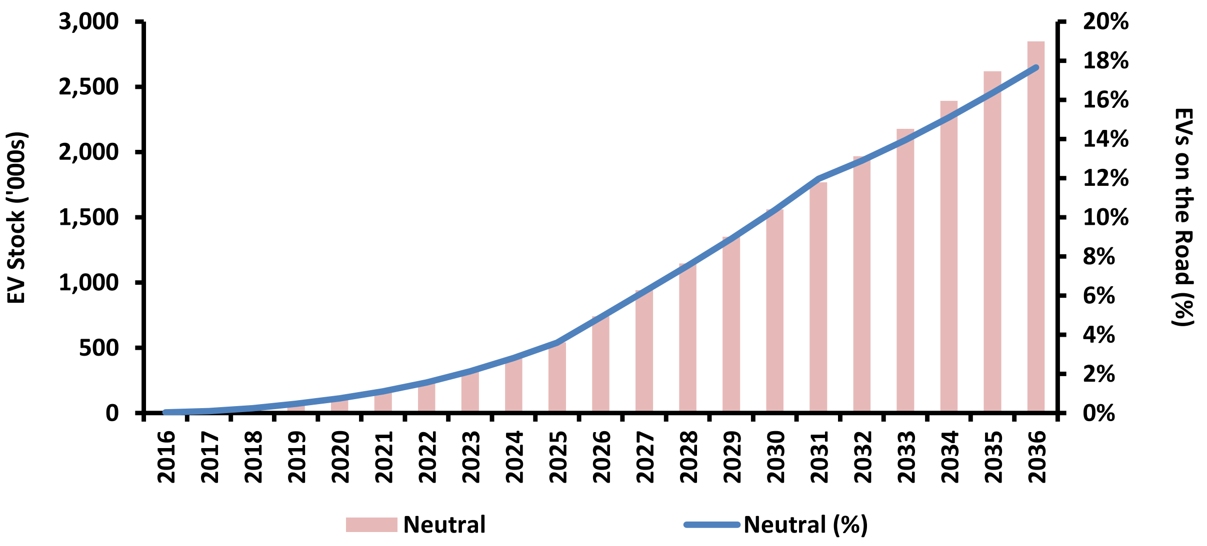
Energeia has used its third generation EV forecasting model, updated to align with AEMO's NEFR assumptions regarding electricity prices as well as market and policy settings, to derive the results.

Results

EV Uptake

EV sales within the National Electricity Market (NEM) are forecast to reach 276,800vehicles per annum by 2036 or 27.1% of sales under the NEFR's neutral sensitivity. As a result, total vehicles on the road are forecast to reach over 2.85 million by 2036 or 17.7% of vehicles by 2036 as shown in Figure 1.

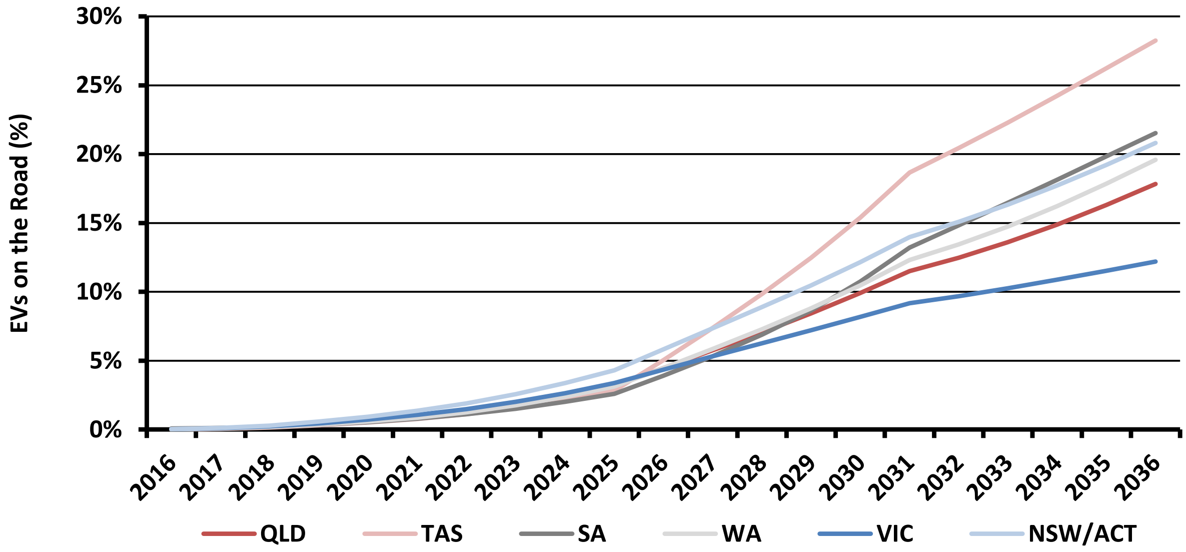
Figure 1 – EV Uptake (NEM, Neutral)



Source: Energeia

Uptake varies by region, predominantly due to market size, but also the relative differential between petrol prices and electricity prices experienced in each state in the early years, with NSW having the greatest differential due to its relatively low priced controlled load tariffs. From 2026, upon the expected introduction of a fleet based greenhouse gas emissions standard, EV sales are encouraged in regions with a lower emission intensity of grid electricity such as Tasmania and South Australia, driving relatively higher uptake as shown in Figure 2.

Figure 2 – EV Uptake by Region (Neutral)

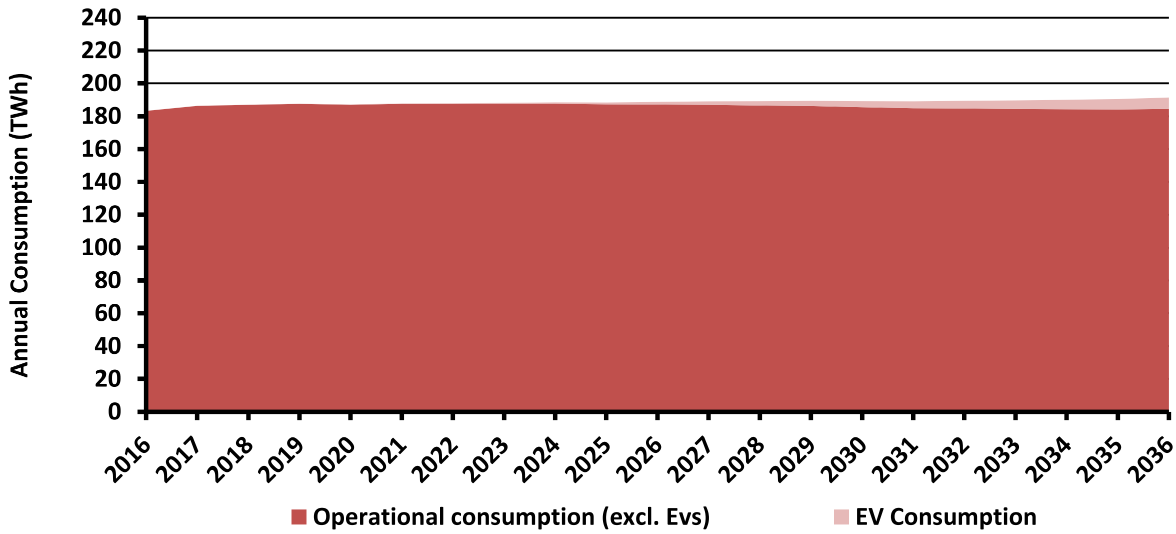


Source: Energeia

EV Consumption

As a result of this uptake, it is forecast that EVs will consume around 6.94 TWh of grid electricity per year by 2036 increasing total consumption by around 4% in 2036 compared to AEMO's NEFR forecasts for primary load under the neutral sensitivity as shown in Figure 3 below.

Figure 3 – EV Electricity Consumption Compared to NEFR Forecast (NEM Operational, Neutral)



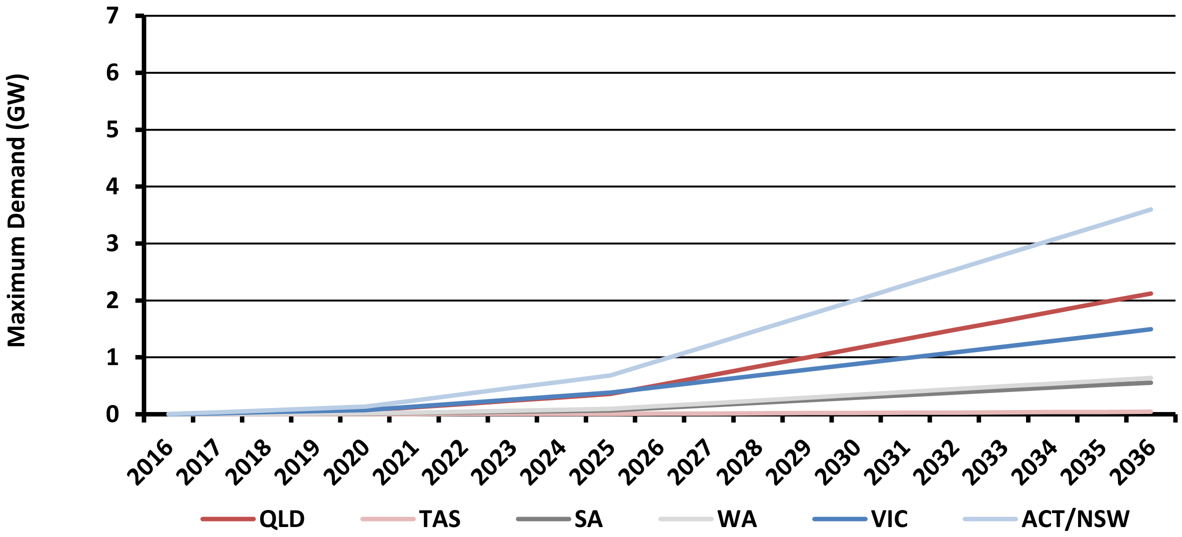
Source: Energeia

EV Maximum Demand

EV annual maximum demand is forecasted to vary by region as shown Figure 4 below. The results below refer to the maximum demand from EV charging which typically occurs late in the evening depending on the structure of the tariff.

It should be noted that EV maximum demand does not necessarily coincide with system maximum demand (and in fact is unlikely to coincide with system maximum demand due to tariff incentives).

Figure 4 – EV Maximum Demand by Region (Neutral)



Source: Energeia

The differences in regions are driven primarily by EV uptake and EV consumption, the latter of which is in turn driven by average driving distances in the region. Maximum demand is also influenced by the characteristics of the underpinning tariff. Tariffs with the greatest restrictions tending to concentrate EV charging over a shorter period and hence increase peak demand.

Impact on NEFR Maximum and Minimum Demand

Despite the increase in overnight demand, it is forecast that EVs will not cause any increase in system maximum demand for any of the regions over the period between 2015 and 2036 due to the non-coincident nature of EV maximum demand with the timing of system maximum demand.

The NEFR minimum demand is forecast to shift from overnight to the middle of the day by 2036 as solar PV penetration increases. As a result, any EV charging during the middle of the day increases minimum demand for all of the regions by 2036. Fleet charging of commercial vehicles slightly increases minimum demand, although the effect is almost insignificant due to the majority of charging still occurring overnight.

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1 Introduction

1.1 Background

The National Electricity Forecasting Report (NEFR) provides electricity consumption forecasts over a 20-year forecast period for the National Electricity Market (NEM), and for each NEM region. In 2015, the NEFR considered the impact of uptake of electric vehicles (EVs) for the first time via the Emerging Technologies Paper accompanying the 2015 NEFR[1].

Accordingly, AEMO has commissioned Energeia to prepare an Electric Vehicles Insights paper to explore the impact of EVs as a key forecast uncertainty of relevance to the main NEFR forecasts.

AEMO will use this analysis as the starting point for monitoring the emergence and use of electric vehicles in Australia, as well as to provide a baseline to commence integration studies.

During the course of 2016 AEMO will monitor feedback on this report, and will continue a work-program to develop this analysis to enable the inclusion of electric vehicles in AEMO's major Forecasting and Planning publications in 2017. A further objective is to provide recommendations as to how the EV forecasts may be better integrated into the NEFR in future years to continually improve forecasting accuracy.

1.2 Objectives

The primary objective of this Electric Vehicles Insights paper is to use the forecasts of AEMO's recently published 2016 National Electricity Forecasting Report (NEFR) as the basis for an impact assessment of the introduction of electric vehicles to Australia's electricity supply system. In doing so, the paper aims to reduce the potential forecasting uncertainty within the main NEFR forecasts with respect to EV uptake.

Specifically the paper provides forecasts of EV uptake for each region of the NEM and the corresponding impact on annual electricity consumption and maximum and minimum demand as a result of charging of EVs from the grid.

1.3 Scope and Approach

The EV forecasts consider impacts from EVs taken up within the passenger vehicle sector only. The passenger sector includes passenger cars, sport utility vehicles and light commercial vehicles adopted across the private, commercial and government markets. The forecasts exclude any uptake of EVs in the heavy vehicle sector.

EV forecasts include both battery electric vehicles (BEVs) and plug-in hybrid vehicles (PHEVs) to the extent that they utilise the grid for charging. The forecasts exclude hybrid electric vehicles (HEVs) which do not charge from the grid.

Battery Electric Vehicle (BEV) – Powered only by energy stored in batteries with batteries charged by plugging into the grid.

Internal Combustion Engine Vehicle (ICE) – Represents the majority of private vehicles, powered by a standard internal combustion engine using petrol, diesel or gas.

Hybrid Electric Vehicle (HEV) – Combines both an ICE with an electric engine. The electrical energy is stored in a battery with the battery charged by the internal combustion engine. Battery capacity is generally limited. Vehicle propulsion is a mix of the ICE and electric engine, but is predominantly powered by the ICE. Does not take energy from the electricity grid.

Plug-in Hybrid Electric Vehicle (PHEV) – Combines both an ICE with an electric engine. Electrical energy is stored in batteries by plugging into the grid. Vehicle propulsion is a mix of the ICE and electric engine, but is predominantly powered by the electric engine. The ICE is used to extend driving range beyond battery capacity for longer distances and to recharge the battery itself.

[1] Emerging Technologies Information Paper, National Electricity Forecasting Report Published: June 2015

Energeia has used its third generation EV forecasting model (described further in Section 2), updated to align with AEMO's NEFR assumptions regarding electricity prices as well as market and policy settings, to derive the results. Further specific EV assumptions were set in conjunction with AEMO as described in Section 3

1.4 Limitations

The EV forecasts contained throughout this paper are independent of the base NEFR forecasts. That is, there is no feedback loop between the forecasted EV uptake and the corresponding response from either networks, retailers or the wholesale market.

Further there are a range of future possibilities as to how the EV market will integrate with the existing solar market and it is foreseeable that tariff products could evolve to encourage increased charging of EVs during solar generation times. Such tariff products have not been considered in these forecasts and all EVs are assumed to adopt existing products.

There is also likely to be some degree of interaction between solar PV, stationary battery storage and EVs at individual customer premises. While AEMO has separately undertaken solar PV and battery storage forecasts, these have not been integrated with the EV forecasts in this paper.

The forecasts include EV charging at home or fleet locations and do not include consideration of fast charging.

The household transport model upon which the EV forecast model relies is derived from the Queensland Household Travel Survey. That is, while the model reflects different average driving distances between states, it assumes that travel patterns (origins, destinations, arrival times and departure times) in all regions of Australia are consistent with those of Queensland drivers.

The model derives its forecasts of uptake based partly on the financial return on investment to vehicles owners owing to the increased vehicle premium and reduced operational costs. The model does not consider any costs associated with any required upgrade to the household circuit although it is acknowledged that this may need to occur in some circumstances to avoid overloading

While all due care has been taken in the preparation of this paper, Energeia has relied upon stakeholder provided information as well as publically available data and information. To the extent these reliances have been made, Energeia does not guarantee nor warrant the accuracy of this paper. Furthermore, neither Energeia nor its Directors or employees will accept liability for any losses related to this paper arising from these reliances.

The forecasts derived from Energeia's EV forecast model are supplied in good faith and reflect the knowledge, expertise and experience of the consultants involved. Energeia does not warrant the accuracy of the model nor accept any responsibility whatsoever for any loss occasioned by any person acting or refraining from action as a result of reliance on the model. The model is for educational purposes only.

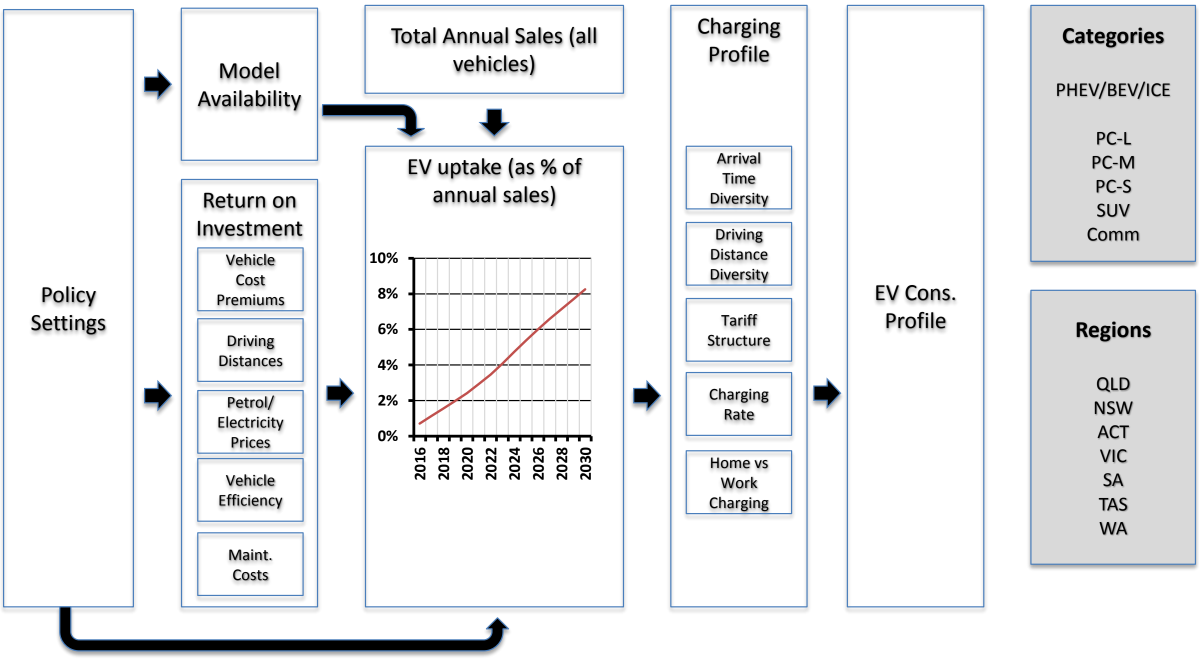
2 EV Forecasting Model Overview

The following section provides an overview of the Energeia's EV forecasting model. The model is part of Energeia's broader energy system model, but has been extracted for the purposes of this study to identify the (non-integrated) impacts of electric vehicles on the energy system. Detailed assumptions are provided in Appendix A.

2.1 Overview

Energeia's EV forecasting model is comprised of two parts, EV uptake and EV charging as shown in Figure 5 below.

Figure 5 – Energeia EV Forecasting Model



Source: Energeia

The EV uptake component drives the forecasts of EV uptake as a percentage of annual vehicle sales for each category of vehicle type. This is based on vehicle model availability and the vehicle owner's return on investment. The EV charging component then applies a charging regime to each vehicle adopted based on the arrival and departure time of the vehicle at the point of charge, the number of kilometres travelled and any incentives or restrictions of the prevailing tariff.

The model considers 45 categories of vehicle types including all combinations of:

- Vehicle Markets
  - Commercial
  - Private
  - Government
- Vehicle class
  - Passenger Car Large (PC-L)
  - Passenger Car Medium (PC-M)
  - Passenger Car Small (PC-S)
  - Sport Utility Vehicle (SUV)

  - Light Commercial (LC)
- Vehicle Technologies
  - Battery Electric Vehicle (BEV)
  - Plug-in Hybrid Electric Vehicle (PHEV)
  - Internal Combustion Engine (ICE)

Each of these categories have specific characteristics which drive both uptake and charging.

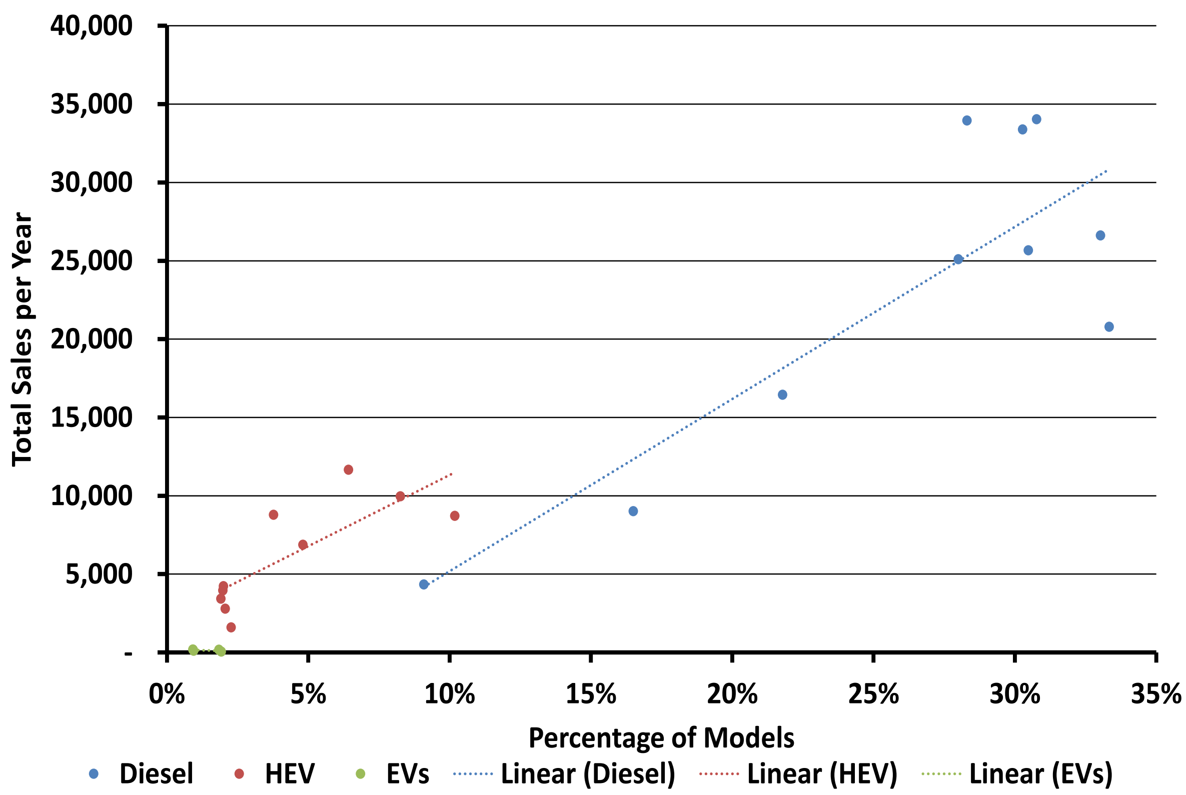
2.2 EV Uptake

EV uptake is determined by a two-parameter function that describes vehicle uptake over time based on:

- Model Availability: The percentage of models within a given vehicle class available in EV form
- Return on Investment: The first year return to the vehicle owner investing in an EV in terms of reduced operational costs (fuel and costs) on the premium paid compared to a conventional ICE vehicle

This functional form accordingly considers the supply side constraints (lack of model availability) as well as demand side drivers (reduced operational costs) in the vehicles owner's decision to adopt. The function is derived from analysis of the diesel vehicle and hybrid electric vehicle markets in Australia whereby uptake can be explained by a combination of both these parameters. The historical relationship between vehicle uptake and model availability in the Australia market for alternative technologies is shown in Figure 6 below.

Figure 6 – Relationship between EV Uptake and Model Availability



Source: VFACTS, Energeia

Detailed assumptions driving the EV Uptake Model are provided in Appendix A.

