Australian Electric Vehicle Market Study

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Australian Government
Australian Renewable Energy Agency

ARENA

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Australian Electric Vehicle Market Study

Prepared by ENERGEIA for
ARENA and CEFC

FINAL

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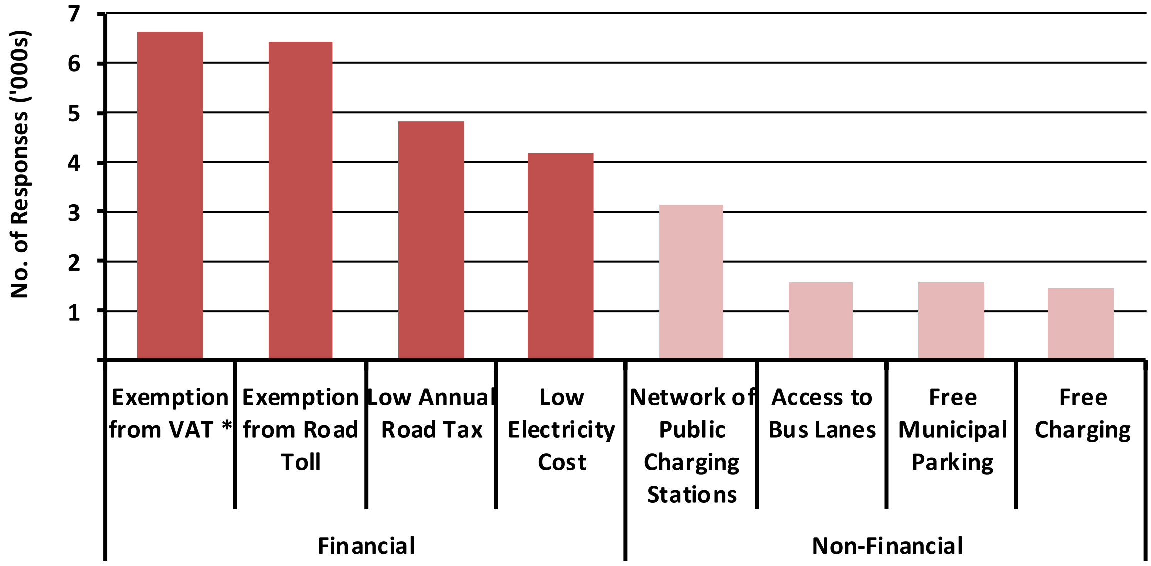
1 Executive Summary

Energeia's research review of Plug-in Electric Vehicles (PEV) charging infrastructure, and market modelling of PEV sales and associated charging infrastructure requirements have uncovered the following key findings.

1.1 Electric Vehicle Charging Infrastructure Policy and Regulation

Energeia's benchmarking of international comparator markets identified the role of financial and non-financial incentives, and reviewed the case study of Norway, the world leader for PEV uptake. This case study showed clearly that financial incentives, and particularly reductions in up-front purchase costs, are the incentives that impact most strongly on PEV purchase decisions, and that non-financial incentives play a supporting rather than leading role.

Buyer Ranking of Incentives (Norwegian Experience)



Source: Norwegian Electric Vehicle Association; Haugneland, et al. (October 2017), 'Put a price on carbon to fund EV incentives - Norwegian EV policy success'; Note: * Value Added Tax

From the review of comparator jurisdictions, Energeia identified the following uptake levers that could be used to drive uptake of PEVs in Australia:

- **Purchase Incentives** – Any increase in direct Australian financial incentives for PEV adoption will drive improved PEV model availability, which in turn will drive demand.
- **Procurement Targets** – Limited numbers (300-500 cars per year) bought via a co-ordinated fleet buying program would be sufficient to attract Original Equipment Manufacturer (OEM) interest to import new right-hand drive models not yet made available in Australia.
- **Import Regulation** – Adoption of third party imports of PEVs would increase both model availability and overall uptake in Australia (in line with the New Zealand experience).
- **Fuel Efficiency Regulation** – Implementation of 105g/km fuel efficiency standard would underpin a significant increase in PEVs in Australia driven by OEMs more aggressively marketing their PEVs in order to meet their compliance targets at least cost.
- **Global Internal Combustion Engine Vehicle Bans** – OEMs are increasingly likely to consider either removing Internal Combustion Engines (ICEs) from their vehicle portfolio and replace those models with PEV alternatives over the 10 to 30-year timeframe.

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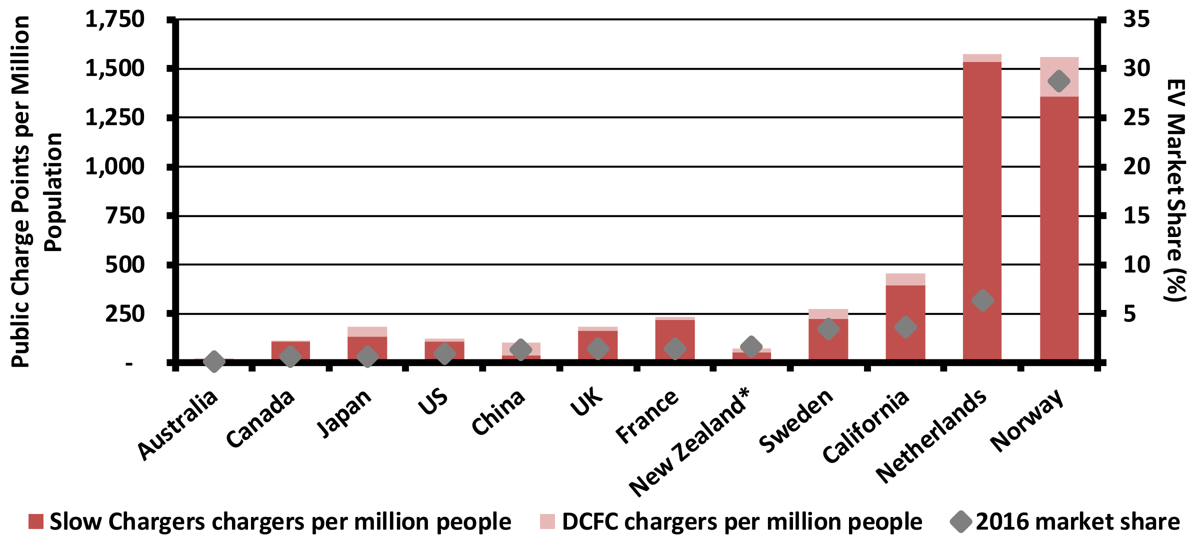
Key Policy and Regulatory Levers and their Expected Impact on Australia's PEV Adoption Rate

Lever	Estimated Impacts from Research
Vehicle Efficiency Regulations	200-300% increase in uptake based on US experience
Third Party Import Regulations	200% increase in PEV models available, 800% increase in uptake based on NZ experience
PEV Purchase Incentives	~$4,000 increases PEV model availability by 20%, increases uptake based on UK experience
Government Purchase Targets	1 new PEV introduced per 300-500 sales based on Australian OEM experience
Public Infrastructure Availability	Increases market size by 20%, increases rate of adoption by 50%, based on UK data and Dutch experience, respectively

Source: Energeia Analysis

Energeia found that investment in public charging infrastructure, particularly Direct Current Fast Chargers (DCFC), is correlated with high levels of PEV uptake globally, as evidenced by the impact of DCFC deployment in Norway.

Public Chargers vs. PEV Uptake



Source: IEA (2017), Energeia Research

Energeia's previous analysis[1] has found that model availability is a key driver of demand in addition to financial incentives. Energeia's research and analysis of international jurisdictions found that public charging infrastructure was a necessary but not sufficient factor in PEV adoption. In other words, the lack of public charging infrastructure will hold back PEV adoption, but it will not, by itself, driver greater levels of PEV adoption.

In Australia, state-level policy settings are mixed, with some policy settings at state level more proactive than at Federal level, and some Federal policy settings more advanced than some policy settings in some states. Energeia considered a basket of these policies (as explained in Section 1.3.1) in two of the three modelled scenario cases, as detailed in Section 1.3.2.

[1] Energeia (2015) 'Review of Alternative Fuel Vehicle Policy Targets and Settings for Australia, prepared by Energeia for the Energy Supply Association of Australia'.

Australian Government Policy Actions and Impacts – Federal and State

Policy Type	AUS	ACT	SA	VIC	NSW	QLD	WA
Sales per 10,000 vehicles (2016)	7	18	9	8	7	5	3
Regulation	✗	✓	✗	✗	✗	✗	✗
Up-front Financial Incentives *	✓	$2,110	$5,000	$100	<$250	$660	✗
Subsidised Charging / Discounted Parking		✗	✓	✓	✓	✓	✓
Non-Financial Incentives	✓	✓	✓	✗	✓	✓	✓

Source: Energeia Research; Note: * ACT, Victoria, New South Wales and Queensland incentives are all discounts to stamp duty or registration for an average vehicle, South Australian incentive is the Adelaide City Council charging infrastructure subsidy.

There are numerous policy drivers available to all levels of government in Australia, the introduction of only a few key policies could be sufficient to drive PEV uptake significantly higher. Energeia considered a basket of these policies (as explained in Section 1.3.1) in two of the three modelled scenario cases, as detailed in Section .

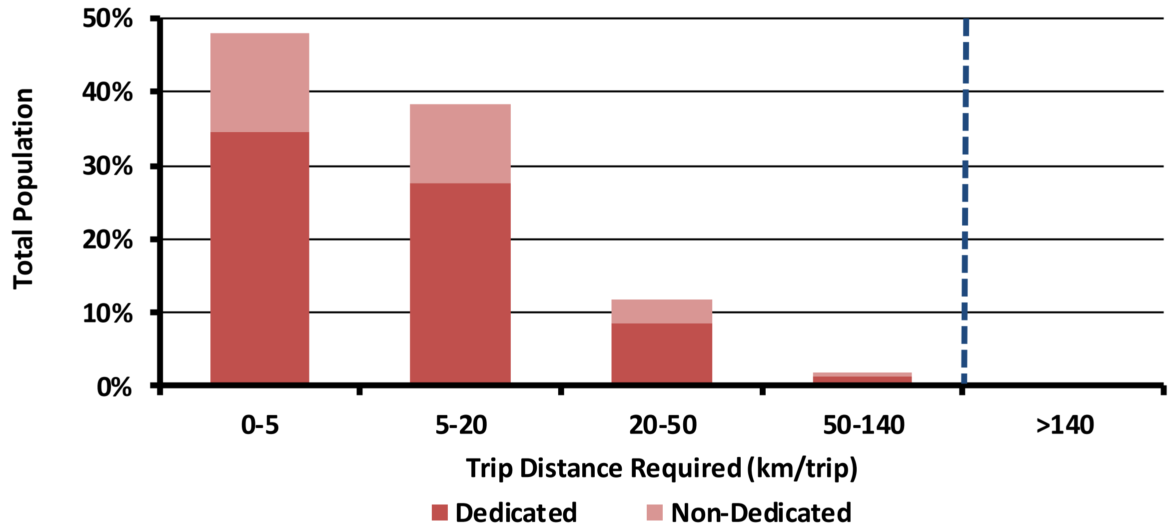
1.2 Demand for Public Charging

Energeia found that PEV drivers prefer to charge in the most convenient way possible, meaning at home when available, and using the most convenient public charging options when necessary (determined mainly by trip destination and vehicle range). A recent Australian study[2] shows that more than 99% of daily trips were under 50 km, implying a round trip distance of 100 km, which is well within the range of new PEVs.

1.2.1 Key Market Segments

Based on our review of charging behaviour, Energeia developed a framework based on dedicated parking availability and trip distance requirements to segment the market into two, as shown below.

Australian Charging Market Segmentation



Source: Energeia Analysis

[2] Victorian Integrated Survey of Travel & Activity (2013)

The market segments Energeia identified[3] for the deployment of Electric Vehicle Supply Equipment (EVSE) are:

- **Drivers with Access to Dedicated Charging –** This segment represents around 70% of the vehicle transportation market and will require public charging for around 1% of kilometres travelled, for long-haul trips.
- **Drivers without Access to Dedicated Charging** – This segment represents around 30% of the market and consumers in this segment will require public charging for 100% of their charging requirements. 99% of their kilometres can be satisfied using Level 2[4] public charging at work, or public DCFCs.

1.2.2 Charging Infrastructure Deployment Requirements

Drivers without access to home charging must rely entirely on public charging. The lack of a reliable public charging infrastructure limits PEV uptake to drivers with access to a dedicated parking spot, which is typically at home, but may also be at work for commercial vehicles.

To meet the demand for PEV uptake, overseas jurisdictions are examining both Level 2 and DCFC charging solutions, with the recent focus being on an elevated role for DCFC charging. However, estimates of public charging requirements per PEV by 2030 in the studies reviewed by Energeia vary by an order of magnitude.

Given the large discrepancy between jurisdictions, and the significant impact this has on estimates of future charging infrastructure requirements, Energeia recommends that the CEFC and ARENA consider further detailed analyses to better understand the key differences between the various approaches.

1.2.3 Demand Uncertainty

The ultimate level of demand for charging is driven by the number of PEVs, which is in turn a function of total annual vehicle sales, and the rate of PEV uptake. Previous research found model availability and purchase premiums are the key drivers of future PEV uptake in Australia.

Summary of Expected Drivers of Future Demand for Public Charging Infrastructure

Key Driver	Expectations from Research
PEV Manufacturing Costs	BNEF[5] and Energeia expect PEVs to be 20% cheaper to manufacture at 1M production scale
Lithium Battery Costs	BNEF and Energeia expect lithium prices to fall by 8-9% per annum
PEV Model Availability	OEMs reporting over 165 new PEVs by 2030, some reporting 100% PEV choice
PEV Driving Range	Trend data shows PEV driving ranges hitting ICE parity by 2024
PEV Refuelling Time	Trend data shows PEV refuelling times hitting ICE parity by 2020 at current battery sizes
Wireless Charging Technology	Stationary wireless technology expected to become standard within 10 years, no impact on requirements
Transport Sector Transformation	Transport-as-a-Service could reduce vehicle fleet, and favour DCFC over Level 2 due to higher utilisation
Fuel Cell Vehicle Technology	Fuel cell technology not expected to be a major competitor to PEVs

Source: Energeia Analysis

[3] Split between dedicated (where permanent parking is provided, such as a garage at a private home, or a set car spot at a workplace) and non-dedicated (such as on-street, shopping centre or communal office or residential parking) parking is drawn from the UK National Travel Survey (2016)

[4] Level 2 chargers are used mainly at private premises for personal use or for public destination-based charging locations to attract drivers

[5] Bloomberg New Energy Finance

A key research finding is the limited expected impact of the following potentially significant vehicle technology risks:

- **Fuel Cell Electric Vehicles** – Energeia research and analysis shows that the risk of Fuel Cell Electric Vehicles (FCEVs) supplanting PEVs in the next 20-30 years is remote (given the slow rate of technological development of FCEVs, the limited model availability, and the imposing infrastructure roll-out challenge).
- **Shared Autonomous Electric Vehicles** – Shared Autonomous Electric Vehicles (SAEVs) could impact the future demand for public charging infrastructure by requiring automated refuelling technology and by reducing the number of cars on the road. While the long-term impacts of SAEVs and TaaS[6] are likely to be significant, there is a lack of data to support a strong view for future likely developments, and more work in this space is needed.