2.3 EV Charging

The EV charging profile is determined by aggregating the unique charging profile of each individual electric vehicle adopted. The individual profiles are assigned based on:

- Whether the vehicle is assigned as home charging or fleet charging (charges at work or depot location)
- The daily travel distance for both weekday and weekend travel (drawn from a database of regionally specific diversified travel distances), which determines the amount of charge to be supplied by day type
- An arrival time for both weekday and weekend travel (drawn from a database of diversified times specific to either home charging or fleet charging) which dictates when charging starts, in the absence of any other tariff restrictions
- A departure time for both weekday and weekend travel (drawn from a database of diversified times specific to either home charging or fleet charging) which dictates when charging must cease in the absence of any other tariff restrictions
- The prevailing tariff and the extent to which it restricts or incentivises charging during certain times. For home charging this is assumed to be the existing controlled load tariff specific to each region generally allowing for charging overnight only, and for fleet charging this is assumed to be the standard business tariff specific to each region without charging restrictions

Detailed assumptions driving the EV charging profiles are provided in Appendix A.

3 Sensitivities

The EV forecasting compares three sensitivities that represent the probable pathway for Australia across weak, neutral (considered the most likely), and strong economic and consumer outlooks aligned with AEMO's broader NEFR sensitivities. The results for the neutral sensitivity are the focus of this paper.

3.1 NEFR Sensitivities

AEMO's 2016 NEFR uses the terms "weak", "neutral", and "strong" throughout the 2016 NEFR documents to identify the three sensitivities with the neutral sensitivity considered the most likely (P50). The weak and strong sensitivities are based on dynamics affecting the total energy consumption of households and businesses and are not necessarily a low and high outcome for the consumption of grid-supplied energy, but rather an internally consistent set of assumptions aligned to strong and weak economies and associated consumer sentiment. The key characteristics of these sensitivities of relevance to EVs are shown in Table 1.

Table 1 – 2016 NEFR Sensitivity Drivers

Driver	Weak Sensitivity	Neutral Sensitivity	Strong Sensitivity
Population Growth	ABS projection C	ABS projection B	ABS projection A
Economic Growth	Weak	Neutral	Strong
Consumer	Low confidence, less engaged	Average confidence and engagement	High confidence and more engaged
Electricity Network Charges, 5 Years	Current AER determinations, fixed after 5 years		
Electricity Retail Costs and Margin	Assume current margins throughout		
Oil Prices	UD30/bbl (BR) over 5 year glide path	UD60/bbl (BR) over 5 year glide path	UD90/bbl (BR) over 5 year glide path
Technology Uptake	Hesitant Consumer in a Weak Economy	Neutral Consumer in a Neutral Economy	Confident Consumer in a Confident Economy
Energy Efficiency Uptake	Low	Medium	High
Renewable Energy Policy	Assume current to 2020, with LGCs/SSTC deemable to 2030		
Climate Policy	Assume Australia's Paris commitment is achieved AEMO has assumed proxy emissions abatement prices of $25/tonne CO_2-e in 2020 rising to $50/tonne CO_2-e by 2030		

3.2 EV Sensitivities

The sensitivities adopted for the EV insights align with AEMO's 2016 NEFR sensitivities and include the additional considerations listed in Table 2.

Detailed assumptions underpinning the EV sensitivities are provided in Appendix A.

Table 2 – Additional EV Sensitivity Drivers

Driver	Weak Sensitivity	Neutral Sensitivity	Strong Sensitivity
Electric Vehicle Premiums	Reduce slowly (aligned to NEFR 2016 battery storage prices as per Appendix A)	Reduce at neutral rate (aligned to NEFR 2016 battery storage prices as per Appendix A)	Reduce quickly (aligned to NEFR 2016 battery storage prices as per Appendix A)
Tariff Settings (Home Charging)	Current controlled load tariffs (generally allowing overnight charging only)		
Tariff Settings (Fleet Charging)	Current business tariffs (allowing anytime charging)		
Model Availability	Capped at 35% of models in 2036	Capped at 55% of models in 2036	Capped at 75% of models in 2036
Vehicle Emission Standards	Commonwealth Government introduces international best practice emission standards (as fleet wide target) by 2030*	Commonwealth Government introduces international best practice emission standards (as fleet wide target) by 2026*	Commonwealth Government introduces international best practice emission standards (as fleet wide target) by 2022*
Carbon Price Application to Fuel Purchases for Passenger Vehicles	Passenger vehicles are exempt	Passenger vehicles are exempt	Applies from 2020 as per main NEFR sensitivities
Indirect EV Policy Support	None	Priority Lanes and Parking	Priority Lanes and Parking

* A fleet wide standard has been assumed, rather than a minimum performance standard, as the most economically efficient means of achieving best practice greenhouse gas emission

4 Results

The results shown below describe forecast EV uptake over the period between 2016 and 2036 and the corresponding contribution to energy consumption and both maximum and minimum demand. The results are presented for the neutral sensitivity unless otherwise indicated.

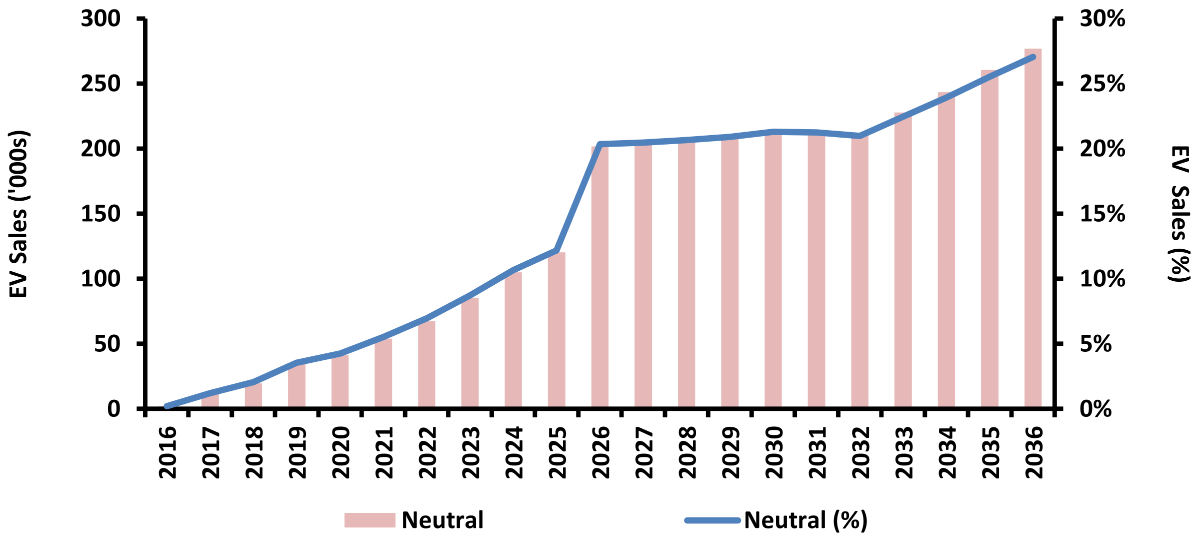
4.1 EV Uptake Forecasts

Section 4.1 presents uptake of electric vehicles in terms of both annual sales and number of vehicles on the road (stock).

4.1.1 NEM

EV sales (both BEV and PHEV) are forecast to reach 277,000 vehicles per annum by 2036 or 27.1% of sales as shown in Figure 7 below.

Figure 7 – Annual EV Sales (NEM)

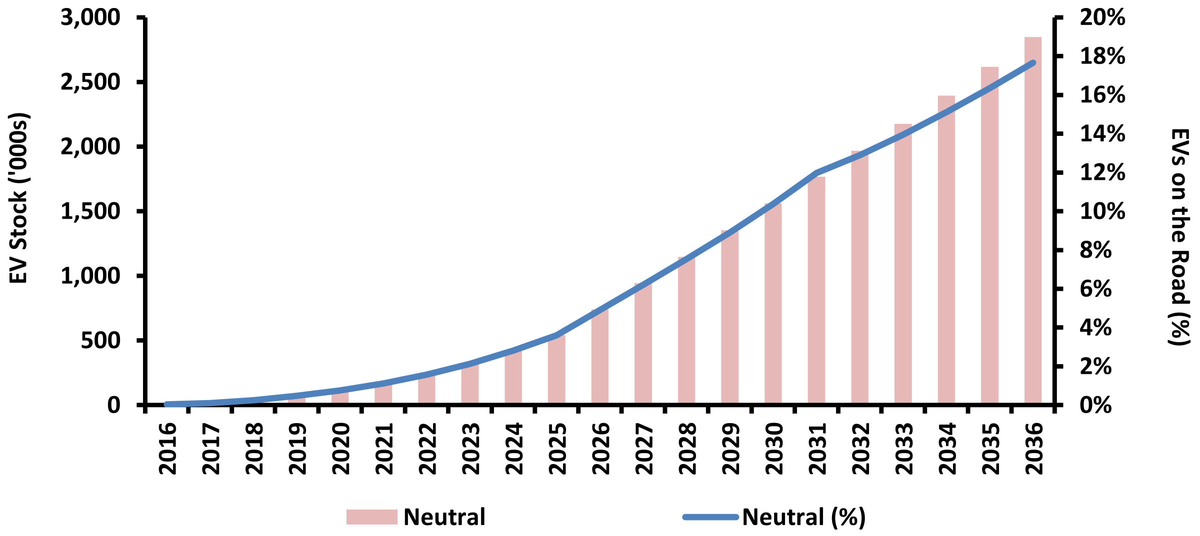


Source: Energeia

Energeia forecasts a relatively steady increase in EV sales of around 36% per annum between 2016 and 2026 driven by a gradual lowering of EV prices, increased model availability by OEMs, as well as an increasing differential between electricity and petrol prices. There is then a forecast step change in sales in 2026 when the greenhouse gas emission standard (fleet based) is introduced, resulting in an effective subsidy of lower emission EVs in preference to ICE vehicles. From 2026 to 2030, annual sales remain relatively flat due to combination of stagnant fuel prices and improving efficiency of ICE vehicles and then increase again after 2030 as petrol prices pick up.

As a result, total vehicles on the road are forecast to reach 2.5 million by 2036 or 17.7% of vehicles by 2036 as shown in Figure 8.

Figure 8 – EV Uptake (NEM, Neutral)



Source: Energeia

4.1.2 Regions

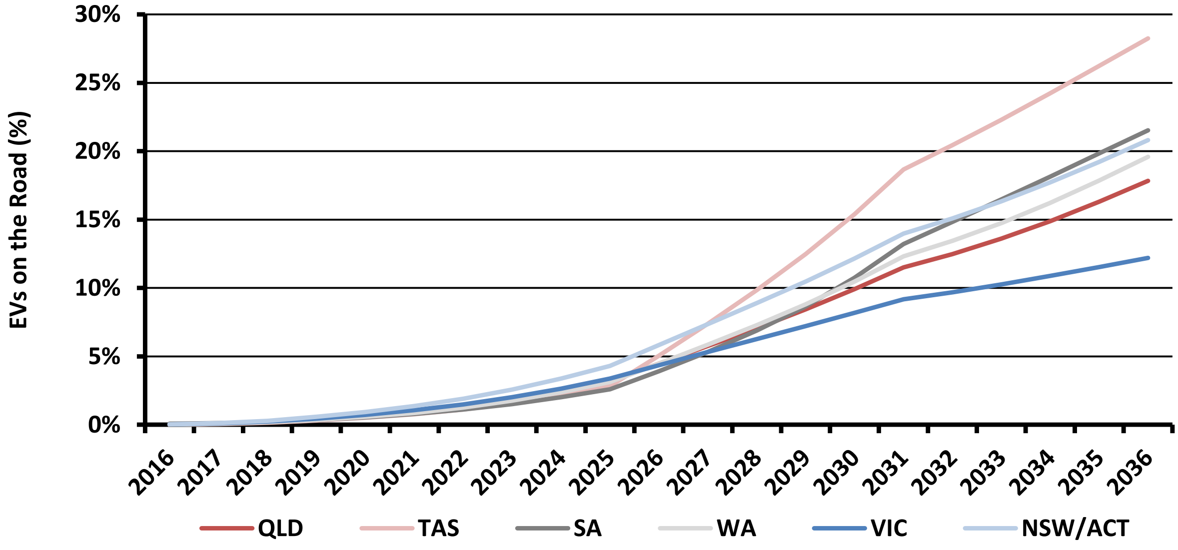
EV uptake is forecast to vary by region as shown in Table 3 and Figure 9.

Table 3 – EV Uptake by Region (Neutral)

Region	2016			2020			2025			2036		
	Yrly Sales (%)	Yrly Sales ('000s)	Stock ('000s)	Yrly Sales (%)	Yrly Sales ('000s)	Stock ('000s)	Yrly Sales (%)	Yrly Sales ('000s)	Stock ('000s)	Yrly Sales (%)	Yrly Sales ('000s)	Stock ('000s)
QLD	0.9%	2	2	5.1%	11	34	19.2%	44	159	31.9%	77	713
NSW	1.1%	4	5	6.6%	24	71	22.8%	84	316	34.3%	130	1,307
VIC	0.9%	3	3	5.5%	16	48	15.3%	46	201	17.5%	55	643
SA	0.9%	0.6	1	4.8%	3	10	20.7%	14	45	34.7%	24	251
TAS	1.0%	0.2	0.2	5.4%	1	3	39.0%	7	17	41.1%	8	90
NEM	1.0%	9	12	5.8%	56	165	19.8%	196	736	28.8%	294	3,004
WA	0.9%	1	1	5.1%	6	18	20.1%	24	84	35.0%	45	410

Source: Energeia

Figure 9 – EV Uptake by Region (Neutral)



Source: Energeia

Absolute number of EVs on the road is predominantly driven by market size. Beyond this, uptake also varies due to the relative differential between petrol prices and electricity prices in each state, with NSW having the greatest differential due to its relatively low priced controlled load tariff. Then, from 2026, upon the introduction of the fleet based greenhouse gas emissions standard, EV sales are in particular encouraged in regions with a lower emission intensity of grid electricity such as Tasmania and South Australia driving relatively higher uptake in these regions.

4.1.3 Sensitivities

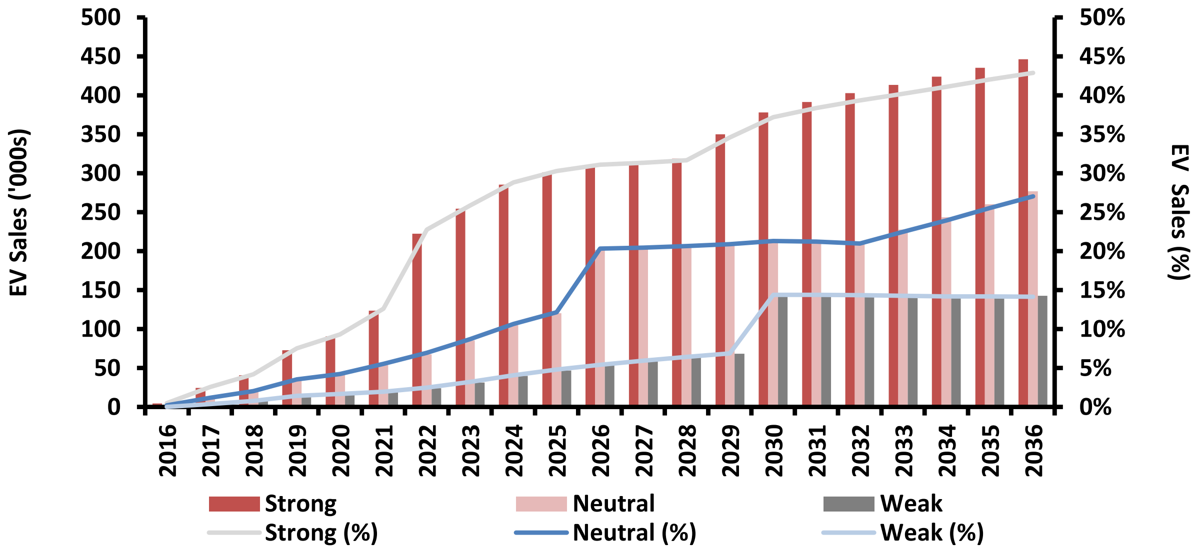
Forecasts of EV uptake vary significantly for the weak and strong sensitivities as shown in Table 4, Figure 10 and Figure 11 below for the NEM. Detailed results by region and sensitivity are presented in Appendix B.

Table 4 – EV Uptake by Sensitivity (NEM)

Sens.	2016			2020			2025			2036		
	Yrly Sales (%)	Yrly Sales ('000s)	Stock ('000s)	Yrly Sales (%)	Yrly Sales ('000s)	Stock ('000s)	Yrly Sales (%)	Yrly Sales ('000s)	Stock ('000s)	Yrly Sales (%)	Yrly Sales ('000s)	Stock ('000s)
Strong	1.4%	13	13	15.1%	147	338	27.0%	269	1,471	44.6%	464	5,180
Neutral	1.0%	9	9	5.8%	56	165	19.8%	196	736	28.8%	294	3,004
Weak	0.6%	6	6	2.8%	27	84	6.5%	64	323	15.8%	160	1,621

Source: Energeia

Figure 10 – EV Annual Sales by Sensitivity (NEM)

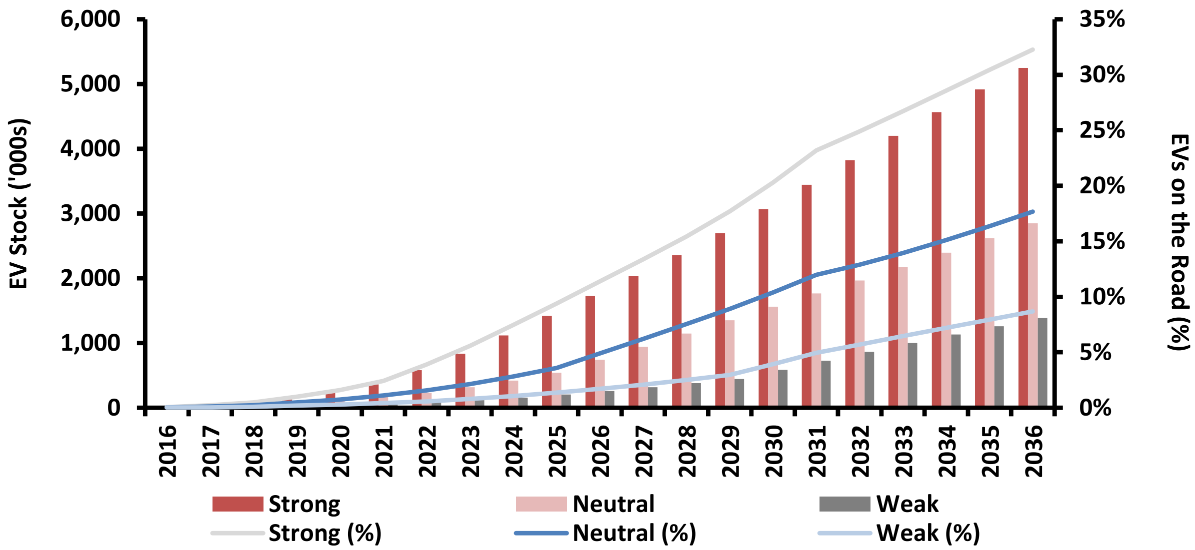


Source: Energeia

In the strong sensitivity, EV sales initially increase at a faster rate than both the neutral or weak sensitivity due to an oil price translating to higher price differential between petrol and electricity, as well as a faster rate of decline in EV price premium and battery storage prices. Under the strong sensitivity, the sales rate further accelerates from 2022 due to the introduction of both a fleet wide greenhouse gas emission standard and a carbon price on petrol from 2020. As a result, by 2036, forecast EV stock under the strong sensitivity reaches 5.25 million vehicles, 84% higher than the neutral sensitivity.

In the weak sensitivity, EV sales increase gradually over time mostly driven by a slower decline in EV price premiums and battery storage prices, keeping the price differential between electricity and petrol relatively stable. The main impact on EV uptake then occurs in 2030 when the fleet based emission greenhouse gas standard is introduced, which has a larger effect than in other sensitivities due to the absence of other factors. As a result, by 2036, forecast EV stock in the weak sensitivity reaches almost 1.4 million vehicles, 51% lower than the neutral sensitivity.

Figure 11 –EV Uptake by Sensitivity (NEM)



Source: Energeia

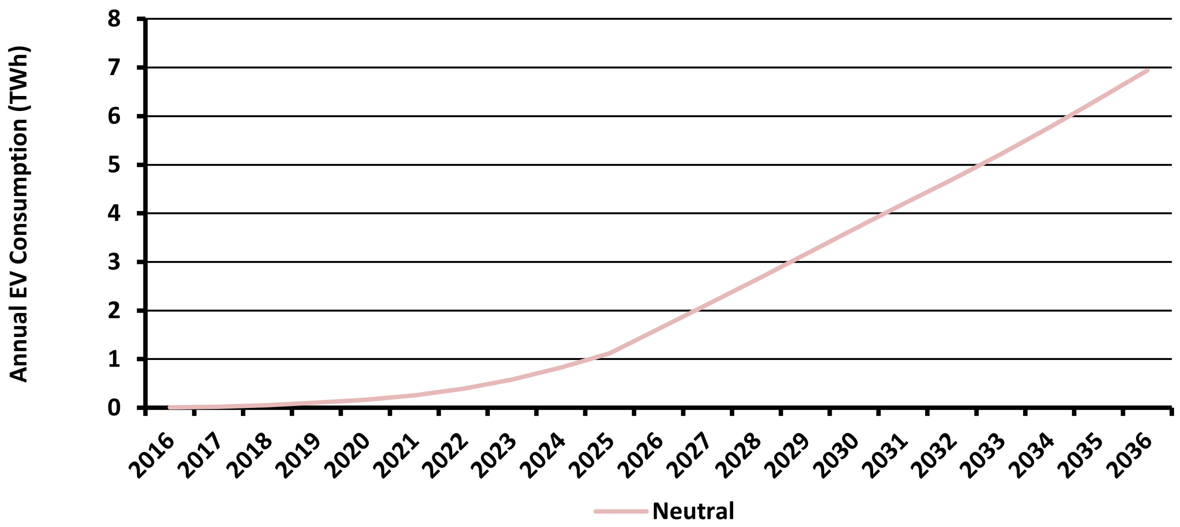
4.2 EV Consumption Forecasts

Section 4.2 presents the forecasts for grid electricity consumption from EV charging associated with EV uptake and assesses the impact of these on the 2016 NEFR forecasts prepared by AEMO. All of the forecasts present electricity consumption in terms of operational requirements (including losses).

4.2.1 NEM

It is forecast that EVs consume around 6.94 TWh of grid electricity per year by 2036 as shown in Figure 12.

Figure 12 – EV Electricity Consumption (NEM Operational, Neutral)

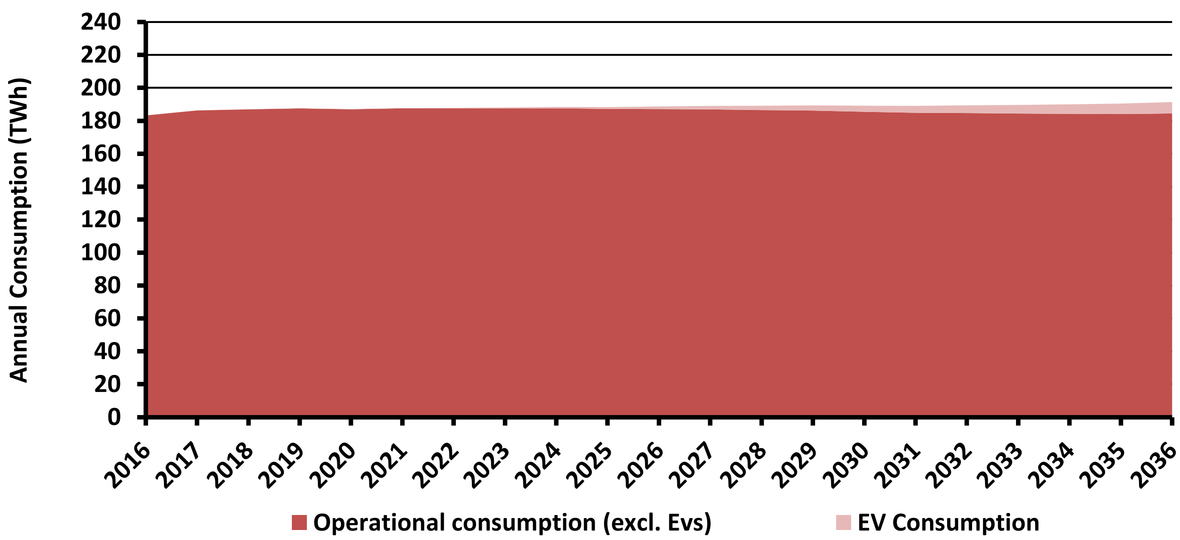


Source: Energeia

The increase in EV consumption over time is directly related to the change in EV uptake as discussed in Section 4.1.