1.3 Market Review of Electric Vehicle Sales, Stock and Infrastructure

Energeia found a wide variation in PEV uptake forecasts at both the global level, and in Australia, with a range of scenarios from capped infrastructure (BNEFs view) through to 100% saturation (DNV GLs view, and that of various Australian studies). Current Energeia forecasts in the public domain (completed for AEMO's Electricity Forecasting Insights program of work) forecast PEV uptake at 20% of new vehicle sales by 2030, compared to the 20-60% of new vehicle sales modelled in this project (refer to detailed model results in Section 1.3.2).

1.3.1 Scenario Design

Three forecast scenarios were modelled that represent the expected pathway for Australia's PEV outlook across a Moderate Intervention, No Intervention and Accelerated Intervention scenario, where the technical barriers/capabilities, consumer sentiment, policy and regulatory outlooks aligned with each forecast scenario.

- **No Intervention Scenario:** assumes no additional action by any stakeholders in Australia, and uptake is driven solely by the economics of PEVs manufactured overseas and shipped to Australia.
- **Moderate Intervention Scenario:** assumes an unco-ordinated mix of policy support, across several layers of government, including potential federal policy changes to luxury car tax, fringe benefits tax and vehicle emissions standards, and a mix of the most likely state and local government PEV support from the list below. This scenario assumes no long-term decarbonisation target.
    - Australian states with net-zero targets and a history of policy action to support this in power generation introduce policies to support PEV uptake in their states. Policies include stamp duty and registration exemptions.
    - Local and state government fleets are pushed to increase fleet purchases of PEVs where there is a comparable PEV in the class.
    - Removal of restrictions on import of second-hand PEVs drives a larger second-hand market.
    - Preferential parking and use of transit lanes.
    - Assumes that a range of actors (governments, motoring associations, private companies) accelerate the roll-out of charging infrastructure which removes range anxiety, e.g. QLD Superhighway and the NRMA network.
    - Assumes OEMs react to this policy support by increasing PEV model availability.
- **Accelerated Intervention Scenario:** assumes the unco-ordinated policy and OEM actions in the Moderate Intervention scenario occur earlier and to a higher level of support, representing a more aggressive push to support PEVs. In addition, it is assumed that as foreign-produced ICEs model

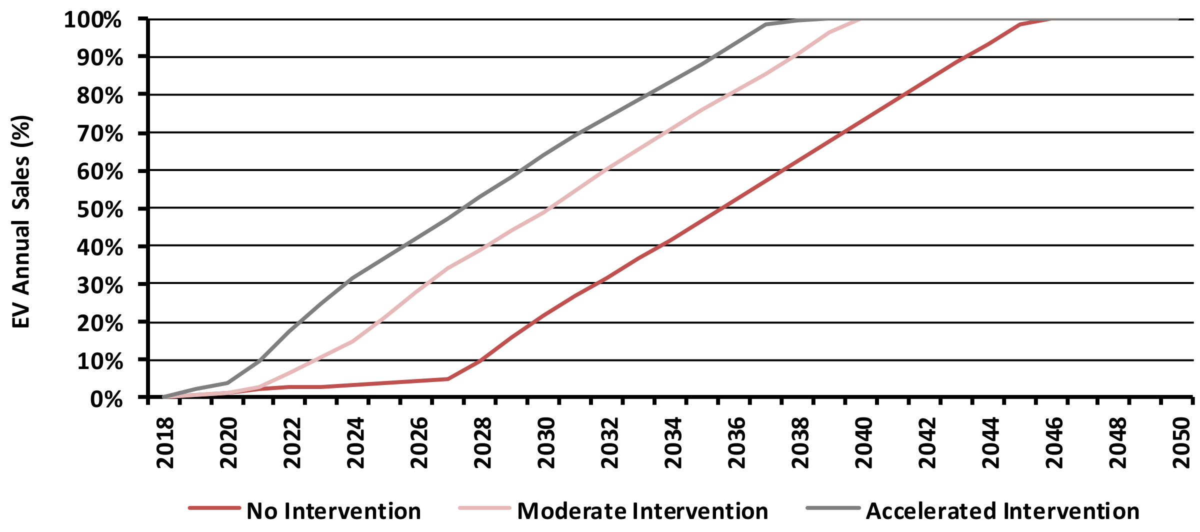
[6] Transportation as a Service

availability decreases that a total ban in ICE sales is implemented towards the end of the projection period.

1.3.2 Australian PEV Adoption Outlook

Under the Energeia Moderate Intervention scenario, PEV sales (both Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs)) are forecast to reach 615,000 vehicles per annum by 2030, increasing to 1.89 million annual new vehicle sales by 2040, or 49% and 100% of sales respectively. There is a relatively steady increase in PEV sales to around 28% per annum by 2026 driven by falling PEV prices supported by falling battery prices, increased model availability by OEMs, and an increasing differential between electricity and petrol prices.

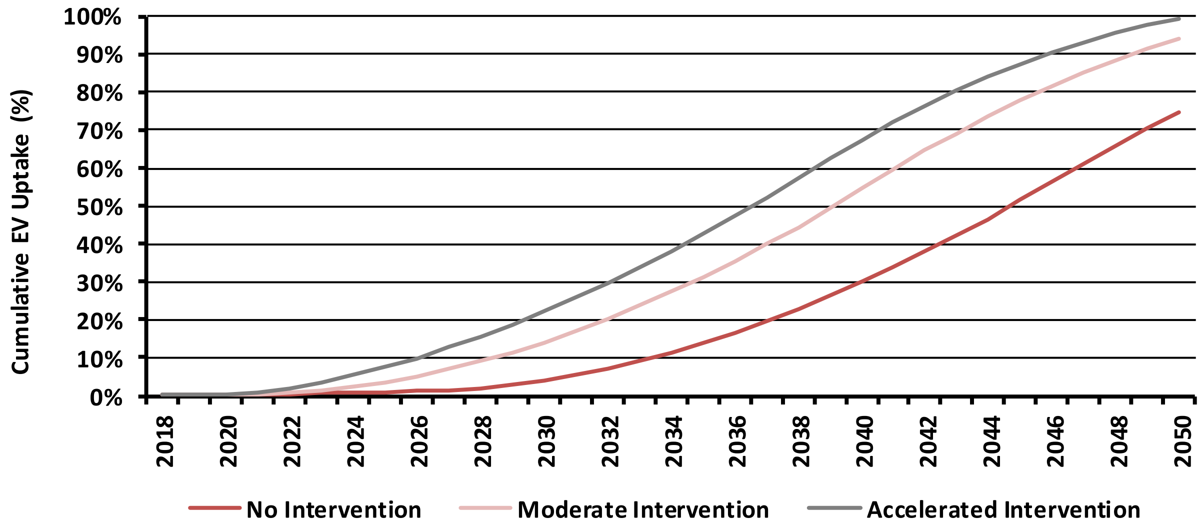
Annual PEV Sales



Source: Energeia Modelling

Under the Moderate Intervention scenario, PEV sales are set to expand over the next five years from 3,100 to 70,700 electric vehicles sales. The rapid rise in uptake is based on a shift in PEV model availability from niche vehicles and non-leading OEMs to electric equivalent models of leading brands' ICE models.

Fleet Proportion

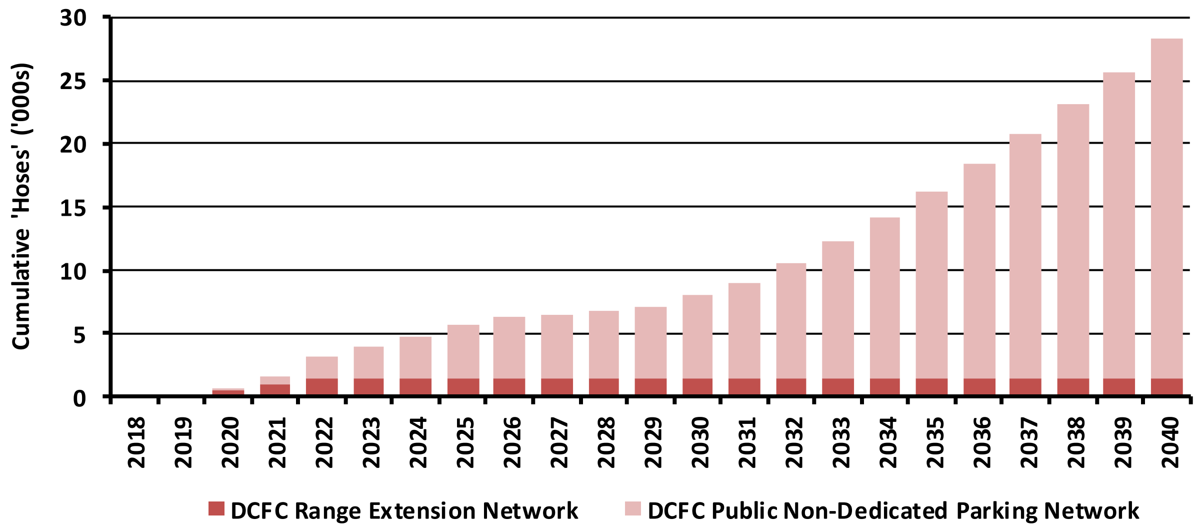


Source: Energeia Modelling

1.3.3 Australian Public Charging Requirements

Public DC fast chargers (DCFC) are required to meet charging demand from PEVs that do not have access to dedicated Level 2 charging at home or the workplace. These estimates are based on the gas station model with charge times at or below five minutes, while range extension chargers are required to supply the <1% trips required for inter-region driving over 150 km. Under the Moderate Intervention case, Australia will require just over 28,370 DCFC hoses over the period to 2040, requiring an estimated $1,688 million in total investment excluding land.

Charging 'Hoses' Required by Type (Moderate Intervention)



Source: Energeia Modelling; Note: Dedicated Level 2 charges not shown in order to avoid overwhelming the number of DCFCs

Energeia's modelling shows PEV charge management avoiding any significant increase in maximum demand in the Moderate Intervention scenario.

- Managing the overnight Level 2 charging load from PEVs with dedicated parking, through either price or control signals, will be able to mitigate potential increases in net system load and ramping rates, while increasing minimum demand and utilisation. The result for the power system is significantly lower costs, which will create a strong industry incentive to implement PEV charging management solutions.
- DCFC is expected to occur in proportion to cars on the road and is therefore not amendable to managed charging. Energeia estimates DCFC without onsite storage will add around 600 MW to system peak by 2040, assuming net system peak moves into the 6-8 pm period by then.

Overall, the impact of PEV charging on system demand is 2.8 GW maximum PEV demand by 2040.

1.4 Supply of Public Charging Infrastructure

Energeia's research found that the leading overseas jurisdictions follow a common approach to scaling their charging infrastructure:

- **Step 1** – Workplace charging for commuters (obsolete given second generation PEV ranges).
- **Step 2** – Range extension (DCFC based).
- **Step 3** – Access to chargers for PEV drivers without a dedicated charger (Level 2 based to date).
- **Step 4** – Scaling up charging networks to match demand as PEV uptake rises is the final step, which addresses increasing congestion as the PEV:EVSE ratio increases.

In overseas jurisdictions that have led the way in EVSE deployment, governments have heavily subsidised the roll-out of public charging infrastructure. Given Australia's current level of EVSE deployment, Australia can skip

Step 1 (redundant due to increases in vehicle ranges that cover most commutes) and focus on Step 2 (range extension deployment is currently at an early stage) and Step 3 (drivers with non-dedicated parking).

Given changes in DCFC technology performance and cost outlooks in the short term, Australian infrastructure deployment can skip deployment of public Level 2 chargers and focus instead on deploying DCFCs, given the relative utilisation characteristics between Level 2 and DCFCs.

1.4.1 EVSE Economics

Energeia analysis on the cost to fill up a PEV found that over the next 10 years, PEVs could expect to pay around $11 to fill up their 100 kWh tank at the local DCFC station in about 5 minutes or less, whilst the same fill-up would take four hours (parked at work during the day or at home overnight) and cost $17-19 using a Level 2 solution. This assumes that DCFC can be expected to cost around USD $60,000-$80,000 in the medium term, once the industry has matured and realises economies of scale.

PEV Charging Models – Economic Comparison

	Public Workplace (Parking Lot)	Public Destination (Parking Lot)	Public Transit (Gas Station)
Equipment Capex	$2,000	$2,000	$60,000
Electricity Connection Capex	$4,000	$4,000	$30,000
Electricity ($/kWh)	$0.15	$0.15	$0.10
Daily Fixed Cost	$2	$2	$36
Per 100 kWh Charge Cost	$17	$19	$11
Power (kW)	9.6	9.6	1,000
Usage Profile	Weekdays	Weekends	7 Days
Charges per Day (Weekly Avg)	1.4	0.6	25.2
Mins per Charge	240	240	5
Total kWh/Day/Charger	55	22	2,099

Source: Energeia Analysis

As EVSE technology has evolved, and DCFCs reach 350 kW levels and are increasingly rolled out, charging has become more competitive in terms of both cost-to-serve and convenience. DCFC manufacturers are already targeting 500 kW capabilities, however, PEVs arriving 2019-2020 will be limited to charging at 350 kW.

1.4.2 EVSE Business Models

Energeia's review of Australian networks has found that free charging is being gradually phased out in favour of a user pays (e.g. ChargeFox, ChargePoint, SA Government and Everty) or 'embedded' revenue model (NRMA/RAC and Tesla)[7]. Internationally, Energeia's research found public charging infrastructure deployment is being led by a mixture of electricity utilities, new entrants and PEV OEMs.

[7] Historically, most public charging revenue is estimated to come from government and business subsidies. Government subsidies and user-pays business models have been more prevalent in Europe and the US, while Australian public charging has been more reliant on businesses paying for the cost of chargers to enable PEV drives to patronise their locations.