The additional EV consumption is forecast to increase total consumption by around 4% compared to AEMO's NEFR forecasts for primary load in 2036 under the neutral sensitivity as shown in Figure 13 below.

Figure 13 – EV Electricity Consumption Compared to NEFR Forecast (NEM Operational, Neutral)



Source: Energeia

4.2.2 Regions

Electricity consumption by EVs is forecast to vary by region as shown in Figure 14 below.

Figure 14 – EV Electricity Consumption by Region (Operational, Neutral)

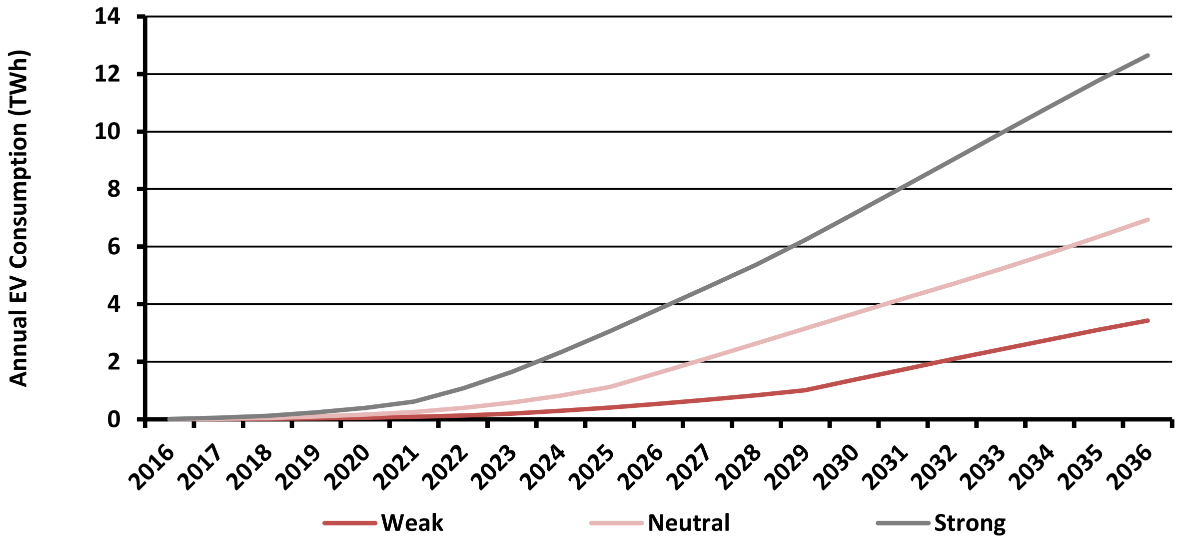
Source: Energeia

The differences in regions are driven primarily by market size, with NSW/ACT having the largest market for new vehicles. The consumption aligns closely to EV uptake by region (as per Figure *9*). Notwithstanding, EV consumption per vehicle does vary slightly by state due to the differences in average travel distances and tariff rates which in turn influence relative uptake of vehicle types (PHEV or BEV) and associated charging requirement. NSW is forecast to have the highest average daily driving distance as well, as result of its lower priced electricity, which increase relative consumption per vehicle in this state.

4.2.3 Sensitivities

Forecasts of EV electricity consumption vary significantly for the weak and strong sensitivities as shown in Figure 15 below for the NEM. Detailed results by region and sensitivity are presented in Appendix B.

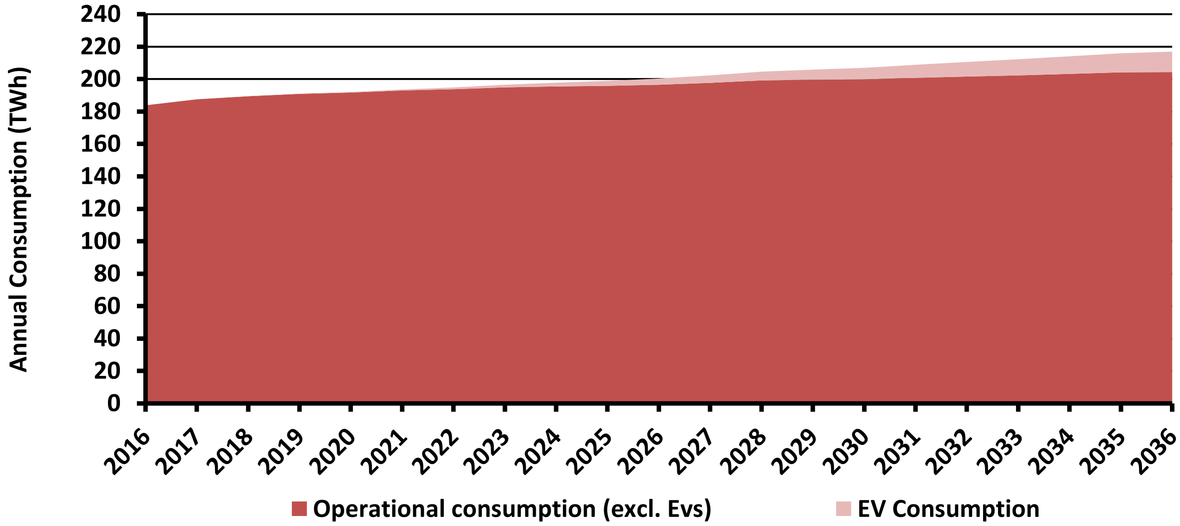
Figure 15 – EV Electricity Consumption by Sensitivity (NEM Operational)



Source: Energeia

Under the strong sensitivity, EV electricity consumption reaches 12.65 TWh per year and equates to around 6.2% of AEMO's NEFR forecasts for primary load in 2036 as shown in Figure 16 below.

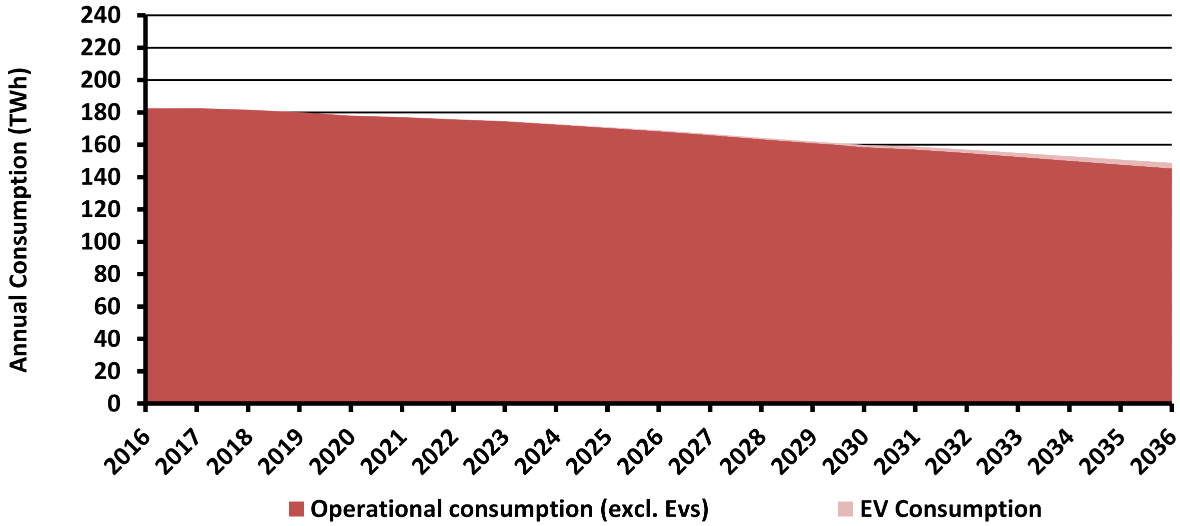
Figure 16 – EV Electricity Consumption (NEM Operational, Strong)



Source: Energeia

Under the weak sensitivity, EV electricity consumption reaches 3.4 TWh per year and equates to around 2.4% of AEMO's NEFR forecasts for primary load in 2036 as shown in Figure 17 below.

Figure 17 – EV Electricity Consumption (NEM Operational, Weak)



Source: Energeia

4.3 EV Maximum Demand Forecasts

Section 4.3 presents Energeia's forecasts for maximum demand by region from EV charging and assesses the impact of these on the 2016 NEFR maximum demand forecasts prepared by AEMO.

Section 4.3.1 describes the forecasts of non-coincident EV maximum demand. That is, the EV maximum charging demand independent of, and unlikely to coincide with, the NEFR forecasts for system maximum demand.

The impact on coincident system maximum demand is then determined separately in Section 4.3.2 by comparing EV demand to system demand for each half hour in order to identify whether EVs have the potential to contribute to the existing peak or to create a new peak.

All of the forecasts present maximum demand in terms of operational requirements (including losses).

4.3.1 EV Maximum Demand

EV annual maximum demand is forecasted to vary by region and sensitivity as shown in Table 5 and Figure 18 below.

It should be noted that EV maximum demand does not necessarily coincide with system maximum demand (and in fact is unlikely to coincide with system maximum demand due to tariff incentives).

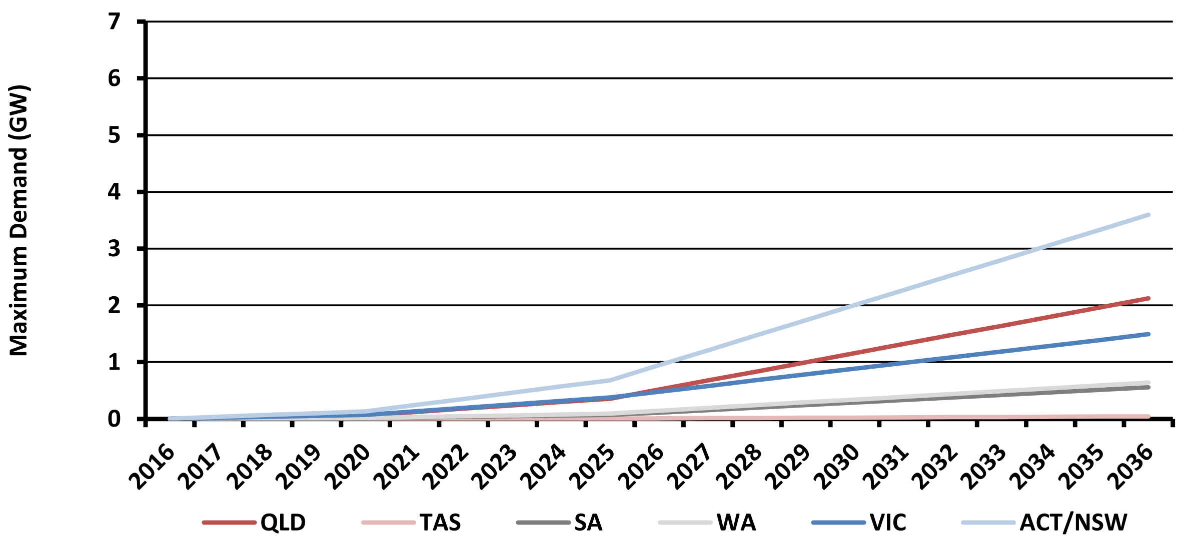
The results below refer to the maximum demand from EV charging which typically occurs late in the evening depending on the structure of the controlled load tariff. The distribution of EV charging over a 24 hour period for each region for each period is provided in detail in Appendix B.

Table 5 – EV Maximum Demand (Non-Coincident) by Sensitivity (Operational NEM)

Region	2016 EV Max Demand (MW)			2020 EV Max Demand (MW)			2025 EV Max Demand (MW)			2036 EV Max Demand (MW)		
	Strng	Neut	Weak	Strng	Neut	Weak	Strng	Neut	Weak	Strng	Neut	Weak
QLD	3	1	0.02	143	64	25	1,003	355	134	3,974	2,123	1,104
NSW	6	3	0.5	264	126	47	1,681	649	241	6,022	3,432	1,631
VIC	3	1	0.1	157	71	27	881	378	139	3,058	1,491	683
SA	0.5	0.2	0.005	31	13	5	235	68	25	870	556	287
TAS	0.04	0.02	0.001	2	0.8	0.3	20	5	2	68	44	28
WA	0.6	0.3	0.01	35	14	5	273	93	34	1,113	638	340

Source: Energeia

Figure 18 – EV Maximum Demand by Region (Operational, Neutral)

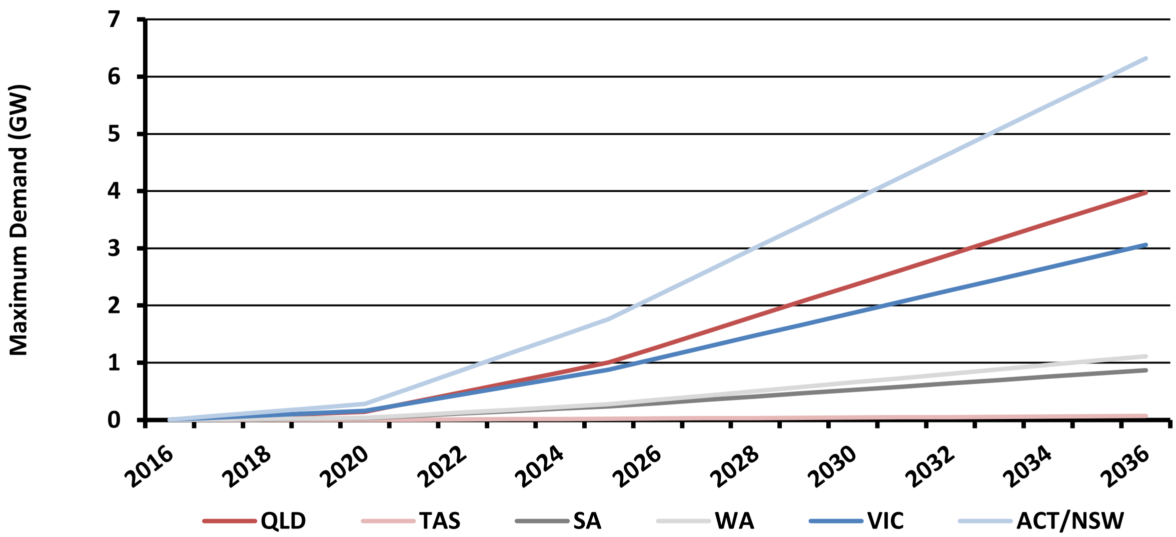


Source: Energeia

The differences in regions are driven primarily by EV uptake and EV consumption as discussed in Section 4.1 and Section 4.2, respectively. In addition, maximum demand is also influenced by the characteristics of the controlled load tariff such that tariffs with the greatest restrictions tend to concentrate EV charging over a shorter period and hence increase peak demand. For example, although EV electricity consumption is significantly higher in WA compared to SA, there is only a minor difference between EV maximum demand. This difference can be attributed to the SA controlled load tariff's later start times, concentrating the commencement of EV charging to later in the evening.

Figure 19 and Figure 20 show EV maximum demand by sensitivity.

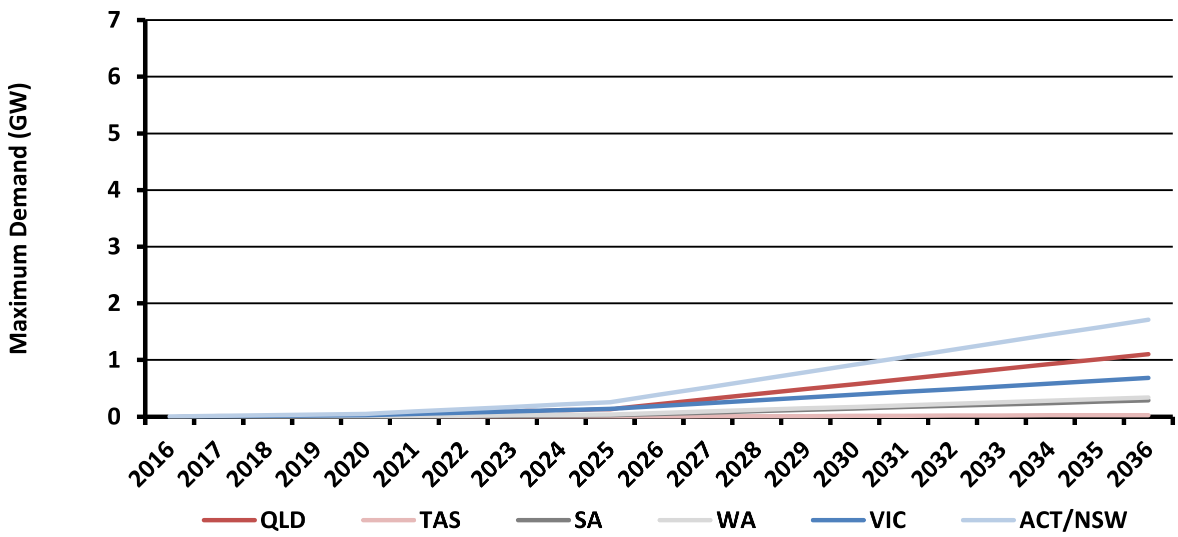
Figure 19 – EV Maximum Demand by Region (Operational, Strong)



Source: Energeia

By 2036, EV maximum demand under the strong sensitivity is between 53% and 105% greater than under the neutral sensitivity, depending on region, due to the higher EV uptake.

Figure 20 – EV Maximum Demand by Region (Operational, Weak)



Source: Energeia

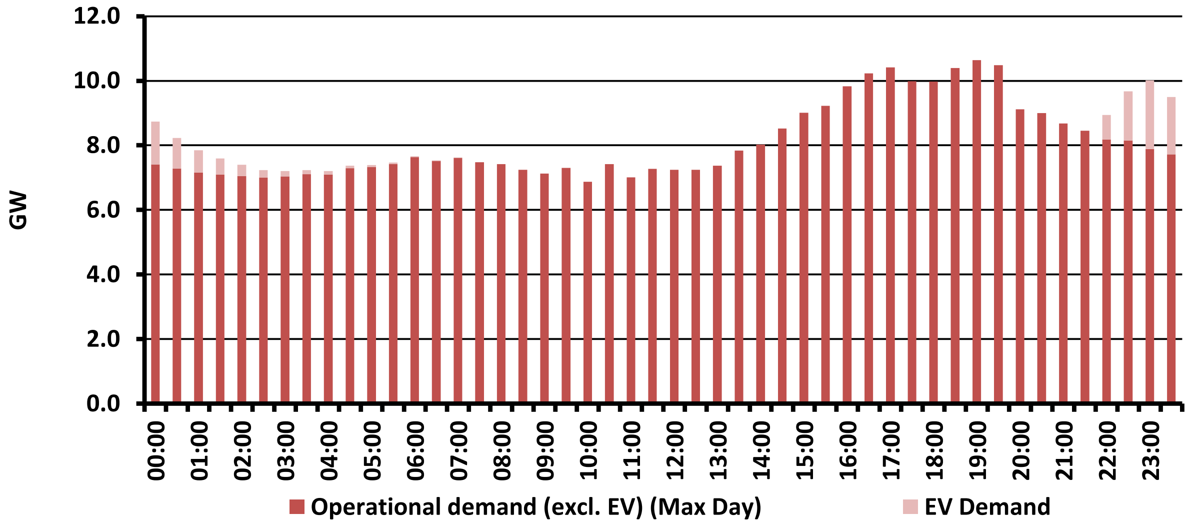
By 2036, EV maximum demand under the weak sensitivity is between 38% and 54% less than under the neutral sensitivity, depending on region, due to the lower EV uptake.

4.3.2 Impact on NEFR Maximum Demand

It is forecasted that EVs will not cause any increase in maximum demand for any of the regions over the period 2015 to 2036. Figure 21 to Figure 25 show the contribution of EVs on the NEFR maximum demand day for each region[2] for the neutral sensitivity.

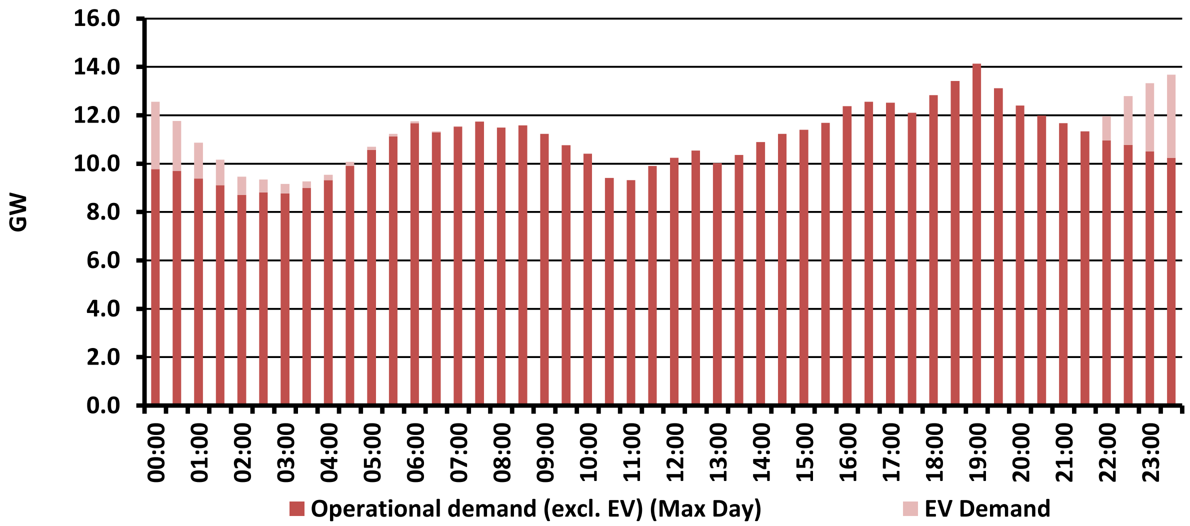
[2] Not available for Western Australia

Figure 21 – Contribution of EVs on QLD Maximum Demand Day (2036, Neutral)



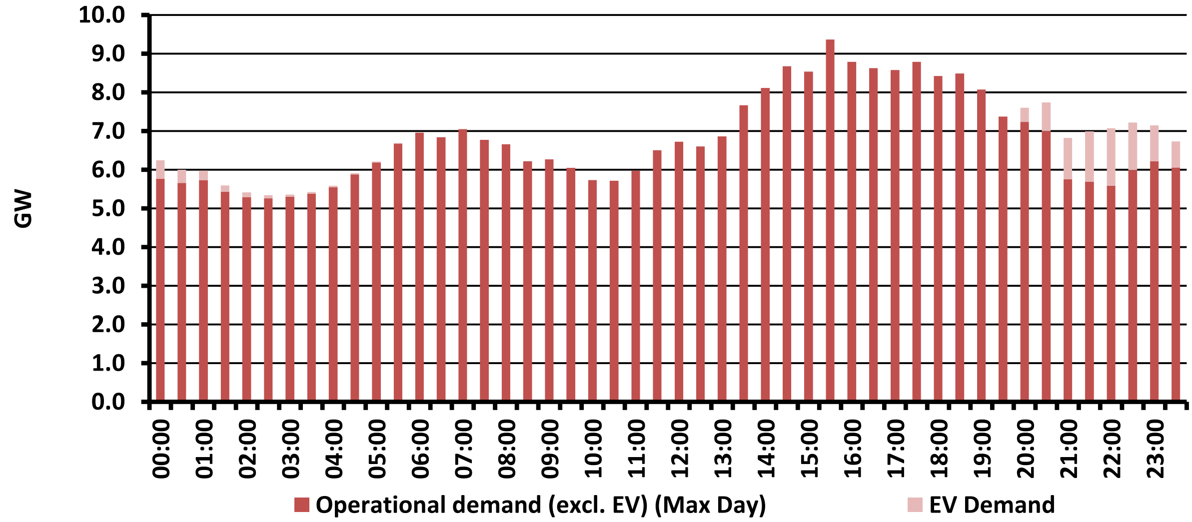
Source: Energeia

Figure 22 – Contribution of EVs on NSW Maximum Demand Day (2036, Neutral)



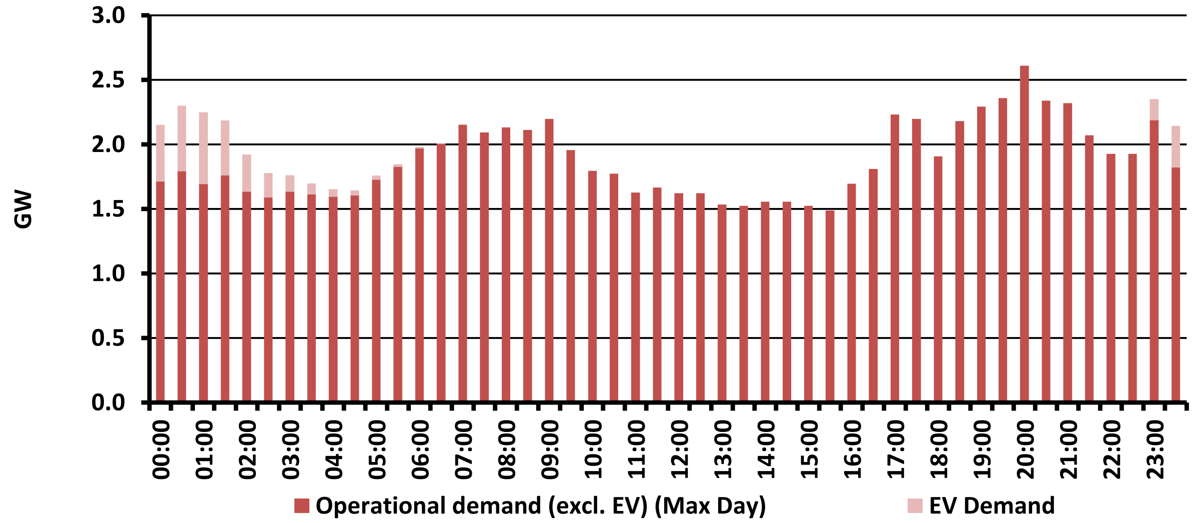
Source: Energeia

Figure 23 – Contribution of EVs on VIC Maximum Demand Day (2036, Neutral)



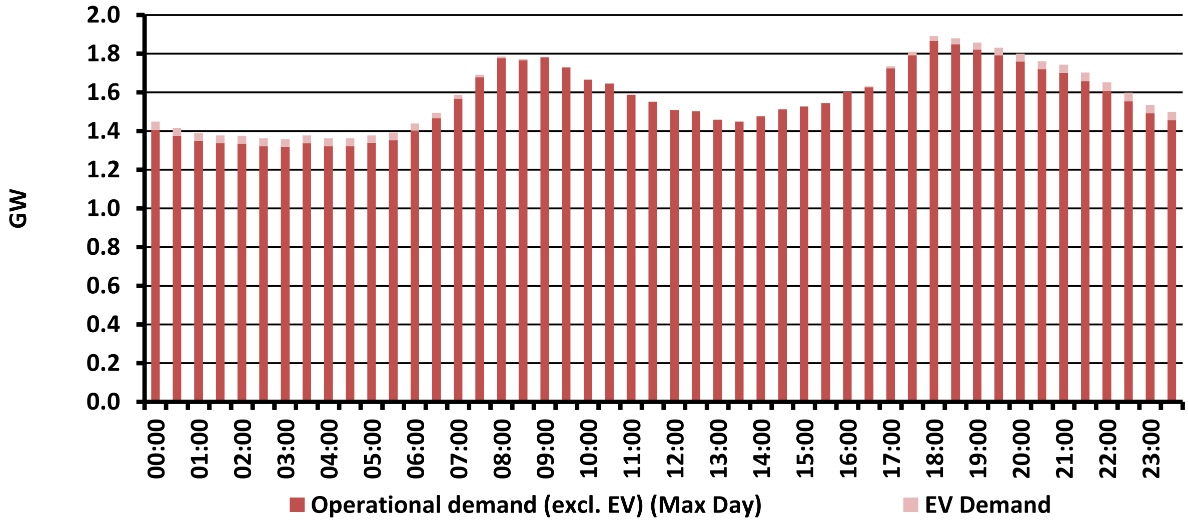
Source: Energeia

Figure 24 – Contribution of EVs on SA Maximum Demand Day (2036, Neutral)



Source: Energeia

Figure 25 – Contribution of EVs on TAS Maximum Demand Day (2036, Neutral)

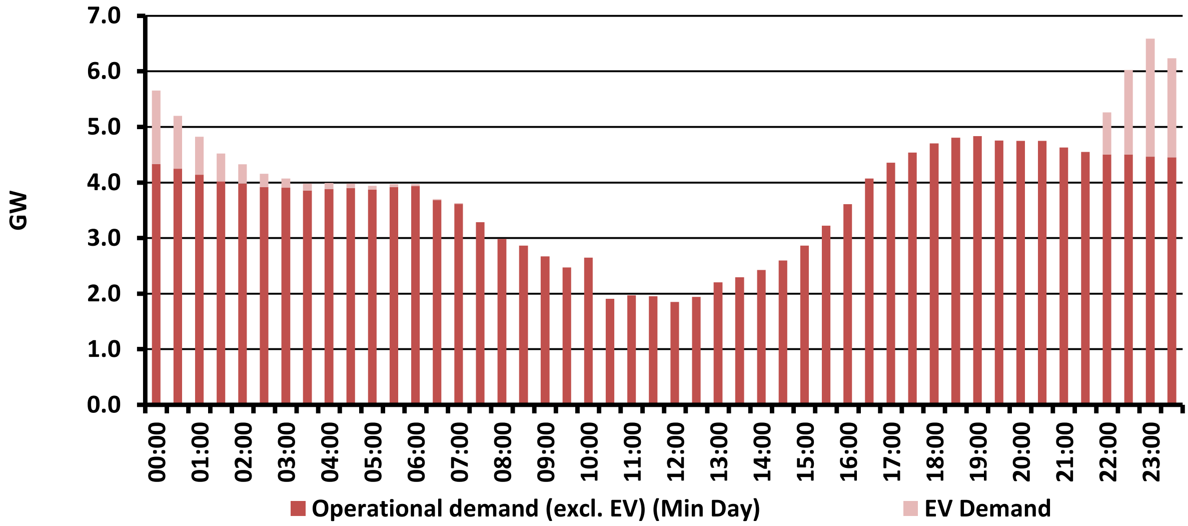


Source: Energeia

4.3.3 Impact on NEFR Minimum Demand

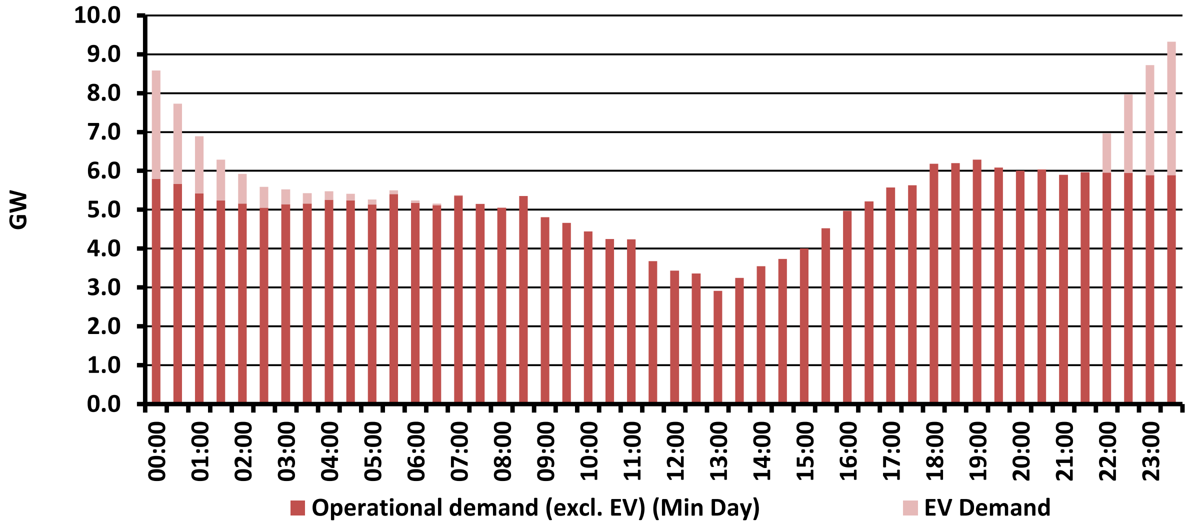
The NEFR forecast minimum demand (90% POE) is forecast to shift from overnight to the middle of the day by 2036 in all states as solar PV penetration increases. As a result any EV charging during the middle of the day increases minimum demand for all of the regions by 2036. Fleet charging of vehicles slightly increases minimum demand, although the effect is almost insignificant due to the majority of charging still occurring overnight as shown in Figure 26 to Figure 30 (although the effect on minimum demand is too small to be seen).

Figure 26 – Contribution of EVs on QLD Minimum Demand Day (2036, Neutral)



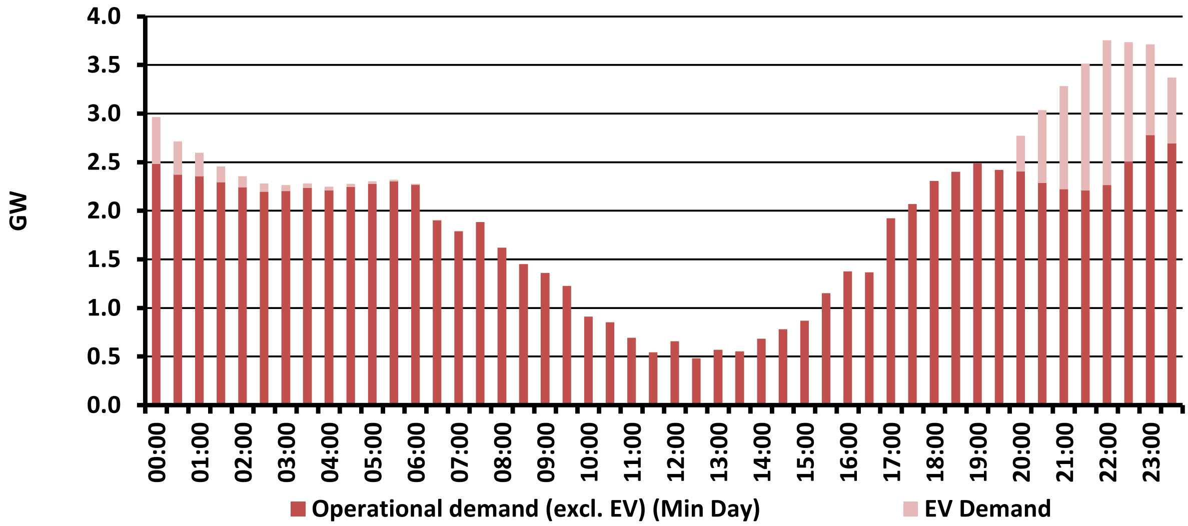
Source: Energeia

Figure 27 – Contribution of EVs on NSW Minimum Demand Day (2036, Neutral)



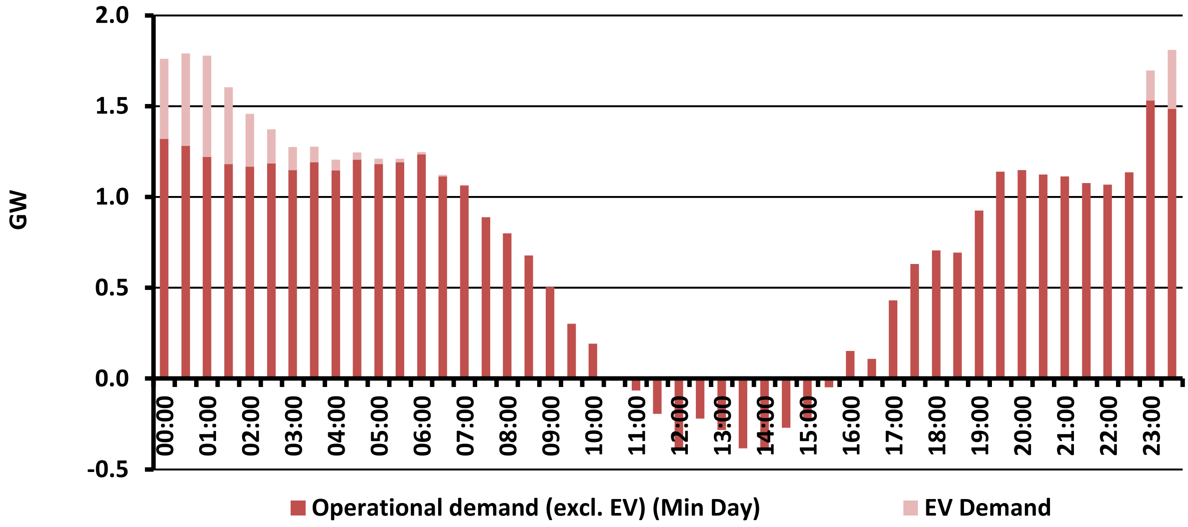
Source: Energeia

Figure 28 – Contribution of EVs on VIC Minimum Demand Day (2036, Neutral)



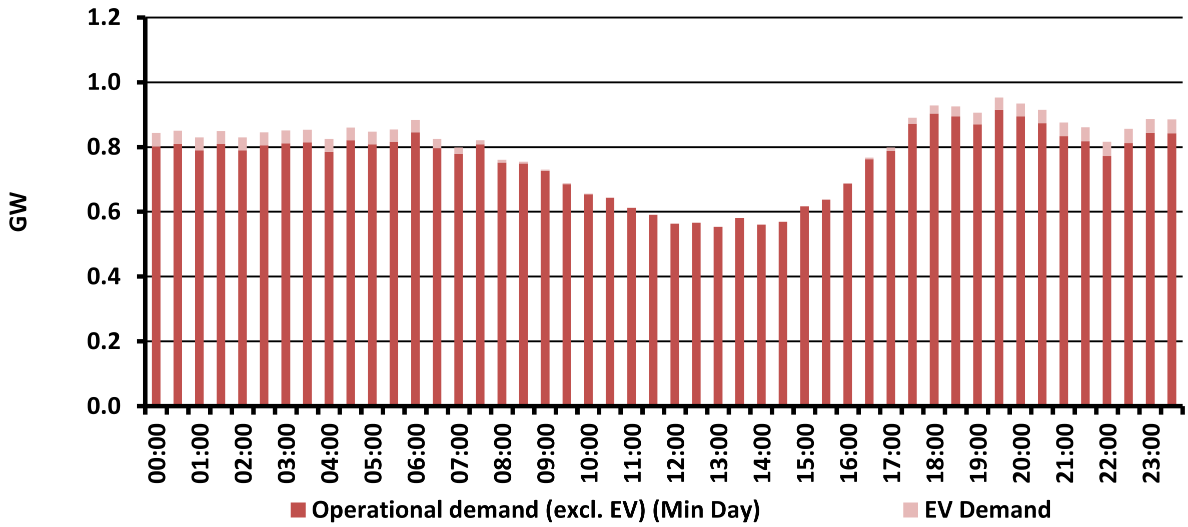
Source: Energeia

Figure 29 – Contribution of EVs on SA Minimum Demand Day (2036, Neutral)



Source: Energeia

Figure 30 – Contribution of EVs on TAS Minimum Demand Day (2036, Neutral)



Source: Energeia

The results above demonstrate an opportunity to encourage daytime charging which suggests future tariffs will need to change from today's This would encourage more demand in the middle of the day which could be the subject of future EV forecasts.

5 Recommendations for Future Modelling

The EV forecasts contained throughout this paper have been prepared to provide an insight into the potential impact of future EV uptake on the main NEFR forecasts. The forecasts have been prepared based on a non-integrated model of EV forecasts and existing publicly available data. In future years, it is understood that AEMO intends to integrate EV forecasting into the NEFR process to allow for greater feedback between the primary forecast and EV uptake drivers.

Accordingly, there are a range of key uncertainties and limitations which Energeia recommends are addressed and/or improved in future modelling.

5.1 Key Uncertainties

The EV forecasts within this paper contain a number of key uncertainties which affect the precision and accuracy of the results. These include:

- The structure of tariffs to be applied to EV charging and changes in these structures over time (See Section 5.2 above)
- Policy uncertainty, with respect to:
    - The mechanism and timing of introduction of a vehicle greenhouse gas emission standard
    - The application of a broader carbon price to vehicle emissions.
- The rate at which vehicle manufacturers make EV models available within the Australian market (nominated as model availability within this paper)
- The number and duty cycle of fast charging

Further, the near term EV forecasts are subject to a high degree of uncertainty due to the immaturity of the market and short term actions that may be taken by the private sector to accelerate uptake. For example, there is the potential for early action by industry to promote EVs via heavily subsidised tariffs[3].

In addition, there are likely to be further drivers, external to the model, relating to substitutable low emission technologies, including natural gas vehicles, fuel cell vehicles. Consideration of the potential impacts of these has been considered within the model in terms of the extent to which new technologies are likely to limit EV model availability. That is, the model assumes that a wholesale transition of the Australian vehicle fleet to EVs will not occur and at some point, new technologies entering the market will slow the growth in EV sales.

Conversely, complementary technologies, such as self-driving cars and wireless induction charging, have the potential to increase the attractiveness of EVs to the Australian public and drive greater levels of penetration (recognising self-driving vehicles also have the potential to reduce total number of vehicles on the road). These factors have not been considered by the model.

5.2 Changes in EV Charging Tariffs over Time

Currently the EV forecasting model assumes that tariff structures do not change over time. That is, all home charging is completed on a controlled load tariff only available overnight and all fleet based charging is undertaken under a default commercial tariff with the timing of charging dependent on the time of vehicle arrival. Due to the dominance of home based charging, the vast majority of EV charging occurs overnight on residential controlled load tariffs. EVs are therefore not forecast to have any significant impact on the minimum demand day.

It is therefore foreseeable that tariff arrangements could be introduced to incentivise greater EV consumption during daylight hours especially towards the end of the forecast period. In such a scenario, service providers would seek to flatten the overall system demand by offsetting predominantly residential based solar PV generation by encouraging work based EV charging within commercial areas. Distribution networks would seek

[3] See for example, Vesey, Andy (@AndyVesey_AGL) *"$1 a day (fully carbon offset) to charge your #EV. AGL to launch Nov 2016. $365 pa max for all your EV trips #AEW16"* 5:37 PM, 20 June 2016. Tweet.

to flatten demand at spatial locations and so would need to carefully manage incentives to ensure that new localised daytime peaks did not arise in commercial areas to offset PV generation in residential areas. These complex interactions require consideration of demand at both the system level as well as the network level (at the zone substation level or lower).

It is recommended that for future EV modelling, AEMO consider incorporating a dynamically controlled load tariff with a structure that varies over time and differs between the commercial and residential sectors to reflect both network and retail drivers.

5.3 Integration with Primary Load

The forecasts assume that the decision to adopt an EV is made independently from any other decisions regarding primary energy consumption. In reality, there will be a subset of customers for whom the decision to purchase an EV could be made more attractive if combined with a solar PV system depending on the tariff arrangements and individual driving patterns.

Further, the present modelling assumes that the EV is not capable of any vehicle to home or vehicle to grid (V2G) charging. Where this is the case, integration with the primary load becomes critical to residential forecasts and interacts with the stationary storage uptake.

While AEMO has separately undertaken solar PV and battery storage forecasts, these have not been integrated with the EV forecasts in this paper.

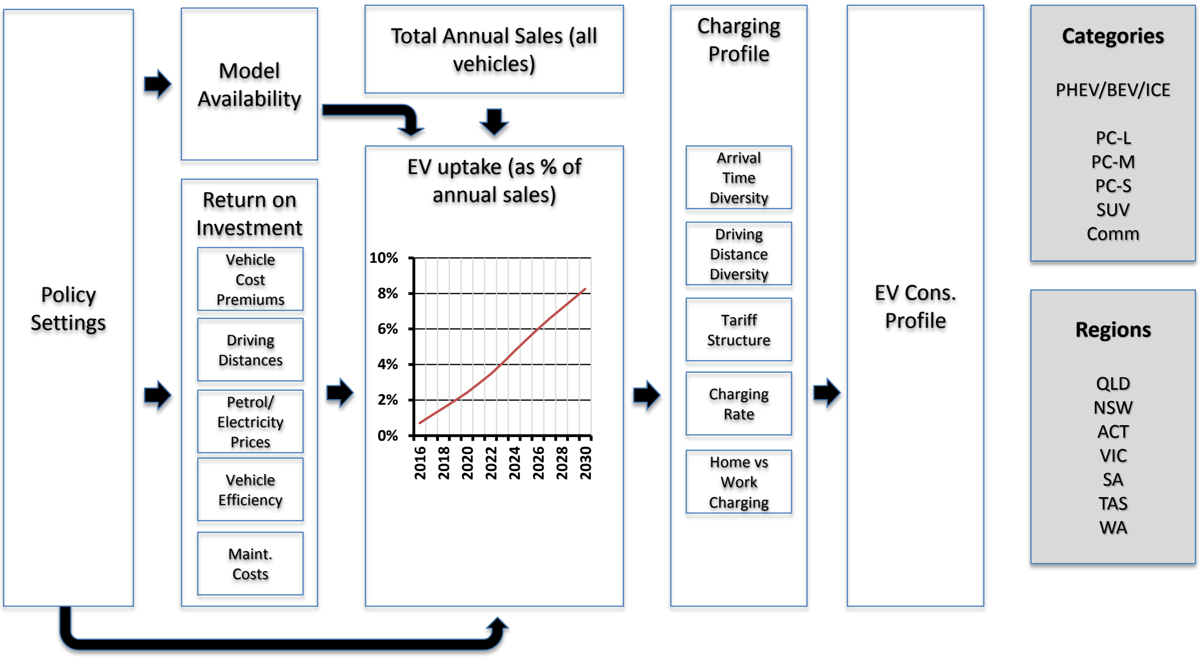
It is recommended that for future EV modelling, AEMO integrates the EV uptake and charging decisions with the broader customer decision making with respect to solar PV and stationary battery storage uptake and operation.

Appendix A: Detailed Assumptions

A.1 Overview of Model Approach

Energeia's EV forecasting model is comprised of two parts, EV uptake and EV charging as shown in Figure 31 below.

Figure 31 – Energeia EV Forecasting Model



Source: Energeia

The EV uptake component drives the forecasts of EV uptake as a percentage of annual vehicle sales for each category of vehicle type. This is based on vehicle model availability and the vehicle owner's return on investment.

The EV charging component then applies a charging regime to each vehicle adopted based on the arrival and departure time of the vehicle at the point of charge, the number of kilometres travelled and any incentives or restrictions of the prevailing tariff.

A.2 EV Uptake

EV uptake is determined by a two-parameter function that describes vehicle uptake over time based on:

$$EV\ Uptake_t = \frac{EV\ Sales_t}{Total\ Vehicle\ Sales_t} = a_t \times ROI_t \times Model\ Availability_t$$

Where:

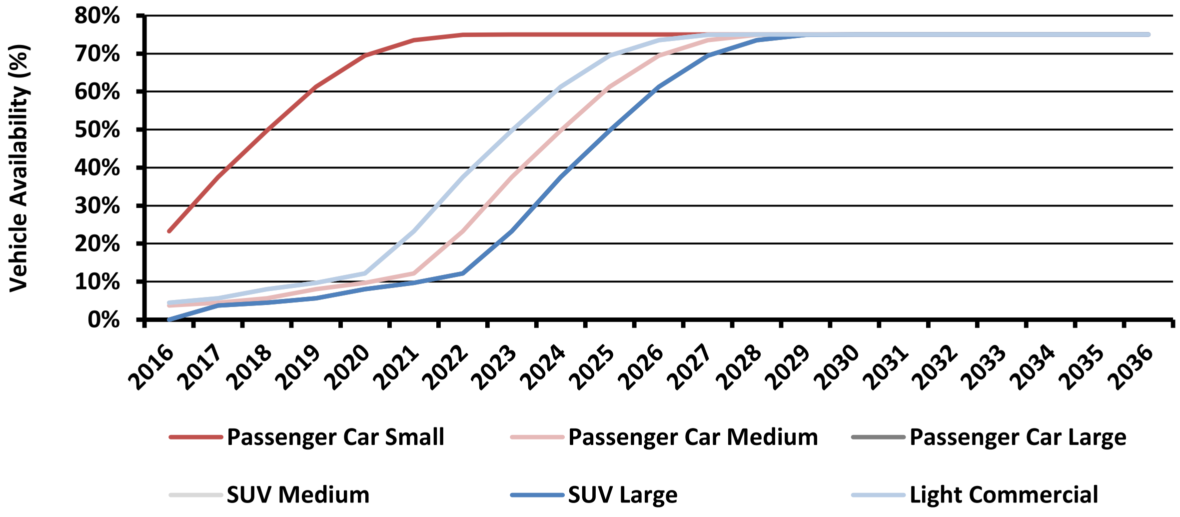
- $Model\ Availability_t$ = Percentage of models within a given vehicle class available in EV form in year t. This inclusion of this factor reflects that for the mass market, the primary driver of vehicle purchase will be based on model and then the availability of that model in EV form is the secondary consideration. This factor effectively places an upper bound on EV adoption.
- ROI_t = The first year return on investment for the vehicle owner investing in an EV in year t in terms reduced operational costs (fuel and costs) on the premium paid compared to a conventional ICE vehicle
- a_t = Model coefficient (derived from historical data of diesel and hybrid electric vehicle uptake for observed ROIs and model availability)

As seen, EV uptake depends on the functional form assumed for model availability and change in ROI over time. These are explained further below.