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Australian Charging Networks and Service Pricing

	Charging Network Operator							
Player								
	Tesla	NRMA	RAC (WA)	Energy Qld	ChargeFox (JetCharge)	chargepoint	City of Adelaide	Everty
Type of Player	EV OEM	Motoring Association		Utility	EVSE Operator	EVSE Operator	Local Gov't	EVSE Operator
Region	AU	NSW	WA	QLD	AU	AU	SA	NSW
Charging Stations	20* (DCFC)	1**	12 (DCFC)	1*** (DCFC)		350 (3 DCFC)	40 (DCFC)	N/A****
Charging Hardware	Tesla L3	-	Circontrol Trio	Tritium Veefill	Wallpod / EV Box	chargepoint CT4000	Tesla L3	N/A
Charging Software	Tesla	-	ChargeStar		EV Connect		Tesla	N/A
Payment Method	Cloud	-	RFID card	RFID card	Cloud	RFID card	Cloud	Cloud
Start of Program	2014	-	2015	2017	-	Pre-2010	2016	2017
Free Charging	1st 400 kWh	-	✗	1st 12 months	Owners Discretion	Owners Discretion	Until end of 2017	✗
c/kWh (Level 2)	✗	✗	$0.75/kWh ++	✗	✓	✓	✗	✗
c/hr (Level 2)	✗	✗	✗	✗	✓	✓	✗	$1-3/min
c/kWh (DCFC)	$0.35/kWh +	-	$0.75/kWh ++	✓	✓	✓	$0.30/kWh	✗

Source: Energeia Research; Notes: * Tesla has announced an additional 18; ** NRMA is planning to roll-out 40 chargers at a cost of $10m as part of their Social Dividend Investment Strategy; *** Energy Queensland is rolling out an Electric Super Highway of 18 superchargers up the Queensland coast from the Gold Coast to Cairns; **** Everty is a P2P charging network, offers PEV owners a platform for listing and monetising their home charger to fellow PEV drivers; + Tesla; ++ Included in this charge is a flat 30c/kWh fee to a payments handling company (Braintree)

1.4.3 EVSE Value Chain

Although they have been slow in moving into the public infrastructure charging market, petrol station operators are moving into this space rapidly, especially in Europe. Key drivers of this move have been the UK's recent legislation requiring petrol stations to offer DCFC, and Shell's acquisition of New Motion, the largest public charging infrastructure operator in Europe.

Based on our review of the key players in Australia and overseas, key lessons learned and critical success factors, Energeia concludes that petrol station operators, major domestic operators, automotive associations, regulated electricity networks and energy retailers are in the strongest positions to deploy Australia's future public charging network.

Potential DC Fast Charging Developers – Strengths and Weaknesses

Category	Examples	Key Strengths								
		Software / Hardware	Infrastructure Development	Asset Management	Regulatory Backing	Access to Capital	Energy Risk Management	Existing Locations	Cost Sharing	Score
Major Petrol Station Operators	Shell, BP	×	✓	✓	×	✓	✓	✓	✓	6
Major Energy Retailers	Origin, AGL	×	✓	✓	×	✓	✓	×	✓	5
Regulated Electricity Networks	Ausgrid, TransGrid	×	✓	✓	✓	✓	×	×	✓	5
Automobile Associations	RACV, NRMA	×	✓	✓	×	✓	✓	×	✓	5
Major Overseas Operators	NewMotion	✓	✓	✓	×	×	✓	×	×	4
Major Infrastructure Developers	CMIC, Lendlease, etc.	×	✓	✓	×	✓	×	×	×	3
Unregulated Electricity Networks	Ausgrid, TransGrid	×	✓	✓	×	✓	×	×	×	3
Car OEMs	Tesla, etc.	×	×	×	×	✓	×	×	✓	2

Source: Energeia Analysis

Table of Contents

Table of Figures

Table of Tables

2 Disclaimer

While all due care has been taken in the preparation of this report, in reaching its conclusions Energeia has relied upon information and guidance from ARENA and CEFC, and other publicly available information. To the extent these reliances have been made, Energeia does not guarantee nor warrant the accuracy of this report. Furthermore, neither Energeia nor its Directors or employees will accept liability for any losses related to this report arising from these reliances. While this report may be made available to the public, no third party should use or rely on the report for any purpose.

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3 Structure of this Report

The remainder of this report is structured as follows:

- **Section 4** – Scope and Approach describes Energeia's understanding of the CEFC/ ARENA scope of work and details our methodology for undertaking this review;
- **Section 5** – Part A: Strategic Review of Electric Vehicle Charging Infrastructure outlines Energeia's desktop research into the interplay between policy and regulatory settings and demand for public charging induced from increased uptake of electric vehicles and the resultant impact on supply of public charging infrastructure;
- **Section 6** – Part B: Market Review of Electric Vehicle Sales, Stock and Infrastructure lays out Energeia's approach to modelling, the key inputs and agreed scenarios and the results of our modelling of electric vehicle uptake, OEM market shares, public charging infrastructure network scaling and impacts of vehicle and charging uptake on electricity networks;
- **Section 7** – Conclusion and Future Direction summarises our key findings from Section 5 and 6, and lays out Energeia's view of a potential future roadmap to encourage both electric vehicle uptake and public charging infrastructure network deployment;

The remaining sections form Appendices to the main report, which describe in turn:

- **Modelling Description** – our modelling results and approach (Appendix A which outline the Scenario Modelling Results, and Appendices B, C and D which summarise the modelling approach for the PEV Uptake, Public Charging Infrastructure Scaling and OEM Market Share Models)
- **Glossary** – an explanation of acronyms and definition of key terms used in the report is included as Appendix E.

4 Scope and Approach

The Australian Renewable Energy Agency and the Clean Energy Finance Corporation engaged Energeia in December 2017 to undertake an Electric Vehicle Market Study focusing on the business models, competitive dynamics and pricing of public charging infrastructure.[8]

4.1 Scope

The CEFC and ARENA developed a scope of work comprised of the following research and modelling elements:

- **Part A: Strategic Review of Electric Vehicle Charging Infrastructure** – Completion of strategic research that describes the current state of play in the Plug-in Electric Vehicles (PEVs) and related charging networks markets and the likely range of possible developments (including possible implementable business models, market and competitor analysis, infrastructure build-out costs and Original Equipment Manufacturer (OEM) strategy).
- **Part B: Market Review of Electric Vehicle Sales, Stock and Infrastructure** – Development of annual forecasts of PEV sales, stocks and infrastructure under a range of different scenarios.

Details of the scope are included as Appendix A.

4.2 Approach

Energeia's approach to addressing ARENA and the CEFC's key research and modelling questions was to undertake a comprehensive program of desktop research to update its information regarding the latest policy, regulatory, demand, technology and supply developments in leading PEV and public charging jurisdictions. We then used that information to update and configure our PEV, PEV charging models, charging infrastructure scaling models, and to develop an OEM market share forecasting function in our PEV uptake model.

Finally, we used the modelling results to develop an estimate of the impact of PEVs on the electricity system, and to develop an optimised public charging infrastructure deployment roadmap for ARENA and the CEFC to consider as part of their respective strategy and planning processes.

[8] Appendix A details the specific research and modelling questions included in the scope of work.

5 Part A: Strategic Review of Electric Vehicle Charging Infrastructure

The following sections outline the policy and regulation factors impacting on charging network development, and the demand for, and supply of, public charging infrastructure. The highlights from this research include:

- **Infrastructure Deployment** –Norway is the leading PEV market with a Battery Electric Vehicle (BEV) fleet more than 100,000 vehicles and a market share of 19% for BEVs across the entire mass-market (passenger and light commercial) vehicle fleet.
- **Model Availability** – The key driver of PEV uptake is PEV model availability, in combination with financial incentives. Model availability could be lifted by government and/or private fleet bulk buying amounting to 200-500 cars per year or by the adoption of the Harper Review recommendations to allow a secondary market in imported vehicles (including PEVs) to emerge.
- **Vehicle Emissions Standards** – Implementation of a 105gCO2/km vehicle emission standard would underpin a significant increase in PEV uptake in Australia
- **Grid Impacts** – Managing the charging load, through either price or control signals, can reduce net system load and ramping rates, while increasing minimum demand and utilisation.
- **Demand for Charging** – PEV driving range determines when and where PEV drivers charge in addition to dedicated home or workplace charging. More than 99% of daily trips are under 50 km, implying a round trip distance of 100 km - well within the range of new PEVs. DCFC is likely to be the longer-term public charging infrastructure winner, mainly due to its superior utilisation characteristics.
- **Potential Wildcard Risks** – These include both wireless charging (which is likely to be the L2 charging technology of choice 10 years from now and could impact on public charging provision) competition from fuel cell electric vehicles (which are approximately 10 years behind the model availability and infrastructure deployment of PEVs)

The strategic review from Part A feeds into updated modelling in Part B.