A.2.1 Model Availability

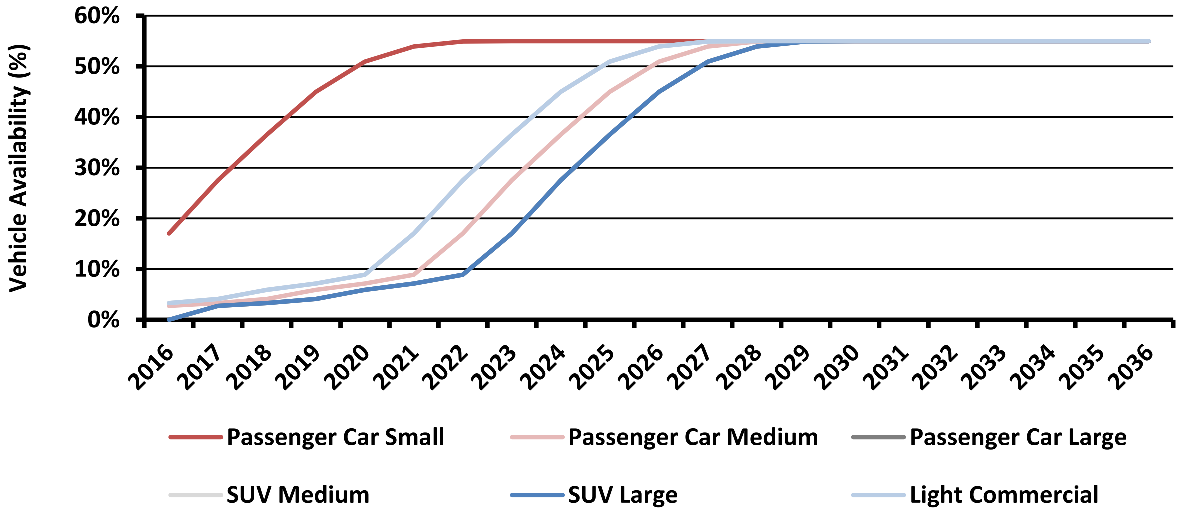
The model availability varies by vehicle class and by sensitivity over the years as shown in Figure 32, Figure *33* and Figure 34 based on analysis of historical model availability trends for the introduction of diesel and HEV vehicles.

Figure 32 – Model Availability Strong Sensitivity



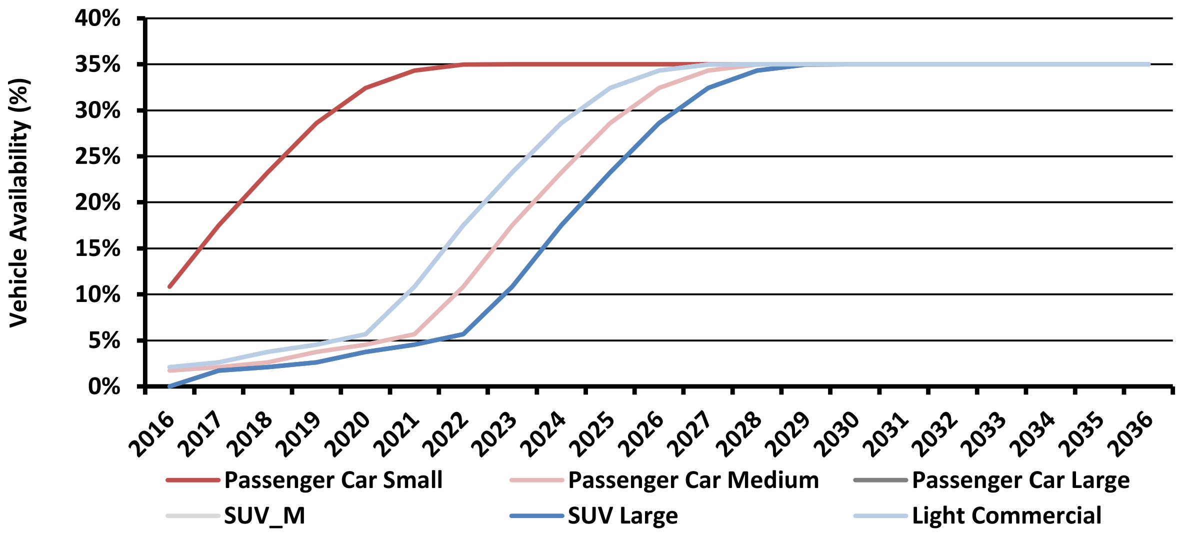
Source: Energeia

Figure 33 – Model Availability Neutral Sensitivity



Source: Energeia

Figure 34 – Model Availability Weak Sensitivity



Source: Energeia

A.2.2 Return on Investment

Return on investment varies over time by model class depending on the differences between equivalent ICE and EV vehicles for capital cost and operational costs as described in Section A.3 and A.4.

A.3 Operation and Maintenance Costs

A.3.1 Electricity Tariffs

The model assumes the EVs are charged either on a control load tariff (home charging mode) or on commercial flat tariff (fleet charging mode). The tariffs described in Table 6 are used in the model and are not sensitivity dependent.

Table 6 – Electricity Tariffs

State	Type of Charging	Tariff Structure	2016 Retail Price ($/kWh)
ACT	Home charging	Control Load	$0.1114
ACT	Fleet charging	Flat	$0.1570
NSW	Home charging	Control Load	$0.0934
NSW	Fleet charging	Flat	$0.2127
QLD	Home charging	Control Load	$0.1605
QLD	Fleet charging	Flat	$0.2224
SA	Home charging	Control Load	$0.1565
SA	Fleet charging	Flat	$0.3110
TAS	Home charging	Control Load	$0.1299
TAS	Fleet charging	Flat	$0.2520
VIC	Home charging	Control Load	$0.1438
VIC	Fleet charging	Flat	$0.2478
WA	Home charging	Control Load	$0.1457
WA	Fleet charging	Flat	$0.2570

A.3.2 Electricity Price

Both the retail and network components of EV charging tariffs are grown over time in the EV uptake model and vary by state and by sensitivity. The model uses the retail electricity price projections developed by Jacobs for the AEMO[4] in real terms.

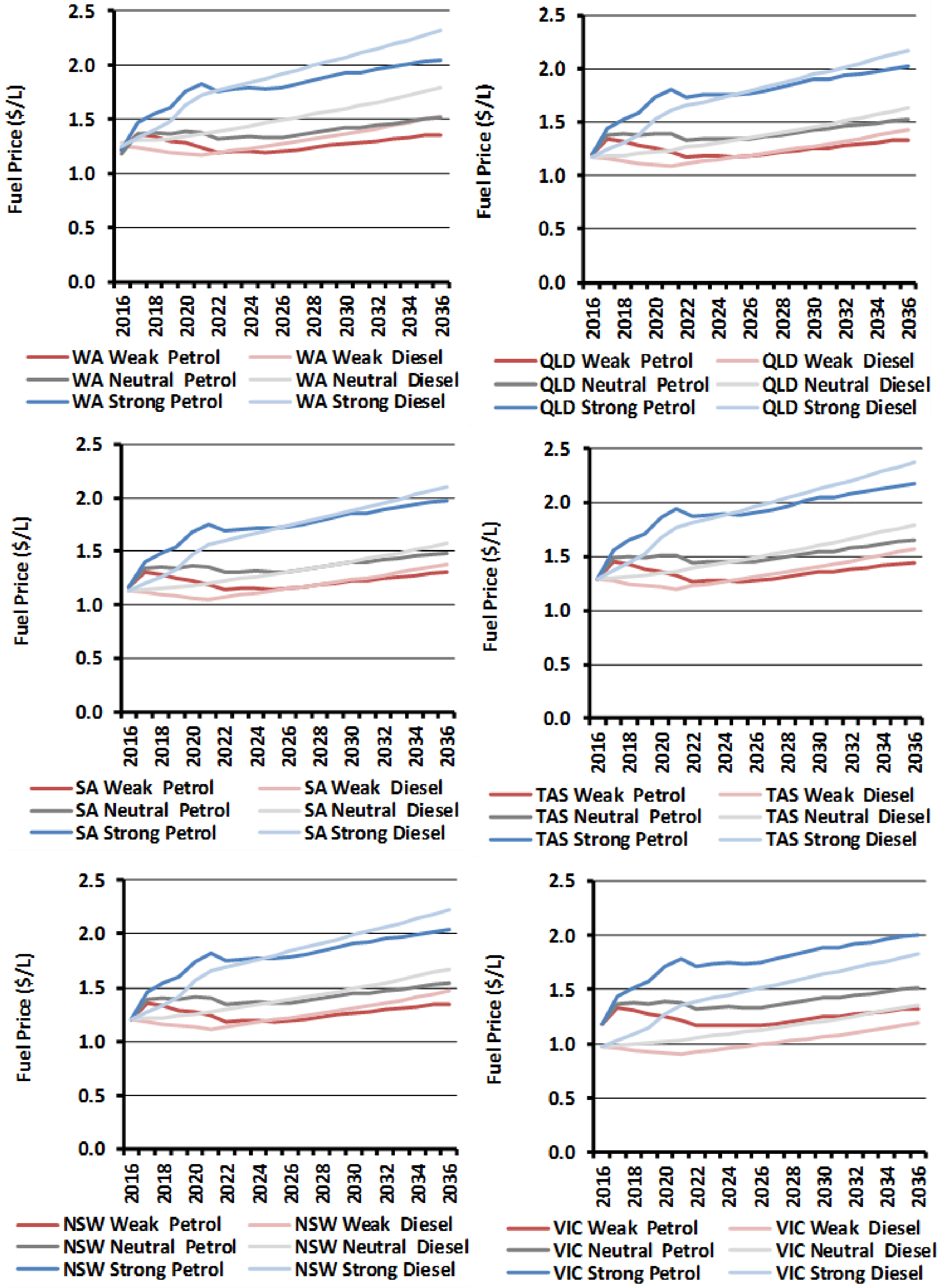
The electricity price trend has a direct impact on EV fuel expenditure.

A.3.3 Fuel Price

Petrol and diesel price growth rates vary by state and by sensitivity as shown in Figure 35. The increase in petrol and diesel prices in 2020 under the strong sensitivity is due to the introduction of a carbon price. The carbon price escalates from \$25/t CO_2e in 2020 to \$50/t CO_2e in 2030. This overall linear trend is reflected in fuel prices.

[4] Jacobs, Retail electricity price history and projections – Public, May 2016

Figure 35 – Fuel Prices



Source: Energeia

A.3.4 Travel Distance

The travel distance dictates energy requirements and therefore has a direct impact on both ICE vehicles and EV annual fuel expenditure. The model adopts an average driving distance in this application to determine annual vehicle costs that vary by state and by vehicle class as summarised in Table 7.

Table 7 – Travel Distance

State	Annual Average Distance Travelled (km/year)	
	Light Passenger	Light Commercial
ACT	13,400	18,000
NSW	13,500	17,200
QLD	12,800	16,300
SA	12,000	14,100
TAS	11,600	12,700
VIC	14,100	15,800
WA	12,000	16,100

Source: ABS Survey of Motor Vehicle Use

A.3.5 Maintenance Costs

The following fixed annual maintenance costs are assumed in the model:

- **PHEV –** $640 per annum
- **BEV –** $380 per annum
- **ICE Vehicle –** $750 per annum.

The above costs were estimated through a bottom up approach based on the relative size of the ICE and battery engine and have a direct impact on EV premium operational expenditures.

A.4 Capital Cost

The vehicle purchase price is broken down into three components in the model as shown in Table 8.

Table 8 – Capital Cost

Cost Component	ICE	BEV	PHEV
Balance of System	✓	✓	✓
Battery		✓	✓
PHEV Premium			✓

Each of the above components is described in the following sections.

A.4.1 Balance of System Cost

The balance of system of a vehicle encompasses all the components of the vehicle other than the EV batteries and the PHEV second engine (i.e. EV engine).

The model assumes the balance of system costs described in Table 9 in 2016. These costs do not vary with sensitivity or the state and grow over time with the Australian transport Consumer Price Index (CPI).

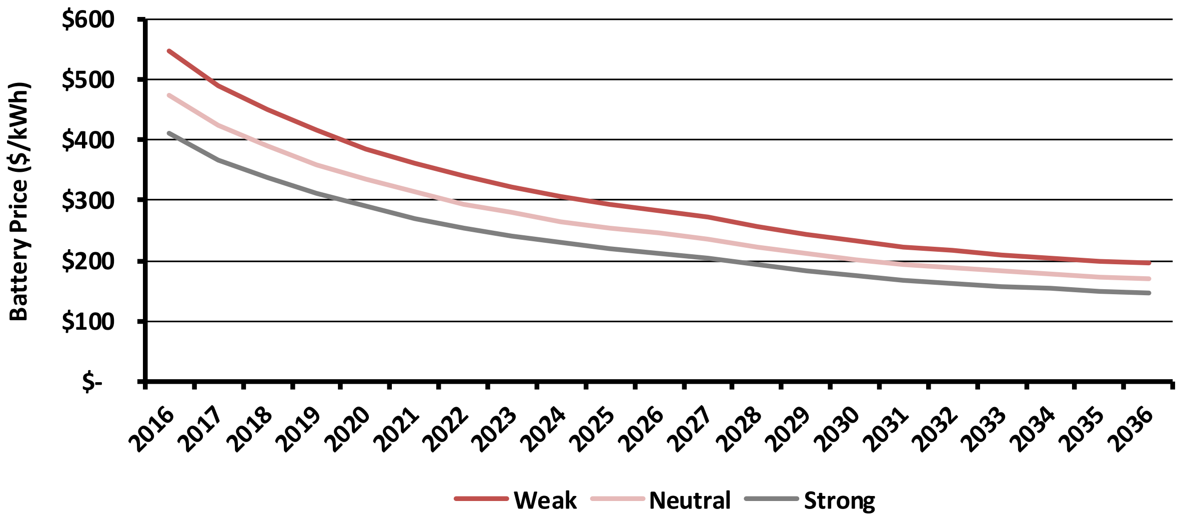
Table 9 – Balance of System Cost

Vehicle Class	ICE	BEV	PHEV
Passenger Car Large	$ 39,000	$ 44,761	$ 43,274
Passenger Car Medium	$ 28,990	$ 32,874	$ 32,603
Passenger Car Small	$ 19,790	$ 31,958	$ 23,422
Sport Utility Vehicle Medium	$ 32,990	$ 52,590	$ 47,478
Sport Utility Vehicle Large	$ 54,990	$ 147,171	$ 68,211
Light Commercial	$ 23,990	$ 24,081	$ 28,718

A.4.2 Battery Cost

The battery price is a direct function of the lithium price. The model assumes a decline in lithium price over the modelling period leading to the battery cost projection shown in Figure 36. The battery price varies with the sensitivity.

Figure 36 – Lithium Price



Source: Jacobs

A.4.3 PHEV Premium

The PHEV premium is the cost of a PHEV second engine (i.e. electric engine). These costs are estimated with the BEV balance of system cost (i.e. the electric engine represents around 9% of a BEV balance of system cost). This input is fixed across all sensitivities.

A.5 EV Charging

The EV charging profile is determined by aggregating the unique charging profile of each individual electric vehicle adopted. The individual profiles are assigned based on:

- Whether the vehicle is assigned as home charging or fleet charging (charges at work or depot location)
- The daily travel distance for both weekday and weekend travel (drawn from a database of regionally specific diversified travel distances) which determines when the amount of charge to be supplied by day type

- An arrival time for both weekday and weekend travel (drawn from a database of diversified times specific to either home charging or fleet charging) which dictates when charging starts, in the absence of any other tariff restrictions
- A departure time for both weekday and weekend travel (drawn from a database of diversified times specific to either home charging or fleet charging) which dictates when charging must cease in the absence of any other tariff restrictions
- The prevailing tariff and the extent to which it restricts or incentivises charging during certain times. For home charging this is assumed to be the existing controlled load tariff specific to each region generally allowing for charging overnight only, and for fleet charging this is assumed to be the standard business tariff specific to each region without charging restrictions

A.5.1 Type of Charging

A vehicle can be assigned to either a home charging mode or a fleet charging mode. The model assumes:

- 100% of the residential EV fleet charges at home
- 90% of the commercial EV fleet charges at home and the remaining 10% charges at work (i.e. fleet charging)
- 90% of the government EV fleet charges at home and the remaining 10% charges at work (i.e. fleet charging.

A.5.2 Vehicle Charging Parameters

Vehicle specific parameters which dictate charging times and rates are shown in Table 10 below.

Table 10 – Vehicle Charging Parameters

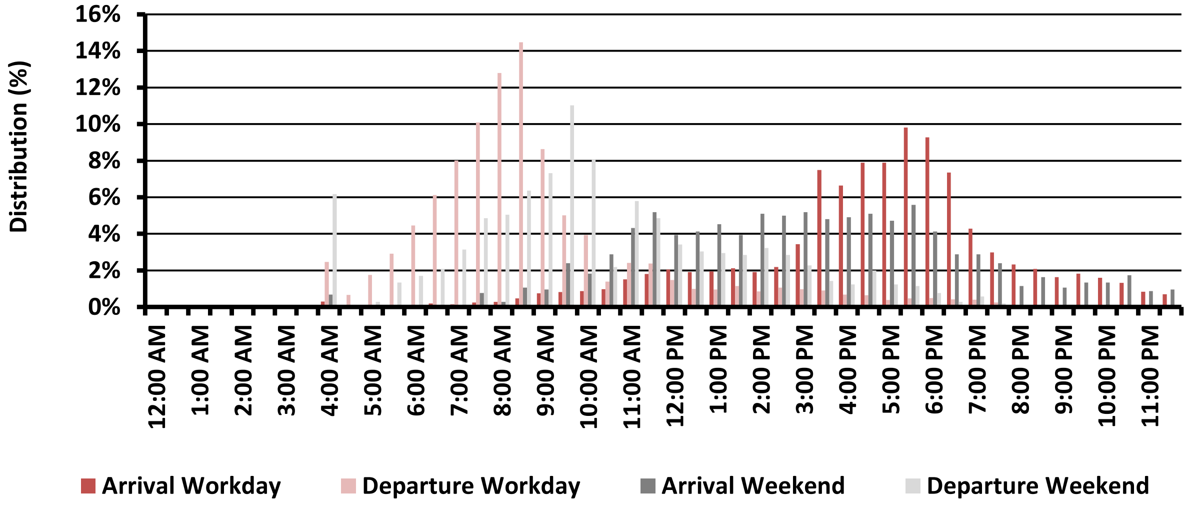
Engine type	Vehicle class	Battery size (kWh)	% km ICE	Charge Rate
BEV	Passenger Car – Small	24	-	3.7 kW
	Passenger Car - Medium	50	-	3.7 kW
	Passenger Car - Large	70	-	3.7 kW
	SUV- Medium	50	-	3.7 kW
	SUV - Large	75	-	3.7 kW
	Light Commercial	23	-	3.7 kW
PHEV	Passenger Car – Small	24	59%	3.7 kW
	Passenger Car - Medium	50	59%	3.7 kW
	Passenger Car - Large	70	59%	3.7 kW
	SUV- Medium	50	57%	3.7 kW
	SUV - Large	75	70%	3.7 kW
	Light Commercial	23	83%	3.7 kW

A.5.3 Home Based Charging Start Times

The home based charging start time is determined by arrival times and the restrictions of the controlled load tariffs.

The model uses the arrival time distribution shown in Figure 37.

Figure 37 – Arrival and Departure Time Distribution



Source: Queensland Household Travel Survey

However, EVs arriving home before the controlled load start hour are not permitted to charge until such time as the controlled load tariff commences. All EVs that have arrived home before the start time are assigned to a controlled load "channel" with charging commencing when each channel opens, staggered by half-hourly intervals.

The control load hours and minimum service requirements assumed in the model are described in Table 11.

Table 11 – Control Load Tariffs

State	CL – Start Hour	CL – End Hour	Minimum Hours of Service
VIC	8:00 PM	7:00 AM	9
ACT	10:00 PM	7:00 AM	7.5
NSW	10:00 PM	7:00 AM	7.5
WA	9:00 PM	7:30 AM	6.5
QLD	10:00 PM	7:00 AM	8
SA	11:00PM	7:00 AM	6
TAS	4:30 PM	11:30 AM	5.5

Source: DNSP Pricing Proposals (Various), Australian Energy Regulator

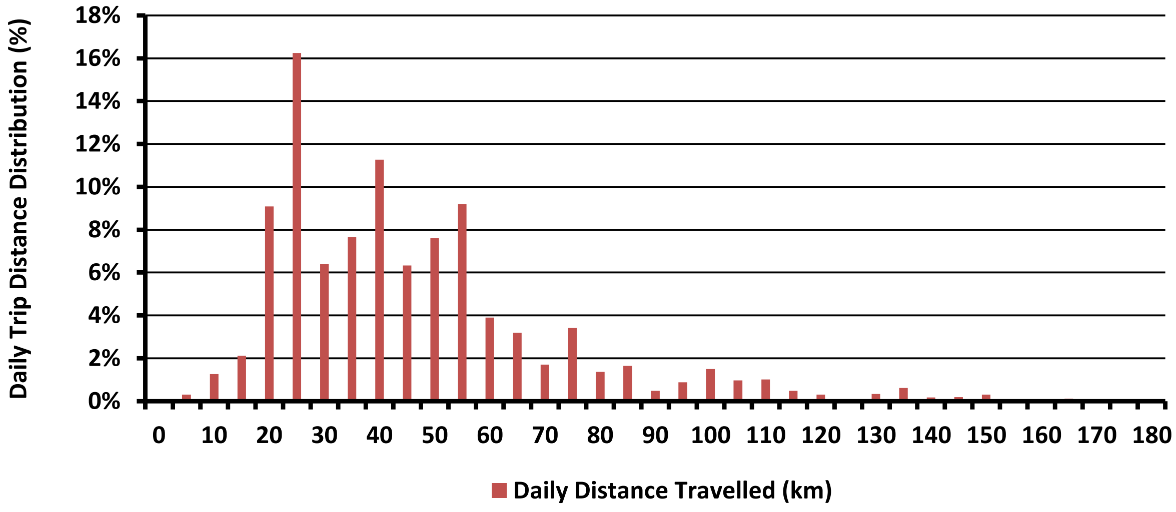
A.5.4 Home Based Charging Completion Times

The home based charging completion time depends upon the end hour of the controlled load tariff (as per Table 11) and/or amount of charge required which is in turn dependent on the daily driving distance.

For the purposes of determining the charging profile, it is assumed that the daily travel distance varies between vehicles using a distribution profile derived from the Queensland Household Travel Survey. The vehicle charging will be complete, once the vehicle is fully charged or once the controlled load tariff end time is reached, whichever occurs soonest.

The distribution of daily distance shown in Figure 38 is scaled down (or up) for each vehicle class and state average travelled distances.