5.1 Policy and Regulation

Energeia reviewed and benchmarked leading international jurisdictions across several key factors driving PEV uptake:

- **PEV Purchase Incentives** – both financial and non-financial were reviewed, and up-front financial incentives, that reduce the purchase cost of the PEV, were identified as the most impactful on PEV uptake.
- **PEV Procurement Targets** – government fleet targets and the potential for increasing PEV model availability through bulk buying was identified as a key driver of PEV uptake.
- **PEV Import and Vehicle Efficiency Regulations** – vehicle emissions (e.g. CO2, P10, etc.), fuel efficiency and vehicle import regulations are a key driver of PEV uptake.

Charging Infrastructure Deployment – market research and results from leading jurisdictions show that availability of public charging infrastructure has a positive correlation with increased PEV uptake. The results of Energeia's investigation into the key policy and regulatory settings of leading international jurisdictions, their impact on PEV demand, and their relevance for Australia are discussed below.

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5.1.1 International Benchmarking

The results of Energeia's review of the policy and regulatory settings[9] of the top five overseas PEV jurisdictions (Norway, Netherlands, California, Oregon and Sweden) by percentage of annual vehicle sales is displayed in Table 1.

Table 1 – Plug-in Electric Vehicle Policy Settings of Leading Markets

Policy Type		Policy Lever	EU			US			
			NO	NL	SE	CA	OR	AU	Score
2016 PEV Market Share (% of new sales p.a.)			28.8%	6.4%	3.4%	3.7%	1.9%	0.1%	
Supply Side		Vehicle Target	✓	✓	✓	✓	✓	✗	5
		Infrastructure Target	✓	✗	✗	✓	✗	✗	2
		R&D Funding	✗	✓	✗	✓	✗	✗	2
		Career Training	✗	✗	✗	✓	✓	✓	3
		Manufacturer Incentives	✗	✗	✗	✓	✓	✗	2
		Emissions Standards	✓	✓	✓	✓	✓	✗	5
Demand Side	Financial	Upfront PEV Subsidy	✓	✓	✓	✓	✓	✓	6
		Annual PEV Subsidy	✓	✓	✓	✗	✗	✗	3
		Infrastructure Subsidy	✗	✗	✓	✗	✓	✓	3
		Government Fleet Subsidy	✗	✗	✗	✓	✓	✓	3
	Non-Financial	Vehicle Lane Privileges	✓	✗	✗	✓	✗	✗	2
		Parking Incentives	✓	✗	✓	✓	✗	✓	4
Score			7	5	6	10	7	5	40

Source: Energeia Analysis

The main difference between the top-two jurisdictions (leader Norway and second place Netherlands) appears to be vehicle lane and parking privileges. However, Energeia notes that Norway has been driving PEV uptake for over a decade, which may explain their relatively higher rate of PEV adoption relative to upfront subsidies.

[9] The effectiveness of individual measures is not easily separated, but as a general statement, the more financial and non-financial measures are put in place, the great the level of PEV model availability, as per Figure 3 (which shows a much higher level of model availability for California relative to Australia, commensurate with the greater number of measures in place within California)

Case Study of Leading PEV Jurisdiction – Norway

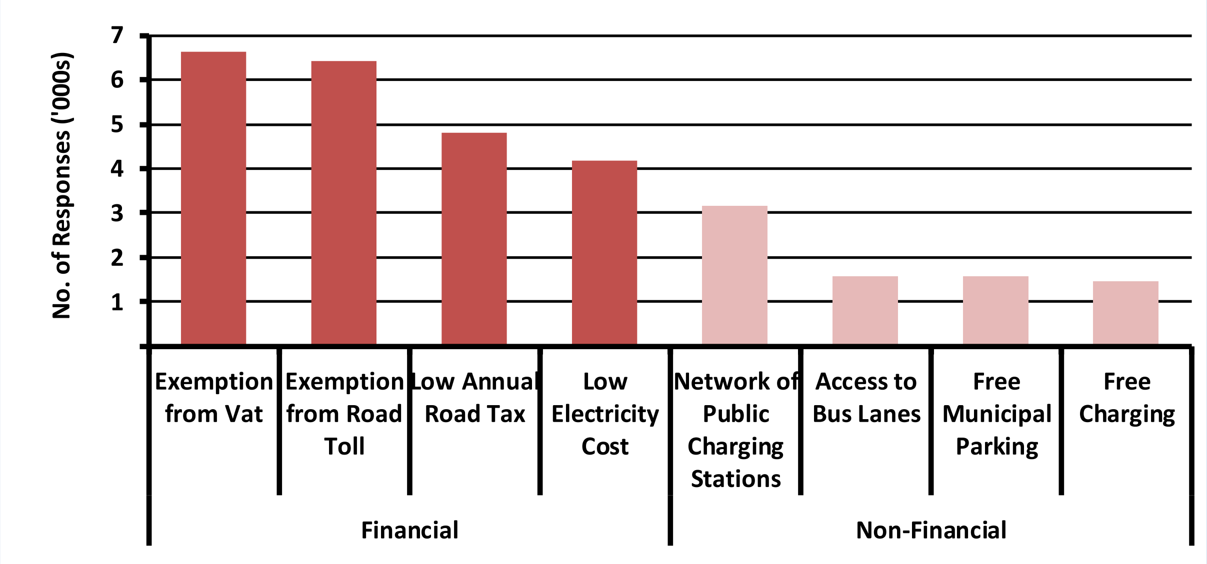
As of June 2017, Norway is the leading PEV market with a Battery Electric Vehicle (BEV) fleet in excess of 100,000 vehicles and a market share of 19% for BEVs across the entire mass-market (passenger and light commercial) vehicle fleet.

To achieve this result, Norway has rolled out an interrelated package of incentives, designed to stimulate PEV uptake, over a long period of time. There has been broad political support for the package of incentives, with different incentives progressively introduced over time by different governments:

- **1990s** – Purchase taxes, which averaged 5-figure sums for ICEs were removed from PEVs in 1990, annual road tax was discounted in 1996 and PEVs where given a road toll holiday from 1997 onwards.
- **2000s** – Taxes on PEVs used as company cars were halved in 2000, an exemption from Value-Added Tax (VAT; charged at 25% in Norway) on PEV purchases was put in place in 2001, and PEVs were given access to bus lanes and to state ferries in 2003 and 2009 respectively.
- **2010s** – Further tax reductions included an exemption from 25% VAT on leasing PEVs in 2015.

Studies of the impact of these incentives, as shown in Figure 1, have identified that financial incentives, and particularly reductions in up-front purchase costs, are the incentives that impact most strongly on PEV purchase decisions. Consumers tend to react strongly to the up-front cost of the car and are less influenced by incentives that reduce the total cost of ownership over time.

Figure 1 – Buyer Ranking of Incentives (Norwegian Experience)



Source: Norwegian Electric Vehicle Association; Haugneland, et al. (October 2017), 'Put a price on carbon to fund EV incentives - Norwegian EV policy success'; Note: VAT = Value-Added Tax

Based on our benchmarking of leading international jurisdictions and detailed investigation of the global leader, Norway, Energeia investigated the following additional key policy and regulatory drivers of demand for the Australia market.

5.1.2 PEV Uptake Levers

Energeia's review of the policy and regulatory framework of leading international jurisdictions by PEV market share identified PEV purchase incentives, government purchase targets, third-party PEV import regulations and fuel efficiency standards as the key policy levers for ensuring PEV model availability and driving PEV uptake.

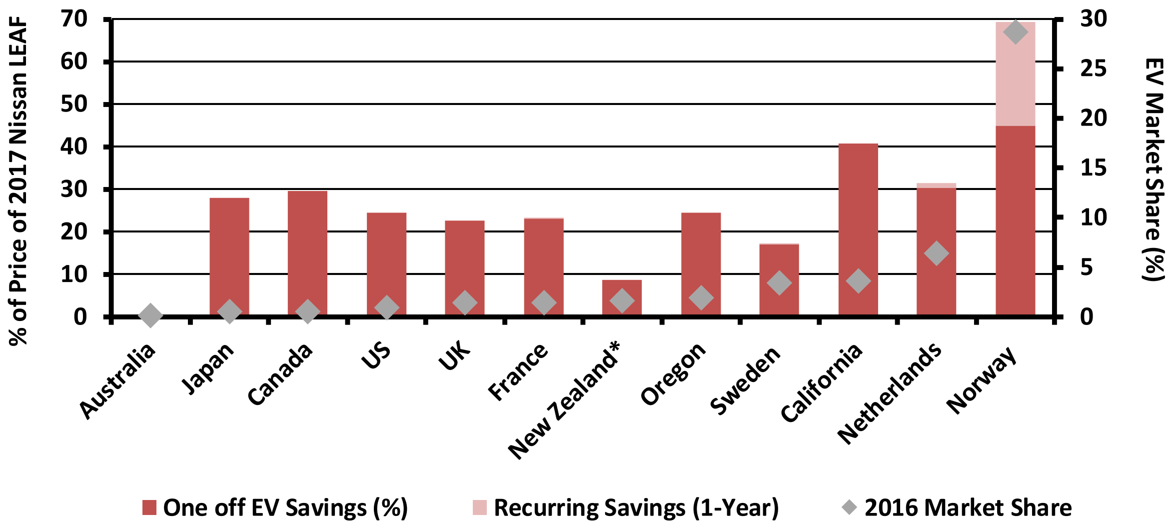
5.1.2.1 *PEV Purchase Incentives*

Figure 2 reports on the relationship between upfront financial incentives and PEV adoption as a percentage of total annual vehicle sales. The upfront financial incentives are shown as a percentage of the price of a 2017 Nissan LEAF the best-selling PEV globally. This is done to show the relative purchasing power of the incentives in each country.

Interestingly, while financial incentives do appear to increase sales of PEVs, the relationship is not strong, with incentives in most jurisdictions shown leading to only a very modest increase in sales. Norway, the leading jurisdiction, sees five times more uptake than second place the Netherlands, with only 33% more incentives than Australia.

Energeia's previous analysis for esaa[10] has found that model availability is a key driver of demand in addition to financial incentives. The Norwegian case study identified that public infrastructure availability and congestion lane access were among the most significant other decision drivers.

Figure 2 – Relationship between PEV Incentive Levels and PEV Uptake



Source: Energeia Research; Note: * The third-party import market largely drives New Zealand's adoption rate.

Energeia's research has found that financial incentives do not only impact on driver purchase decisions, but they also impact on OEM decision making regarding PEV model allocation. Figure 3 displays the difference in PEV model availability over time across the UK, California and Australia.

In Energeia's view, the analysis reported in Figure 3, when compared to the summary of incentives in Table 1[11], shows that California, with the highest number of incentives, is getting significantly more models than the UK, which in turn offers more incentives than Australia, who is getting the lowest number of PEV models by comparison. Changes in Australian financial incentives for PEV adoption are therefore likely to not only increase customer adoption of PEVs, but also increase the availability of PEVs in Australia, which will itself lead to increased demand.

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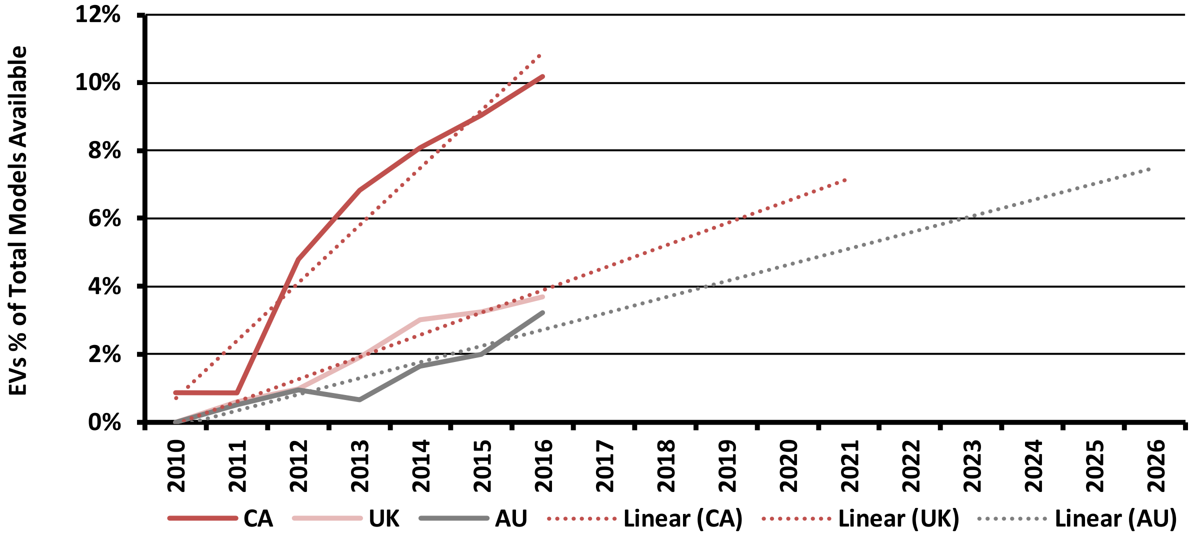
[10] Energeia (2015) 'Review of Alternative Fuel Vehicle Policy Targets and Settings for Australia, prepared by Energeia for the Energy Supply Association of Australia'. Access from: http://energeia.com.au/wp-content/uploads/2016/03/Energeia-Report-for-ESAA_-Optimal-AFV-Policy-Targets-and-Settings-for-Australia.compressed.pdf

[11] California = 10 different measures, both financial and non-financial, vs. Australia's 5 measures.

Figure 3 – Model Availability by Jurisdiction



Source: Energeia Research

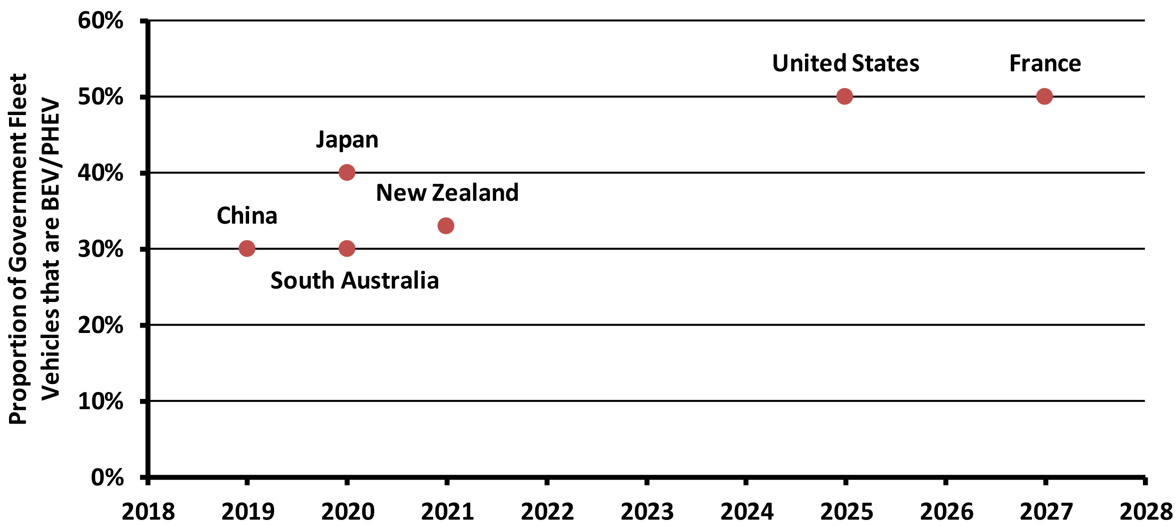
5.1.2.2 *PEV Procurement Targets*

Another key policy lever that Energeia identified for this project was government fleet purchase targets and incentives. Government fleets in leading jurisdictions are often the largest fleets in the country, and they therefore represent a significant volume.