Figure 38 – Daily Trip Distance Distribution



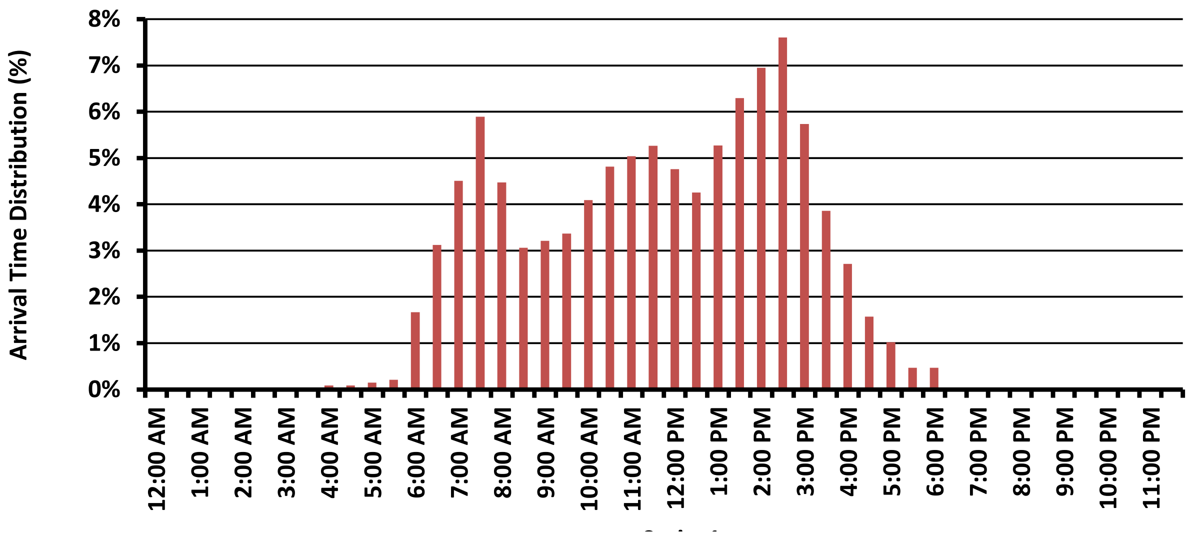
Source: Queensland Household Travel Survey

A.5.5 Fleet Based Charging Times

EV fleet charging of a vehicle starts as soon as the vehicle arrives at the charging depot and is only completed once it reaches full charge.

The charging start time is based on the arrival time distribution for commercial vehicles taken from the Victorian EV Trial in Australia and is shown in Figure 39.

Figure 39 – Arrival Time Distribution



Source: Victorian Department of Economic Development, Jobs, Transport and Resources

The distribution of daily distances under the fleet charging mode is identical to the home charging mode.

A.6 Vehicle Stock Model

The vehicle stock model uses the following approach to determine overall change in stock for each state.

$$ICE_t = \sum^{i,j} \Bigg[ICE_{i,j(t-1)} + (1 - EV\ Uptake_{i,j(t)}) \times Vehicle\ Sales_{i,j(t)} - \text{if}\left(t \le AvgLifetime\ , \frac{ICE_{i,j(0)}}{AvgLifetime}, 0\right) - \sum_{k=0}^{t} [(1 - EV\ Uptake_{i,j(t-k)}) \times Vehicle\ Sales_{i,j(t-k)} \times Failure\ Rate_k] \Bigg]$$

$$EV_t = \sum^{i,j} \Bigg[EV_{i,j(t-1)} + EV\ Uptake_{i,j(t)} \times Vehicle\ Sales_{i,j(t)} - \text{if}\left(t \le AvgLifetime\ , \frac{EV_{i,j(0)}}{AvgLifetime}, 0\right) - \sum_{k=0}^{t} [EV\ Uptake_{i,j(t-k)} \times Vehicle\ Sales_{i,j(t-k)} \times Failure\ Rate_k] \Bigg]$$

Where:

- ICE_t = Total stock of ICE vehicles in year t
- EV_t= Total stock of EV vehicles in year t
- ICE_0 = Opening stock of ICE vehicles
- EV_0 = Opening stock of EV vehicles
- $ICE_{i,j(t-1)}$ = Stock of ICE vehicles in market i in class j in year t-1
- $EV_{i,j(t-1)}$ = Stock of EV vehicles in market i in class j in year t-1
- EV $Uptake_{i,j(t)}$ = % EV sales in market i in class j in year t
- Vehicle $Sales_{i,j(t)}$ = Vehicle sales in market i in class j in year t
- Failure $Rate_k$ = Probability a vehicle fails at age k from failure rate function

- Average Lifetime = Mean age of failure derived from failure rate function

A.6.1 Opening Stock

The opening stock of vehicles by vehicle class is sourced from VFACTS data for the calendar year 2015[5] for both EV and ICE vehicles for each state. The opening stock feeds into the vehicle stock model at t=0 in the above equations.

A.6.2 Market Growth

Each year, each of the vehicle classes in each vehicle market is assumed to grow at a constant rate per capita based on growth observed over the last five years[5]. This allows for observed trends such as decline in the large passenger car vehicle to be reflected in the results.

Population growth data is taken from ABS.

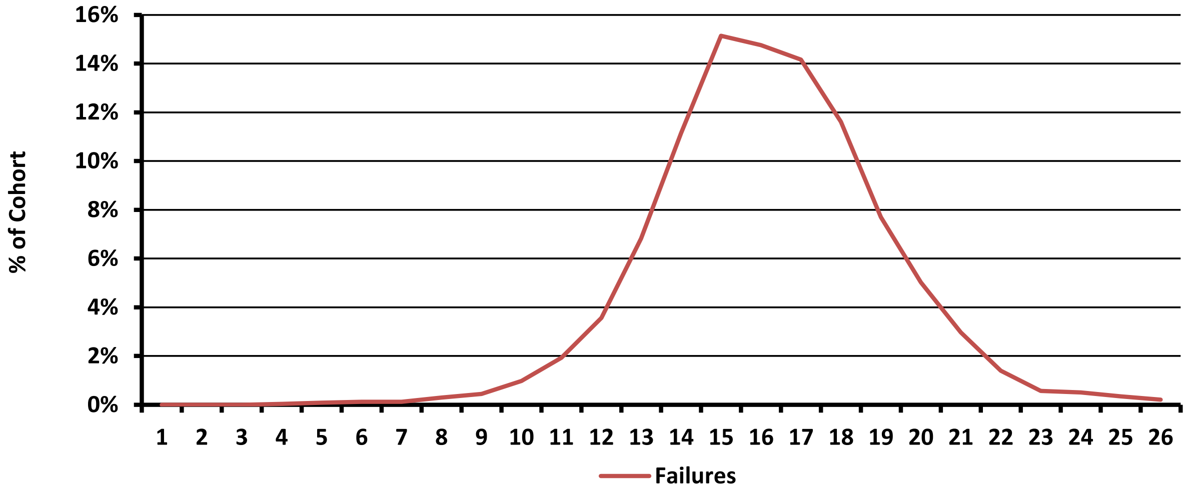
A.6.3 Average Lifetime

Average vehicle lifetime of all vehicles is assumed to be 16.2 years[6].

.A.6.4 Failure Rate

The assumed failure rate for new vehicles relative to purchase date is shown in Figure 40.

Figure 40 – Failure Rate



Source: Ricardo-AEA Ltd

[5] Federal Chamber of Automotive Industry, VFACTS December National Report, 2015

[6] Ricardo-AEA Ltd, Report for European Commission – DG Climate Action, Improvements to the definition of lifetime mileage of light duty vehicles, 2015 <http://ec.europa.eu/clima/policies/transport/vehicles/docs/ldv_mileage_improvement_en.pdf>

A.7 Policy Settings

The various policy settings impact model availability, return on investment and/or shift the uptake curve directly.

A.7.1 Fuel Efficiency Standards (Fleet)

The policy introduces fuel efficiency standards to improve the fuel efficiency of Australia's light vehicle fleet and bring Australia into line with international standards reducing greenhouse gas emissions from all light vehicles from the current 192gCO2/km to 105gCO2/km. The standards are assumed mandatory on a fleet basis. That is the 105g/CO2/km must be met across Australia's light vehicle fleet rather than a minimum performance for individual vehicles based on the improved economic efficiency of such a policy.

The policy both increases the average upfront cost of an ICE vehicle and PHEV their PHEV fuel expenditures.

Given an OEM has to comply with the standards on a fleet basis, it is assumed that selling an EV can save an OEM the cost of upgrading some of its ICE vehicles and that is passed onto the EV purchases as a reduced premium improving the ROI. The reduced premium for BEV and PHEV depends on the percentage the vehicle improves the greenhouse gas intensity compared to a 2016 ICE vehicle. Therefore, the reduction in EV premium depends on the emission intensity of the grid, which differs by state.

The policy key assumptions are described in Table 12 and vary with the sensitivities.

Table 12 – Fuel Efficiency Standards Key Assumptions

Assumption	Weak Sensitivity	Neutral Sensitivity	Strong Sensitivity
Standard introduction date	2030	2026	2022
ICE and PHEV cost increase	$1,500	$1,500	$1,500
Annual rate reduction in greenhouse gas emissions	7% over 7 years	7% over 7 years	7% over 7 years

A.7.2 Priority Lanes

The policy allows the EV drivers to use existing bus priority lanes and dedicated free parking spaces created in Australian capital cities' central business district and high-density suburbs.

A Californian survey indicates that vehicle lane privileges can be a primary motivation for purchasing for 17% of buyers. This shows that priority lanes can act as a strong incentive and directly increase EV uptake. The EV uptake improvement factor has been scaled down for each state based on Los Angeles and Australian capital city congestion metrics.

The policy assumptions are described in Table 13 and vary with the sensitivities.

Table 13 – Priority Lanes Key Assumptions

Assumption	Weak Sensitivity	Neutral Sensitivity	Strong Sensitivity
Policy introduction date	-	2017	2017
ACT increase factor	-	3%	3%
NSW increase factor	-	12%	12%
QLD increase factor	-	3%	3%
SA increase factor	-	3%	3%
TAS increase factor	-	5%	5%
VIC increase factor	-	5%	5%
WA increase factor	-	3%	3%

Source: Energeia, based on congestion model from: https://www.tomtom.com/en_au/trafficindex/list

A.7.3 Carbon Price

The policy introduces a carbon price that is applied to petrol prices. This policy increases the operational cost of ICE vehicles and has an impact of EV uptake by improving EV ROI.

The policy is only modelled under the strong sensitivity, detailed assumptions are described in Table 14.

Table 14 – Carbon Price Assumptions

Assumption	Weak Sensitivity	Neutral Sensitivity	Strong Sensitivity
Policy introduction date	-	-	2020
2020 carbon price ($/tCO2e)	-	-	$25/t CO2-e in 2020 escalating to $50/t CO2-e in 2030

Appendix B: Detailed Results

B.1 EV Uptake

State	Scenario	Chart	Data	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
QLD	Strong	EV Uptake	EV on Road (%)	0.0%	0.2%	0.4%	0.8%	1.3%	2.1%	3.5%	5.1%	7.0%	8.9%	10.9%	12.9%	15.0%	17.4%	20.2%	23.3%	25.3%	27.3%	29.3%	31.3%	33.3%
			EV on Road (#)	1,246	5,919	13,836	28,312	46,707	72,538	122,466	180,380	246,180	316,190	388,649	462,274	537,662	622,828	717,889	815,513	913,094	1,009,533	1,103,678	1,194,295	1,279,841
		EV Sales	EV Sales (%)	0.4%	2.1%	3.5%	6.4%	8.1%	11.3%	21.9%	25.2%	28.4%	30.1%	31.0%	31.3%	32.0%	36.0%	40.3%	41.7%	42.3%	42.8%	43.4%	44.0%	44.5%
			EV Sales (#)	852	4,700	7,945	14,506	18,424	25,864	50,185	58,182	66,091	70,330	72,837	74,123	76,076	86,223	96,840	100,680	102,681	104,551	106,436	108,430	110,371
	Neutral	EV Uptake	EV on Road (%)	0.0%	0.1%	0.2%	0.4%	0.6%	0.9%	1.3%	1.8%	2.5%	3.2%	4.5%	5.7%	7.1%	8.4%	9.9%	11.5%	12.5%	13.6%	14.9%	16.3%	17.8%
			EV on Road (#)	741	2,857	6,597	13,291	21,357	32,258	46,325	64,329	86,706	112,546	158,442	204,840	252,027	300,071	349,184	397,941	445,853	497,788	553,395	612,931	676,191
		EV Sales	EV Sales (%)	0.2%	1.0%	1.7%	3.0%	3.6%	4.8%	6.2%	7.9%	9.7%	11.2%	19.9%	20.0%	20.3%	20.7%	21.2%	21.2%	21.1%	23.2%	25.4%	27.7%	30.2%
			EV Sales (#)	347	2,142	3,767	6,722	8,094	10,930	14,099	18,041	22,423	25,900	46,188	46,738	47,628	48,673	50,090	50,320	50,353	55,669	61,029	66,938	73,093
	Weak	EV Uptake	EV on Road (%)	0.0%	0.0%	0.1%	0.2%	0.2%	0.4%	0.5%	0.7%	0.9%	1.2%	1.5%	1.9%	2.3%	2.7%	3.8%	4.9%	5.7%	6.6%	7.5%	8.4%	9.3%
			EV on Road (#)	400	1,052	2,496	5,238	8,468	12,260	17,295	23,962	32,561	42,776	54,415	67,236	81,182	96,190	131,334	167,095	203,182	239,564	275,907	312,451	348,924
		EV Sales	EV Sales (%)	0.0%	0.3%	0.7%	1.2%	1.5%	1.7%	2.2%	2.9%	3.8%	4.5%	5.1%	5.6%	6.1%	6.5%	15.3%	15.6%	15.9%	16.1%	16.3%	16.7%	17.0%
			EV Sales (#)	6	678	1,471	2,768	3,257	3,818	5,063	6,696	8,631	10,252	11,684	12,884	14,041	15,164	35,678	36,521	37,172	37,959	38,552	39,517	40,349
NSW + ACT	Strong	EV Uptake	EV on Road (%)	0.1%	0.3%	0.6%	1.2%	1.9%	2.9%	4.6%	6.6%	8.8%	11.1%	13.4%	15.7%	18.0%	20.7%	23.6%	26.9%	28.8%	30.8%	32.9%	35.0%	36.9%
			EV on Road (#)	2,769	13,070	30,457	62,000	101,486	154,631	250,095	359,288	481,842	611,337	745,003	880,347	1,017,904	1,168,581	1,327,857	1,488,352	1,647,803	1,804,002	1,954,873	2,098,253	2,231,600
		EV Sales	EV Sales (%)	0.6%	2.9%	4.8%	8.7%	10.8%	14.5%	26.4%	30.0%	33.4%	35.2%	36.2%	36.6%	37.2%	40.7%	43.3%	44.2%	44.9%	45.5%	46.2%	46.9%	47.5%
			EV Sales (#)	2,184	10,352	17,448	31,628	39,573	53,253	96,147	109,859	123,224	130,213	134,469	136,339	138,931	152,815	162,929	166,837	170,115	173,096	176,150	179,349	182,484
	Neutral	EV Uptake	EV on Road (%)	0.0%	0.1%	0.3%	0.6%	0.9%	1.4%	1.9%	2.6%	3.4%	4.3%	5.8%	7.3%	8.9%	10.5%	12.2%	14.0%	15.1%	16.3%	17.7%	19.2%	20.8%
			EV on Road (#)	1,595	6,767	15,560	30,750	49,233	73,140	102,855	140,097	185,539	237,460	324,339	411,987	500,703	590,543	681,559	771,361	858,982	951,395	1,047,792	1,148,244	1,251,212
		EV Sales	EV Sales (%)	0.3%	1.5%	2.5%	4.2%	5.1%	6.6%	8.2%	10.2%	12.4%	14.1%	23.7%	23.9%	24.2%	24.5%	24.9%	24.9%	24.8%	26.7%	28.7%	30.8%	32.6%
			EV Sales (#)	1,010	5,219	8,846	15,255	18,547	23,981	29,801	37,343	45,566	52,082	87,626	88,503	89,799	91,352	93,321	93,432	93,225	100,861	108,396	116,591	124,015
	Weak	EV Uptake	EV on Road (%)	0.0%	0.0%	0.1%	0.2%	0.4%	0.5%	0.7%	1.0%	1.3%	1.6%	2.0%	2.4%	2.9%	3.4%	4.5%	5.6%	6.5%	7.3%	8.2%	9.0%	9.9%
			EV on Road (#)	775	2,509	5,878	11,867	18,835	27,227	37,920	51,659	68,991	89,270	112,124	137,040	163,864	192,459	250,848	309,412	367,631	425,265	481,778	537,306	591,330
		EV Sales	EV Sales (%)	0.1%	0.5%	0.9%	1.7%	1.9%	2.3%	3.0%	3.8%	4.7%	5.5%	6.2%	6.8%	7.3%	7.8%	16.0%	16.1%	16.2%	16.3%	16.3%	16.4%	16.5%
			EV Sales (#)	190	1,774	3,408	6,028	7,008	8,432	10,735	13,784	17,386	20,343	22,939	25,041	27,024	28,941	59,593	60,271	60,650	61,109	61,306	61,874	62,171
VIC	Strong	EV Uptake	EV on Road (%)	0.0%	0.2%	0.5%	1.0%	1.6%	2.3%	3.5%	4.9%	6.3%	7.8%	9.3%	10.7%	12.2%	13.8%	15.6%	17.7%	18.9%	20.3%	21.8%	23.3%	24.7%
			EV on Road (#)	2,016	8,934	20,505	41,422	67,663	103,105	156,581	216,967	283,826	353,323	423,858	493,890	563,137	638,065	718,431	802,012	888,169	975,474	1,062,619	1,148,773	1,232,530
		EV Sales	EV Sales (%)	0.5%	2.4%	4.0%	7.1%	8.9%	11.9%	18.0%	20.1%	22.1%	22.9%	23.2%	22.9%	22.7%	24.6%	26.5%	28.0%	29.6%	31.1%	32.5%	34.0%	35.4%
			EV Sales (#)	1,319	6,967	11,622	20,971	26,296	35,503	53,623	60,530	67,007	69,667	70,760	70,390	69,875	76,124	82,615	87,627	92,967	98,043	103,019	108,302	113,245
	Neutral	EV Uptake	EV on Road (%)	0.0%	0.1%	0.2%	0.5%	0.7%	1.1%	1.5%	2.0%	2.6%	3.4%	4.4%	5.3%	6.3%	7.2%	8.2%	9.2%	9.7%	10.3%	10.9%	11.5%	12.2%
			EV on Road (#)	1,250	4,469	10,083	19,887	31,625	46,757	65,620	89,468	118,893	152,731	198,433	243,733	288,368	331,931	374,100	413,720	450,538	488,041	525,724	563,320	600,241
		EV Sales	EV Sales (%)	0.2%	1.1%	1.9%	3.3%	4.0%	5.1%	6.4%	8.0%	9.8%	11.3%	15.2%	15.0%	14.8%	14.4%	14.1%	13.5%	12.9%	13.6%	14.4%	15.1%	15.8%
			EV Sales (#)	553	3,267	5,663	9,855	11,789	15,186	18,922	23,914	29,505	33,939	45,912	45,569	45,026	44,196	43,267	41,524	39,930	42,355	44,761	47,299	49,689
	Weak	EV Uptake	EV on Road (%)	0.0%	0.0%	0.1%	0.2%	0.3%	0.4%	0.6%	0.7%	1.0%	1.3%	1.6%	1.9%	2.3%	2.7%	3.3%	3.9%	4.3%	4.7%	5.0%	5.3%	5.6%
			EV on Road (#)	737	1,760	3,928	7,900	12,527	17,824	24,501	33,131	44,181	57,282	72,224	88,683	106,539	125,687	151,719	176,406	199,670	221,161	240,681	258,150	273,325
		EV Sales	EV Sales (%)	0.0%	0.4%	0.8%	1.4%	1.6%	1.8%	2.3%	2.9%	3.7%	4.4%	5.0%	5.5%	6.0%	6.4%	8.7%	8.4%	8.0%	7.6%	7.2%	6.9%	6.5%
			EV Sales (#)	41	1,069	2,214	4,019	4,673	5,344	6,725	8,680	11,105	13,164	15,017	16,559	18,003	19,386	26,510	25,461	24,465	23,353	22,213	21,131	19,944
SA	Strong	EV Uptake	EV on Road (%)	0.1%	0.2%	0.4%	0.8%	1.2%	1.8%	3.2%	4.8%	6.7%	8.8%	11.0%	13.3%	15.8%	18.5%	21.4%	24.8%	26.5%	28.3%	30.2%	32.1%	33.9%
			EV on Road (#)	1,025	2,656	5,227	9,590	14,610	21,444	37,302	55,691	76,760	99,425	123,458	148,605	173,968	199,850	226,103	252,407	278,636	304,441	329,499	353,435	375,715
		EV Sales	EV Sales (%)	0.3%	2.6%	3.9%	6.6%	7.6%	10.3%	23.9%	27.6%	31.4%	33.7%	35.6%	37.2%	37.5%	38.3%	39.0%	39.6%	40.2%	40.8%	41.4%	42.0%	42.7%
			EV Sales (#)	227	1,685	2,626	4,418	5,076	6,892	16,103	18,636	21,316	22,919	24,299	25,439	25,708	26,332	26,923	27,366	27,872	28,350	28,836	29,369	29,883
	Neutral	EV Uptake	EV on Road (%)	0.1%	0.1%	0.2%	0.4%	0.5%	0.8%	1.1%	1.5%	2.0%	2.6%	3.9%	5.3%	6.9%	8.6%	10.7%	13.2%	14.8%	16.5%	18.1%	19.8%	21.5%
			EV on Road (#)	887	1,438	2,470	4,334	6,526	9,373	12,958	17,455	22,991	29,329	43,957	59,166	75,446	93,138	112,953	134,236	155,267	176,188	196,892	217,301	237,290
		EV Sales	EV Sales (%)	0.1%	0.9%	1.6%	2.9%	3.4%	4.3%	5.4%	6.8%	8.3%	9.5%	22.0%	22.9%	24.5%	26.6%	29.7%	32.0%	31.9%	32.2%	32.4%	32.7%	33.0%
			EV Sales (#)	89	605	1,086	1,918	2,247	2,903	3,641	4,555	5,597	6,403	14,919	15,532	16,663	18,129	20,333	21,954	21,894	22,119	22,342	22,574	22,803
	Weak	EV Uptake	EV on Road (%)	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.6%	0.8%	1.0%	1.2%	1.5%	1.8%	2.2%	3.7%	5.2%	6.5%	7.6%	8.8%	10.0%	11.1%
			EV on Road (#)	800	915	1,264	1,983	2,833	3,809	5,030	6,612	8,644	11,062	13,824	16,870	20,181	23,738	38,483	52,992	67,306	81,326	95,021	108,366	121,329
		EV Sales	EV Sales (%)	0.0%	0.3%	0.6%	1.2%	1.4%	1.5%	1.9%	2.4%	3.1%	3.7%	4.2%	4.6%	5.0%	5.4%	22.4%	22.1%	21.8%	21.6%	21.3%	21.0%	20.8%
			EV Sales (#)	2	168	403	772	903	1,029	1,274	1,636	2,087	2,474	2,821	3,108	3,382	3,645	15,216	15,032	14,871	14,701	14,536	14,379	14,219

Source: Energeia

State	Scenario	Chart	Data	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
TAS	Strong	EV Uptake	EV on Road (%)	0.0%	0.2%	0.5%	0.9%	1.3%	1.9%	3.8%	6.0%	8.4%	11.0%	13.8%	16.7%	19.8%	23.2%	27.1%	31.7%	33.7%	36.0%	38.4%	40.7%	43.0%
			EV on Road (#)	129	811	1,803	3,344	4,900	7,061	13,573	20,911	28,765	36,874	45,090	53,307	61,464	69,838	78,401	87,039	95,691	104,271	112,659	120,697	128,179
		EV Sales	EV Sales (%)	0.5%	3.9%	5.6%	8.5%	8.6%	11.9%	36.2%	40.6%	43.3%	44.5%	45.1%	45.0%	44.8%	46.0%	47.4%	48.5%	49.7%	50.9%	52.2%	53.5%	54.8%
			EV Sales (#)	85	685	995	1,545	1,560	2,166	6,565	7,390	7,906	8,164	8,275	8,288	8,248	8,506	8,777	8,998	9,238	9,487	9,736	9,998	10,266
	Neutral	EV Uptake	EV on Road (%)	0.0%	0.1%	0.2%	0.3%	0.5%	0.8%	1.1%	1.6%	2.2%	2.8%	5.0%	7.4%	9.8%	12.5%	15.4%	18.7%	20.4%	22.3%	24.2%	26.2%	28.2%
			EV on Road (#)	80	270	603	1,189	1,888	2,826	4,023	5,521	7,351	9,433	16,418	23,413	30,368	37,261	44,078	50,764	57,301	63,824	70,295	76,692	82,966
		EV Sales	EV Sales (%)	0.2%	1.1%	1.9%	3.3%	3.9%	5.2%	6.7%	8.3%	10.1%	11.5%	39.0%	39.0%	38.8%	38.5%	38.2%	37.7%	37.3%	37.8%	38.3%	38.9%	39.4%
			EV Sales (#)	36	193	335	590	702	942	1,200	1,502	1,835	2,089	7,073	7,088	7,051	7,003	6,953	6,873	6,800	6,895	6,989	7,094	7,201
	Weak	EV Uptake	EV on Road (%)	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%	0.6%	0.8%	1.1%	1.4%	1.8%	2.2%	2.7%	5.0%	7.6%	9.5%	11.5%	13.4%	15.3%	17.2%
			EV on Road (#)	47	108	238	480	762	1,093	1,529	2,095	2,813	3,655	4,600	5,632	6,743	7,929	14,179	20,343	26,421	32,398	38,265	44,019	49,653
		EV Sales	EV Sales (%)	0.0%	0.4%	0.7%	1.4%	1.6%	1.9%	2.5%	3.2%	4.0%	4.7%	5.3%	5.8%	6.3%	6.7%	35.6%	35.2%	34.9%	34.6%	34.3%	34.0%	33.8%
			EV Sales (#)	3	64	133	245	285	334	439	569	722	846	950	1,038	1,120	1,201	6,369	6,301	6,240	6,180	6,122	6,075	6,033
NEM	Strong	EV Uptake	EV on Road (%)	0.0%	0.2%	0.5%	1.0%	1.6%	2.4%	3.9%	5.6%	7.4%	9.4%	11.4%	13.4%	15.4%	17.7%	20.3%	23.2%	24.9%	26.7%	28.6%	30.4%	32.2%
			EV on Road (#)	7,184	31,389	71,828	144,669	235,365	358,780	580,017	833,237	1,117,372	1,417,148	1,726,058	2,038,422	2,354,135	2,699,161	3,068,680	3,445,323	3,823,393	4,197,721	4,563,328	4,915,453	5,247,865
		EV Sales	EV Sales (%)	0.5%	2.6%	4.2%	7.5%	9.3%	12.6%	22.8%	25.9%	28.8%	30.3%	31.1%	31.4%	31.7%	34.6%	37.2%	38.4%	39.3%	40.2%	41.1%	42.0%	42.9%
			EV Sales (#)	4,667	24,389	40,636	73,068	90,928	123,678	222,625	254,596	285,544	301,293	310,640	314,579	318,838	350,000	378,085	391,508	402,874	413,527	424,177	435,447	446,248
	Neutral	EV Uptake	EV on Road (%)	0.0%	0.1%	0.2%	0.5%	0.8%	1.1%	1.6%	2.1%	2.8%	3.6%	4.9%	6.2%	7.5%	8.9%	10.4%	12.0%	12.9%	14.0%	15.1%	16.4%	17.7%
			EV on Road (#)	4,553	15,801	35,312	69,451	110,629	164,355	231,780	316,869	421,480	541,499	741,588	943,139	1,146,912	1,352,945	1,561,873	1,768,023	1,967,940	2,177,236	2,394,098	2,618,489	2,847,900
		EV Sales	EV Sales (%)	0.2%	1.2%	2.0%	3.5%	4.3%	5.5%	7.0%	8.7%	10.7%	12.2%	20.4%	20.5%	20.7%	20.9%	21.3%	21.2%	21.0%	22.5%	23.9%	25.5%	27.1%
			EV Sales (#)	2,036	11,427	19,698	34,340	41,379	53,941	67,663	85,355	104,925	120,412	201,718	203,430	206,167	209,352	213,963	214,104	212,203	227,899	243,517	260,496	276,800
	Weak	EV Uptake	EV on Road (%)	0.0%	0.0%	0.1%	0.2%	0.3%	0.4%	0.6%	0.8%	1.1%	1.4%	1.7%	2.1%	2.5%	3.0%	3.9%	4.9%	5.7%	6.5%	7.2%	7.9%	8.7%
			EV on Road (#)	2,759	6,344	13,804	27,468	43,426	62,213	86,276	117,459	157,191	204,045	257,187	315,460	378,509	446,003	586,562	726,249	864,210	999,714	1,131,651	1,260,292	1,384,561
		EV Sales	EV Sales (%)	0.0%	0.4%	0.8%	1.4%	1.7%	2.0%	2.5%	3.2%	4.1%	4.8%	5.4%	5.9%	6.4%	6.9%	14.4%	14.4%	14.3%	14.3%	14.2%	14.2%	14.1%
			EV Sales (#)	242	3,753	7,628	13,832	16,126	18,956	24,236	31,366	39,931	47,080	53,411	58,629	63,571	68,335	143,366	143,585	143,398	143,302	142,730	142,975	142,717
WA	Strong	EV Uptake	EV on Road (%)	0.0%	0.2%	0.4%	0.8%	1.3%	2.0%	3.4%	5.0%	6.9%	8.9%	11.0%	13.2%	15.5%	18.1%	21.1%	24.4%	26.3%	28.3%	30.3%	32.3%	34.3%
			EV on Road (#)	726	3,567	8,141	16,001	25,327	38,352	64,830	95,824	131,546	169,933	210,194	251,642	294,661	342,600	393,856	445,468	497,180	548,431	598,633	647,116	693,041
		EV Sales	EV Sales (%)	0.4%	2.5%	3.9%	6.8%	8.0%	11.1%	22.3%	25.9%	29.6%	31.6%	32.9%	33.6%	34.7%	38.5%	41.2%	41.7%	42.4%	43.0%	43.5%	44.2%	44.8%
			EV Sales (#)	487	2,857	4,592	7,879	9,346	13,047	26,688	31,214	35,961	38,639	40,533	41,772	43,442	48,559	52,269	53,323	54,527	55,661	56,799	57,978	59,141
	Neutral	EV Uptake	EV on Road (%)	0.0%	0.1%	0.2%	0.4%	0.6%	0.9%	1.3%	1.8%	2.4%	3.1%	4.5%	5.8%	7.3%	8.8%	10.5%	12.3%	13.4%	14.7%	16.2%	17.9%	19.6%
			EV on Road (#)	443	1,576	3,570	7,057	11,188	16,737	24,109	33,593	45,505	59,336	84,644	110,561	137,273	164,782	193,284	221,958	250,572	281,740	315,382	351,671	389,286
		EV Sales	EV Sales (%)	0.2%	1.0%	1.7%	3.0%	3.6%	4.8%	6.2%	8.0%	10.0%	11.5%	21.1%	21.4%	22.0%	22.6%	23.4%	23.7%	23.9%	26.3%	28.7%	31.5%	33.3%
			EV Sales (#)	204	1,150	2,011	3,505	4,148	5,569	7,392	9,507	11,940	13,868	25,532	26,171	27,028	27,934	29,124	29,616	30,025	33,257	36,576	40,257	42,870
	Weak	EV Uptake	EV on Road (%)	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.5%	0.7%	0.9%	1.2%	1.5%	1.9%	2.3%	2.8%	3.9%	5.2%	6.2%	7.2%	8.3%	9.4%	10.5%
			EV on Road (#)	249	602	1,372	2,781	4,400	6,325	8,965	12,467	17,039	22,502	28,757	35,674	43,216	51,325	71,411	92,221	113,622	135,705	158,289	181,138	204,100
		EV Sales	EV Sales (%)	0.0%	0.3%	0.7%	1.2%	1.4%	1.7%	2.3%	3.0%	3.9%	4.6%	5.3%	5.8%	6.3%	6.7%	16.8%	17.4%	17.9%	18.6%	19.2%	19.7%	20.1%
			EV Sales (#)	10	369	785	1,426	1,635	1,941	2,656	3,519	4,590	5,485	6,281	6,952	7,594	8,194	20,462	21,316	22,085	23,038	23,878	24,559	25,169

Source: Energeia

B.2 EV Consumption

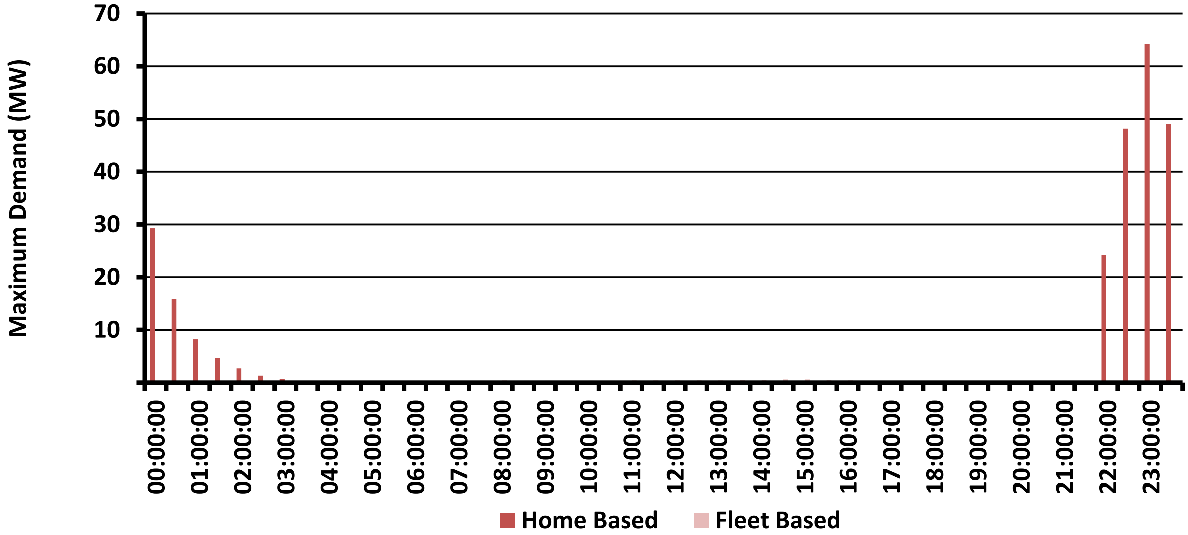
State	Scenario	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
QLD	Weak	498	1,246	3,177	7,072	11,338	16,984	26,648	41,187	61,557	86,841	116,221	148,811	184,330	222,594	316,667	412,305	508,684	605,831	702,852	800,340	897,335
	Neutral	863	3,529	8,599	18,301	29,649	48,690	77,625	118,267	172,208	236,634	355,073	475,092	597,046	721,048	847,705	973,232	1,096,446	1,231,174	1,376,533	1,532,853	1,699,417
	Strong	1,500	9,415	22,712	46,975	75,847	124,140	231,746	366,464	528,145	705,059	890,081	1,078,301	1,270,586	1,488,601	1,730,964	1,977,888	2,225,193	2,470,947	2,713,074	2,949,399	3,176,726
NSW/ACT	Weak	1,012	3,203	7,949	16,865	26,565	40,168	61,150	91,168	132,169	182,224	239,770	302,948	371,087	443,823	597,929	752,577	906,345	1,058,827	1,208,654	1,356,066	1,499,279
	Neutral	1,980	8,920	21,750	45,385	73,603	116,649	177,913	261,784	370,871	499,856	721,586	946,200	1,173,684	1,404,192	1,638,022	1,869,127	2,095,309	2,335,833	2,588,835	2,854,008	3,125,542
	Strong	3,611	20,783	50,537	105,205	169,668	270,000	473,526	724,211	1,021,238	1,344,167	1,681,640	2,024,205	2,371,624	2,750,213	3,146,148	3,545,250	3,944,136	4,339,090	4,726,565	5,102,883	5,462,830
VIC	Weak	1,085	2,391	5,568	11,743	18,440	26,699	39,101	57,009	81,988	113,116	149,519	190,042	234,160	281,565	346,489	407,920	465,695	519,117	567,764	611,407	649,249
	Neutral	1,685	6,152	14,476	29,894	47,653	74,124	111,562	163,291	231,607	313,093	424,317	535,026	643,970	749,995	852,330	948,277	1,037,454	1,129,235	1,222,542	1,316,583	1,409,490
	Strong	2,773	14,916	35,001	71,574	114,369	180,147	288,881	420,867	575,251	740,462	910,349	1,079,400	1,246,080	1,426,949	1,621,658	1,825,120	2,036,353	2,252,437	2,470,488	2,688,458	2,902,027
SA	Weak	941	1,057	1,515	2,521	3,618	4,962	7,003	10,006	14,219	19,499	25,682	32,563	40,065	48,136	82,805	116,848	150,307	183,040	214,994	246,122	276,316
	Neutral	1,031	1,705	3,070	5,673	8,563	13,006	19,473	28,361	40,104	54,056	87,918	123,279	161,186	202,314	248,298	297,392	345,694	393,787	441,492	488,636	534,941
	Strong	1,195	4,509	9,256	16,754	23,995	35,417	66,208	104,531	150,751	201,806	256,555	313,801	371,378	430,038	489,565	549,383	609,355	669,003	727,884	785,602	841,477
TAS	Weak	54	117	271	575	904	1,330	2,020	3,023	4,401	6,085	8,014	10,134	12,421	14,864	28,699	42,356	55,823	69,084	82,119	94,926	107,474
	Neutral	86	299	697	1,443	2,300	3,675	5,689	8,434	12,000	16,192	30,922	45,682	60,335	74,850	89,194	103,269	117,040	130,813	144,532	158,157	171,607
	Strong	142	1,538	3,420	6,070	8,149	11,501	23,627	38,149	54,067	70,711	87,675	104,675	121,562	138,919	156,742	174,856	193,203	211,701	230,210	248,605	266,707
WA	Weak	298	680	1,646	3,523	5,528	8,318	13,260	20,703	31,257	44,426	59,788	76,881	95,543	115,627	168,415	223,159	279,481	337,709	397,309	457,008	516,173
	Neutral	493	1,836	4,381	9,204	14,789	24,141	38,801	59,551	87,415	120,888	184,644	250,156	317,720	387,335	459,540	532,137	604,592	683,988	770,166	863,305	958,237
	Strong	834	6,064	14,105	27,371	41,388	64,788	120,043	190,094	275,532	369,956	470,145	573,502	680,672	799,299	923,770	1,049,117	1,175,071	1,300,675	1,424,899	1,546,610	1,664,191

Source: Energeia

B.3 EV Load Profiles

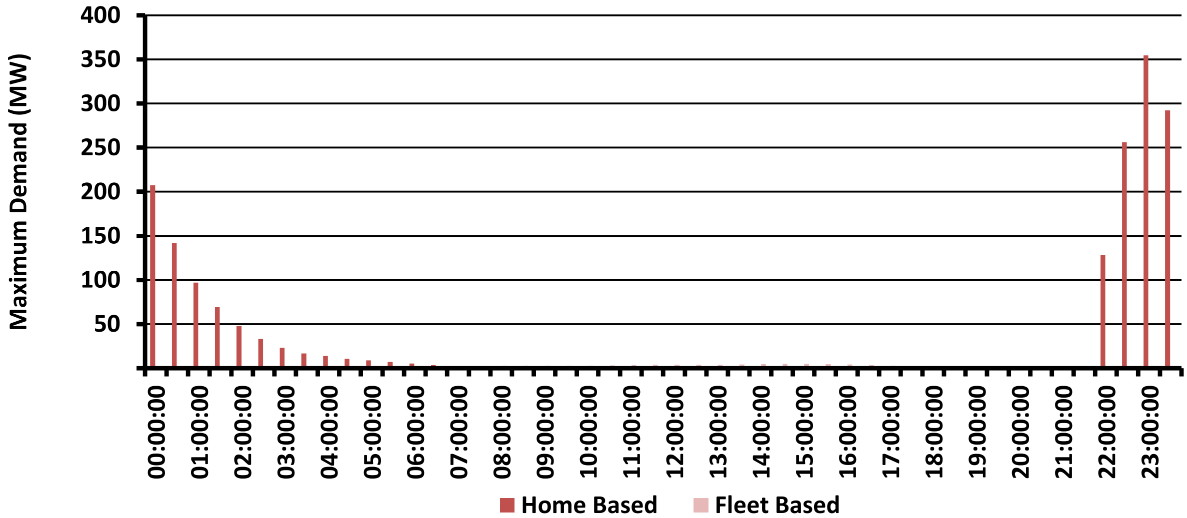
B.3.1 Queensland - Neutral

2020



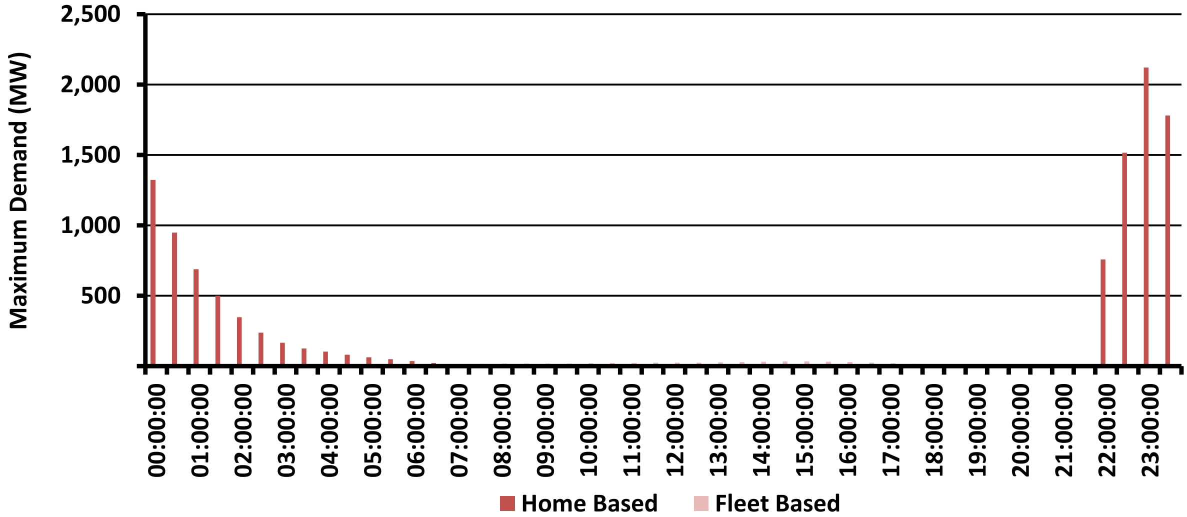
Source: Energeia

2025



Source: Energeia

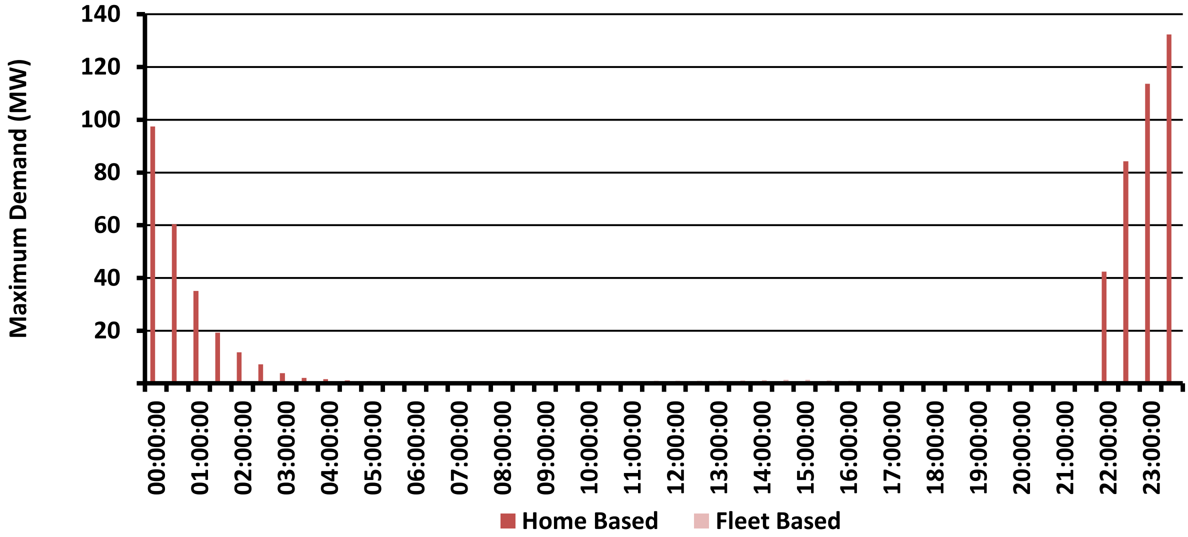
2036



Source: Energeia

B.3.2 New South Wales + ACT - Neutral

2020



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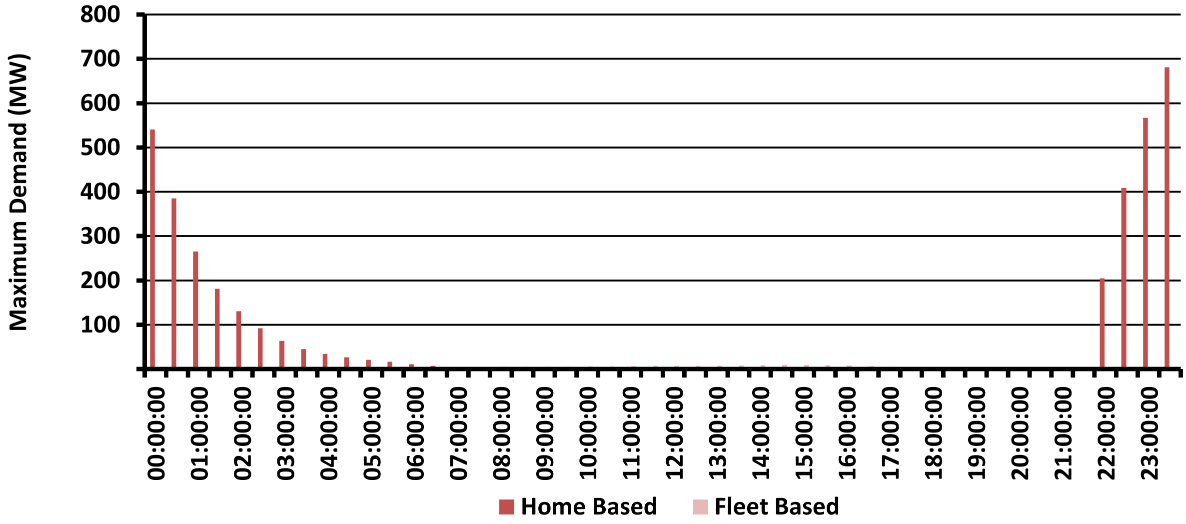
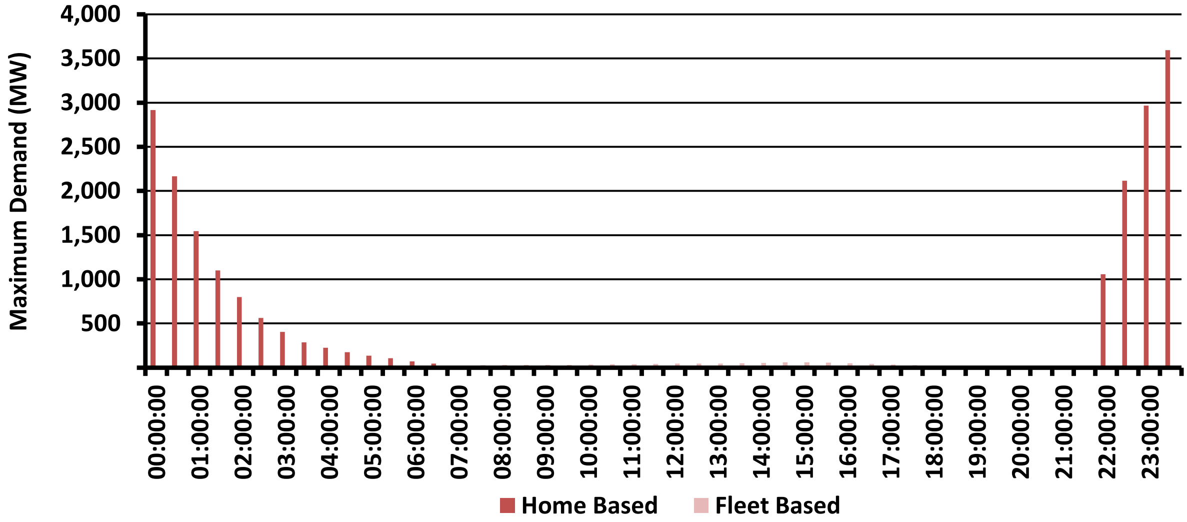
2025



Source: Energeia

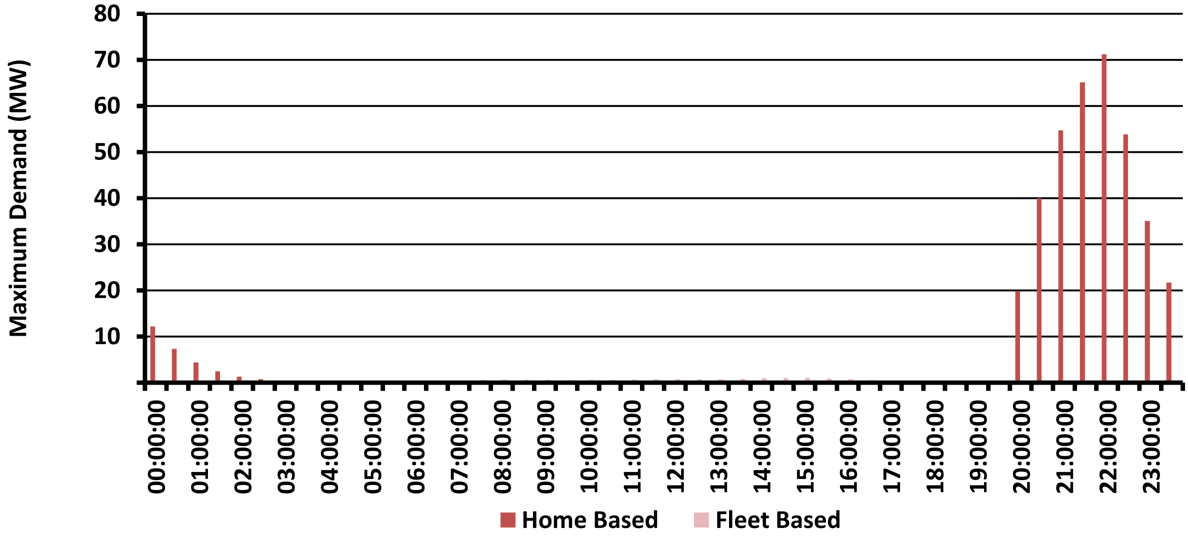
2036



Source: Energeia

B.3.3 Victoria - Neutral

2020



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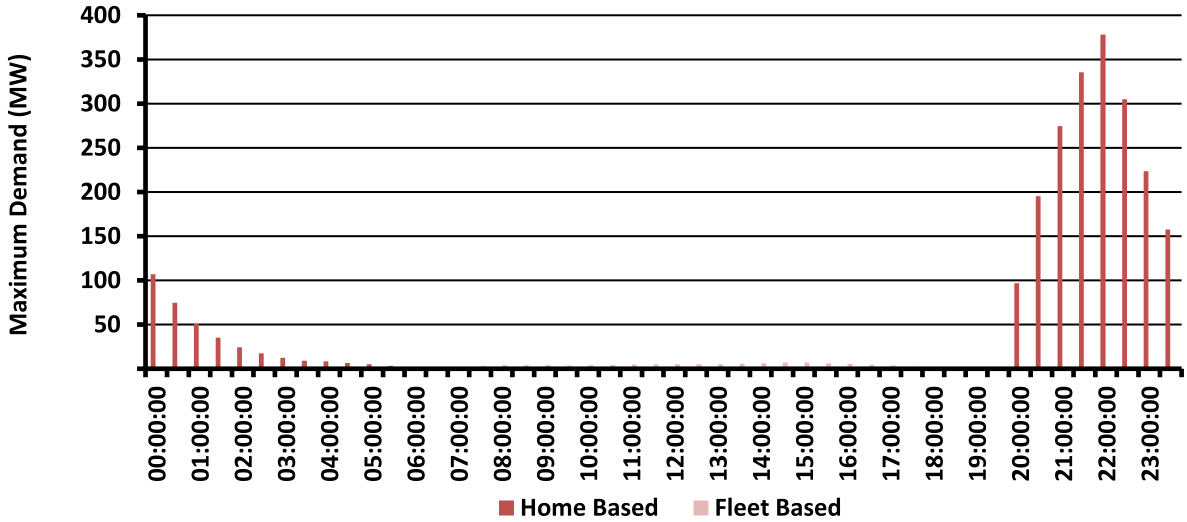
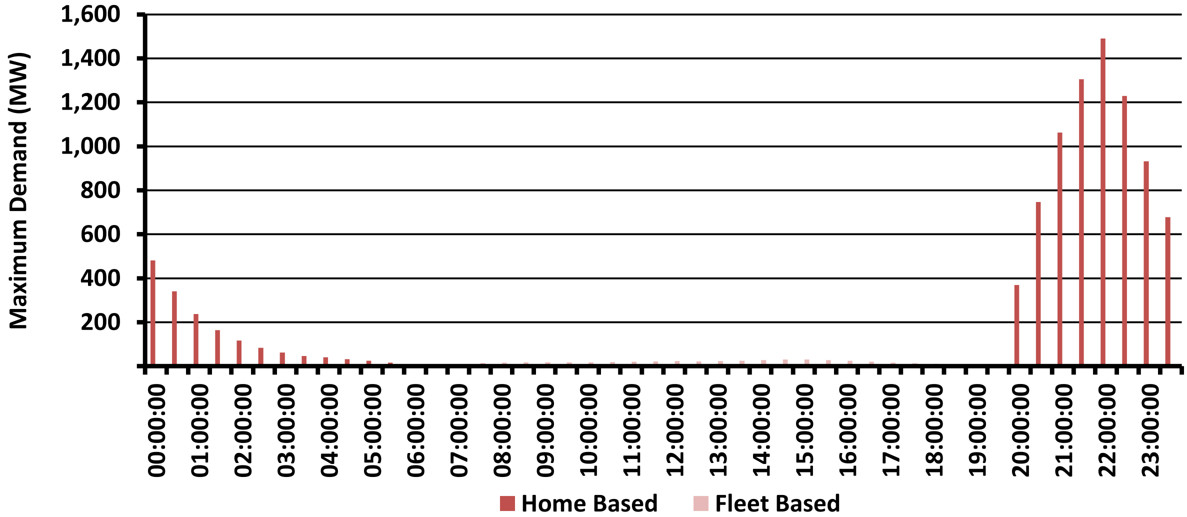
2025



Source: Energeia

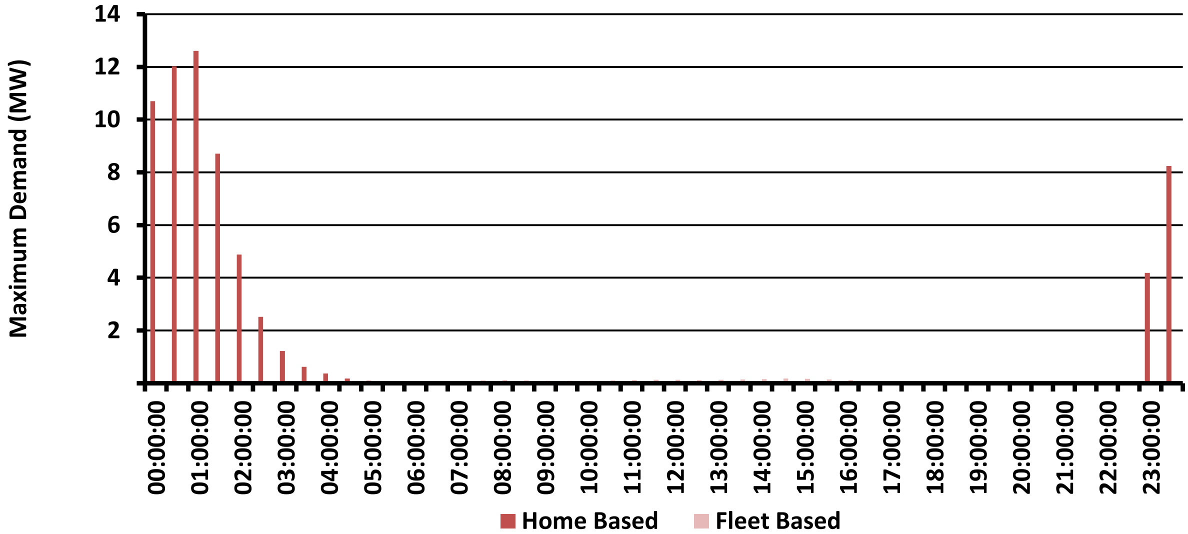
2036



Source: Energeia

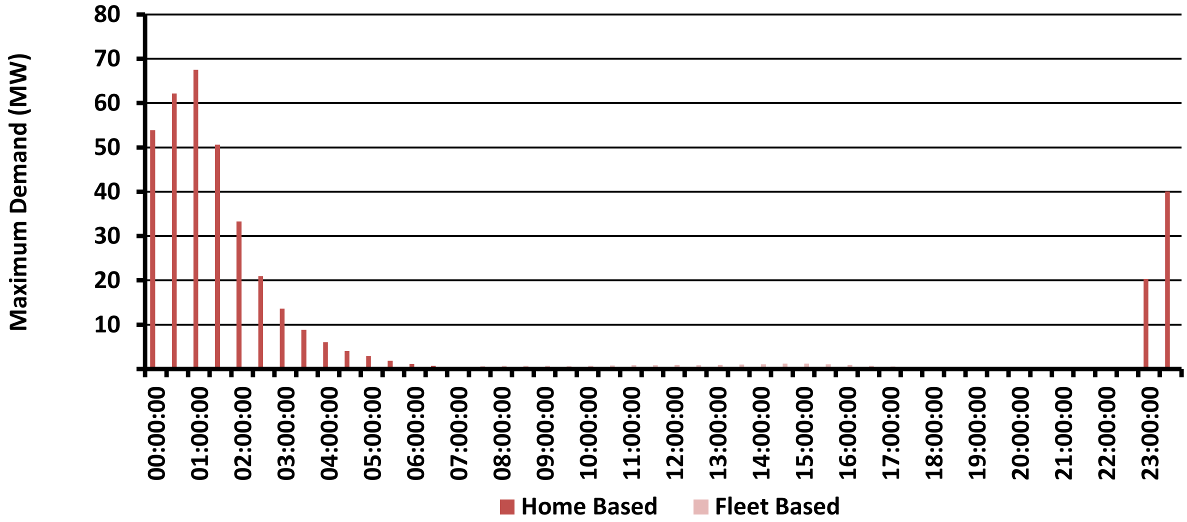
B.3.4 South Australia - Neutral

2020



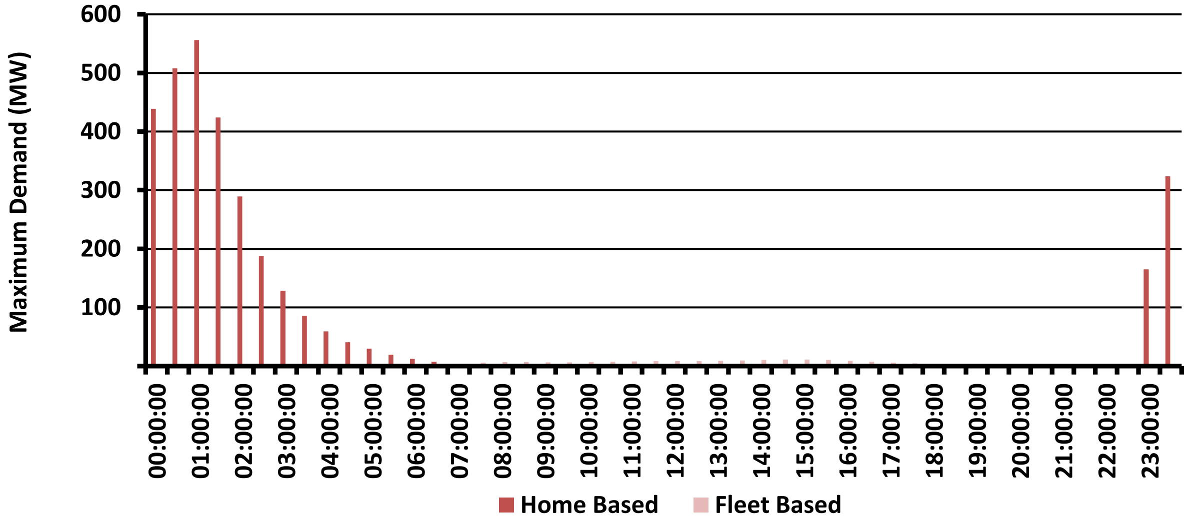
Source: Energeia

2025



Source: Energeia

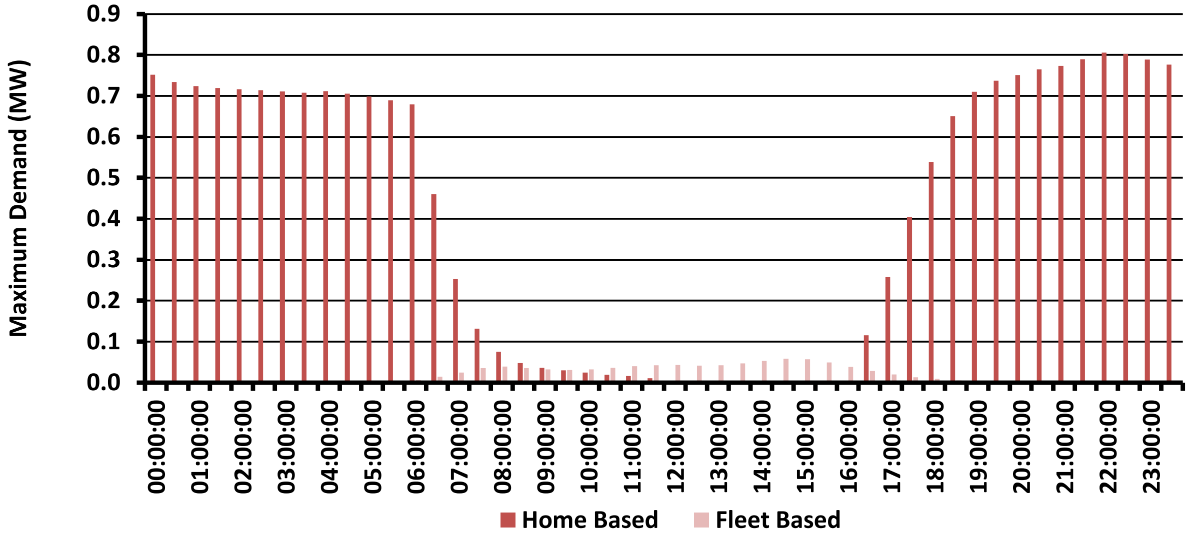
2036



Source: Energeia

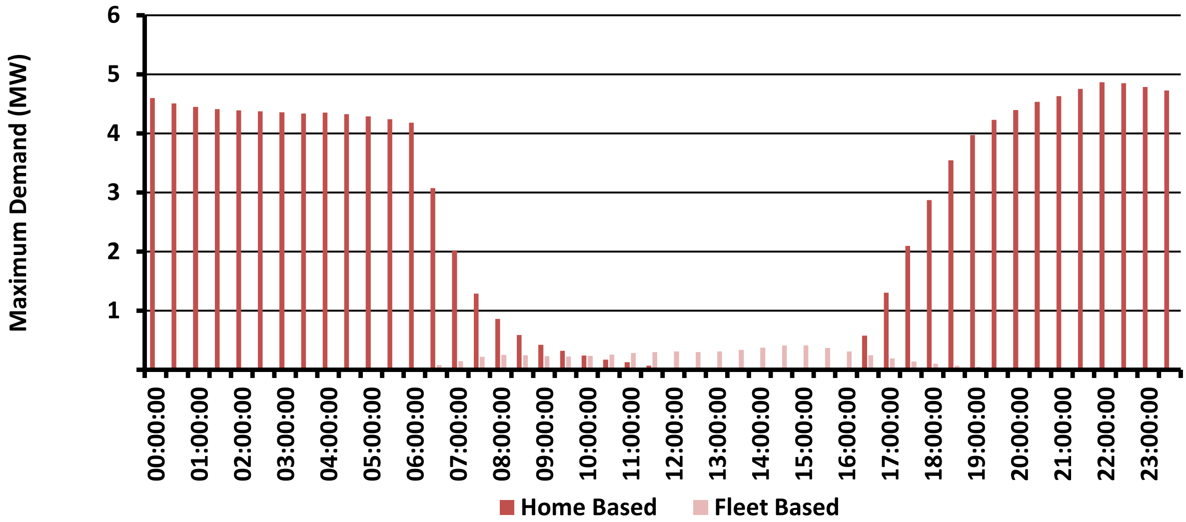
B.3.5 Tasmania - Neutral

2020



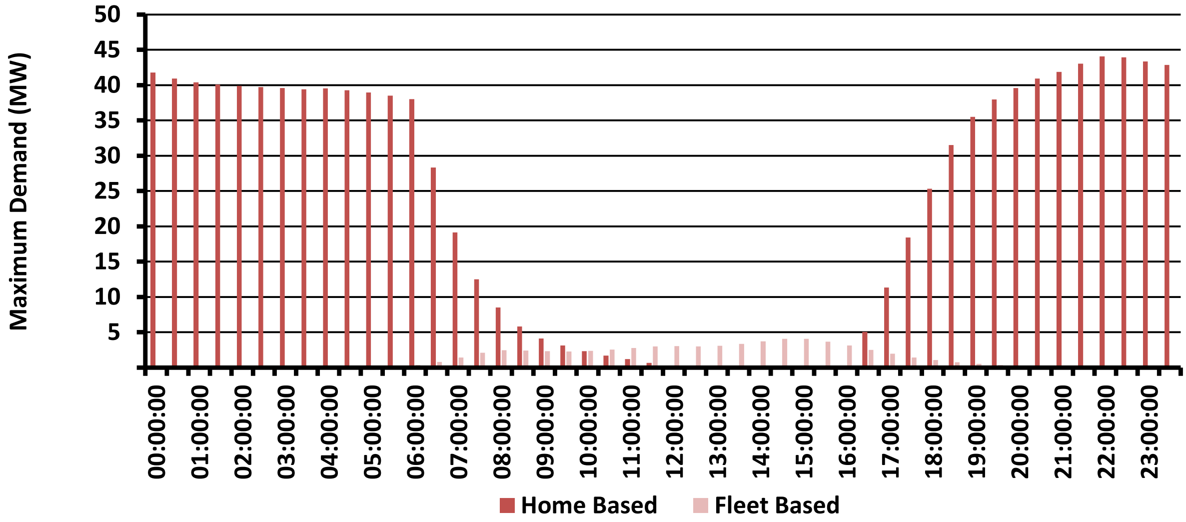
Source: Energeia

2025



Source: Energeia

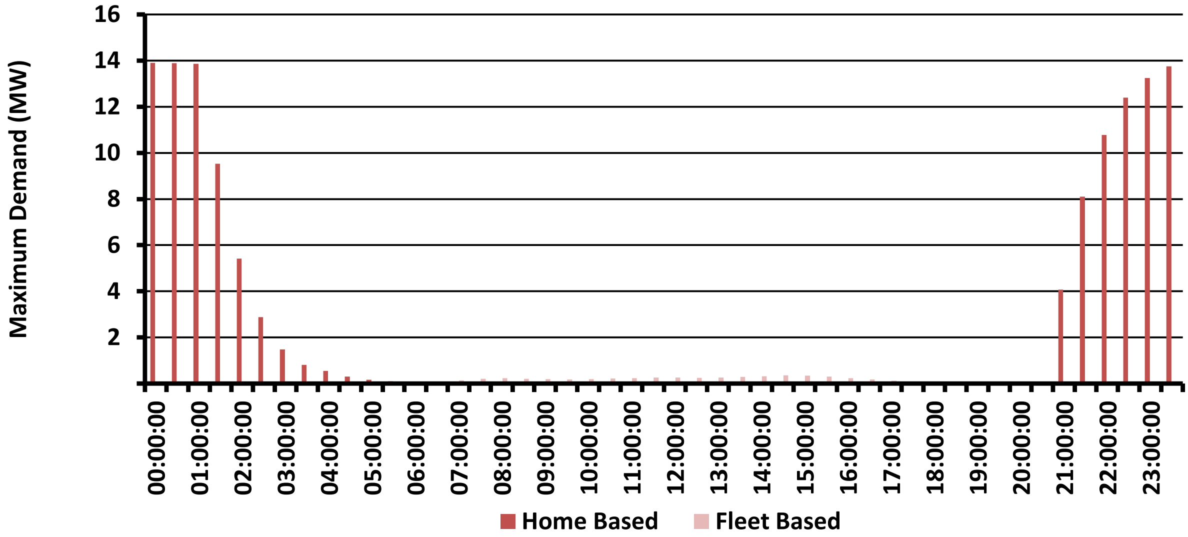
2036



Source: Energeia

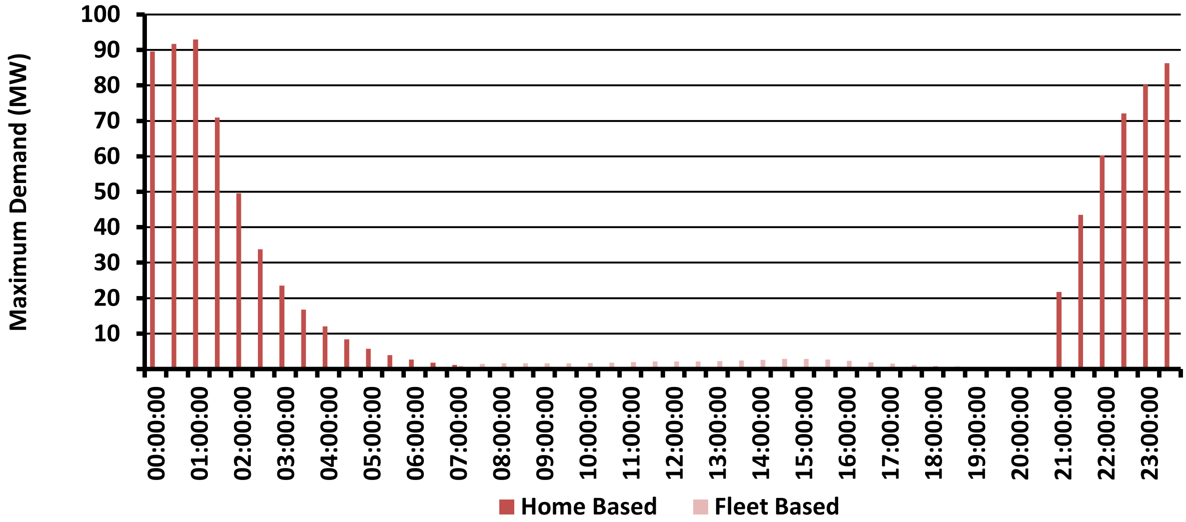
B.3.6 Western Australia - Neutral

2020



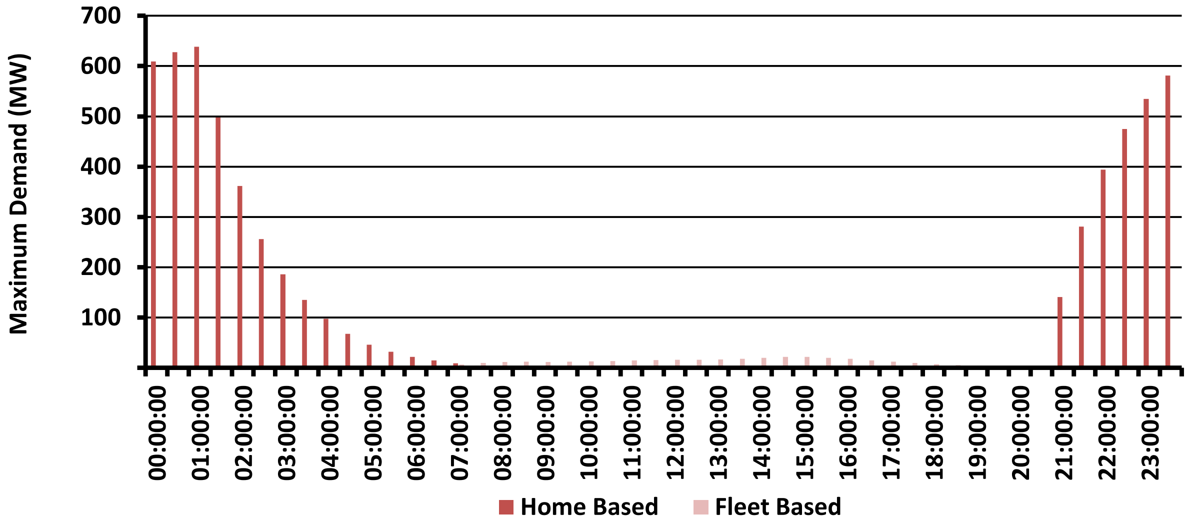
Source: Energeia

2025



Source: Energeia

2036



Source: Energeia