Government action can increase vehicles sales directly, which leads to an increase in the secondary market as these vehicles are sold. Government bulk buying can be used to negotiate the availability of targeted PEV models that OEMs may not otherwise bring into the market, increasing demand from other fleets and drivers.

Energeia's findings regarding government PEV purchase targets and/or incentives are displayed in Figure 4.

Figure 4 – Government Fleet PEV Targets



Source: Energeia Research

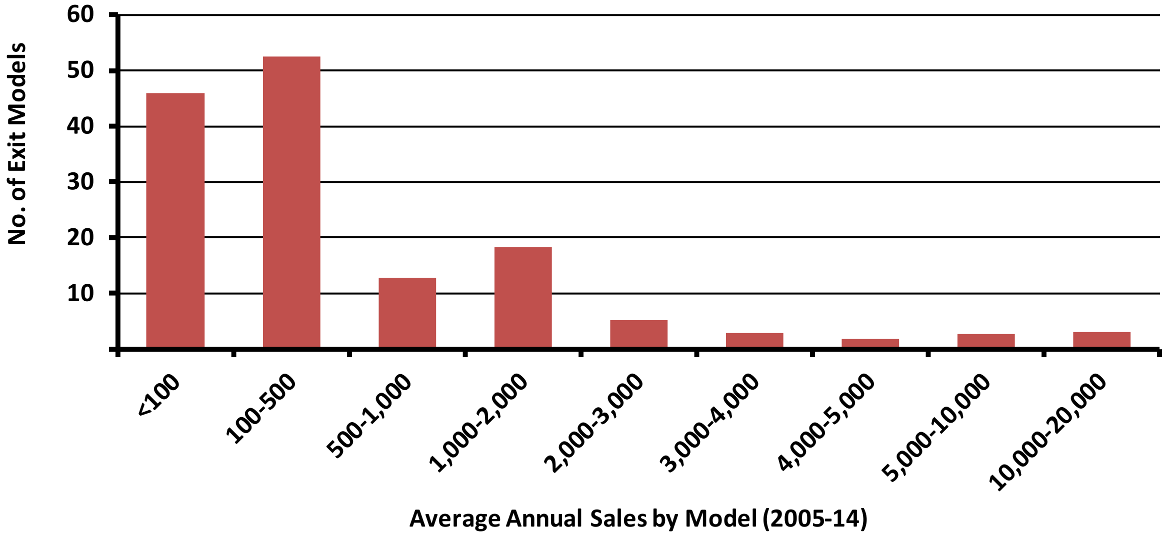
The research shows that some jurisdictions have committed to targets for electrifying their fleet, including the US who is targeting as much as 50% of its fleet be PEVs by 2020. Most of the countries, however, are targeting between 30% and 40% by 2019 to 2021, including South Australia. The key question is what impact these purchases are likely to have in Australia.

Interviews with OEMs conducted by Energeia as part of our work for the esaa[12] found that a minimum of 200 units in expected sales is needed to introduce a new PEV model into Australia. Therefore, if government or private fleet operators see an overseas model that will suit their fleet requirements, and they can promise 200 sales per year, OEMs may be willing to introduce that model into Australia.

Energeia also analysed Australian data on vehicle discontinuation to determine what level of sales may be required based on empirical data, which is displayed in Figure 5. The data shows that models with less than 500 annual sales are over 4 times more likely to be withdrawn.

Based on our discussions with Australian OEMs and analysis of vehicle discontinuation data, Energeia concludes that government and/or private fleet bulk buying amounting to 200-500 cars per year would be sufficient to access overseas right-hand drive models not yet made available in Australia.

Figure 5 – Discontinued Models in Australia vs 10-year Sales History



Source: Federal Chamber of Automotive Industries (2014), VFACTS

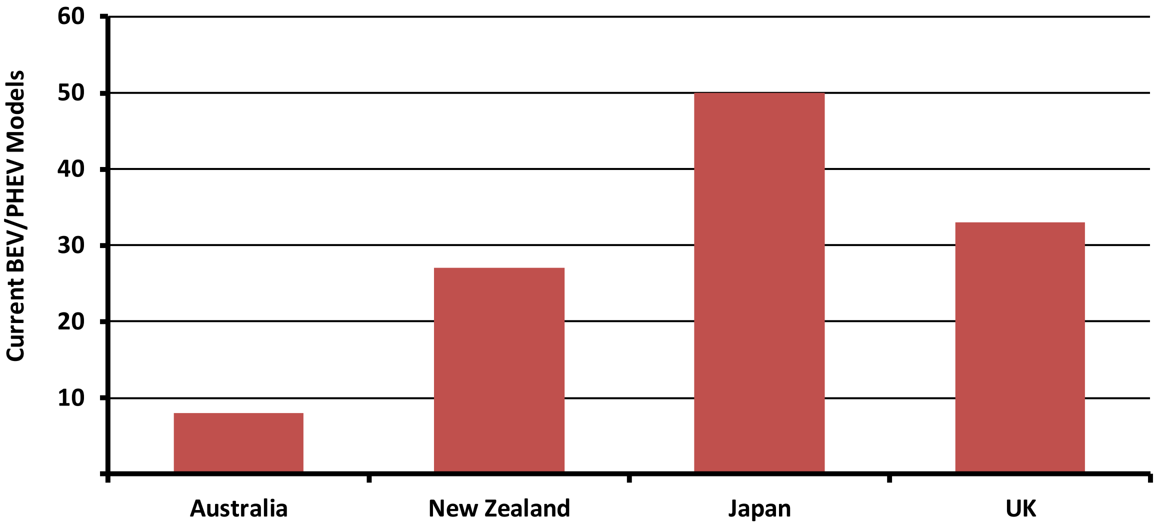
Our modelling shows that the more PEV options available, the higher the expected uptake of PEVs. The impact of new vehicles introduced through bulk buying targeted model introductions has been modelled as part of the future PEV uptake scenarios, reported in Section 6.3.1.

5.1.2.3 *PEV Import Regulation*

As shown in Figure 6, Australia's PEV model choice is minimal relative to other right-hand drive markets, such as Japan, the UK and New Zealand. The variability in the availability in PEV models between Australia (<10 models in 2016) and Japan and the UK (where between 4 and 5 times more PEV model choice is available for consumers), is partly explained by market size and partly by domestic manufacturing.

[12] Energeia (2015) 'Review of Alternative Fuel Vehicle Policy Targets and Settings for Australia, prepared by Energeia for the Energy Supply Association of Australia'. Access from: http://energeia.com.au/wp-content/uploads/2016/03/Energeia-Report-for-ESAA_-Optimal-AFV-Policy-Targets-and-Settings-for-Australia.compressed.pdf

Figure 6 – PEV Model Availability (2016) – Selected Right-Hand Drive Markets



Source: Energeia Research

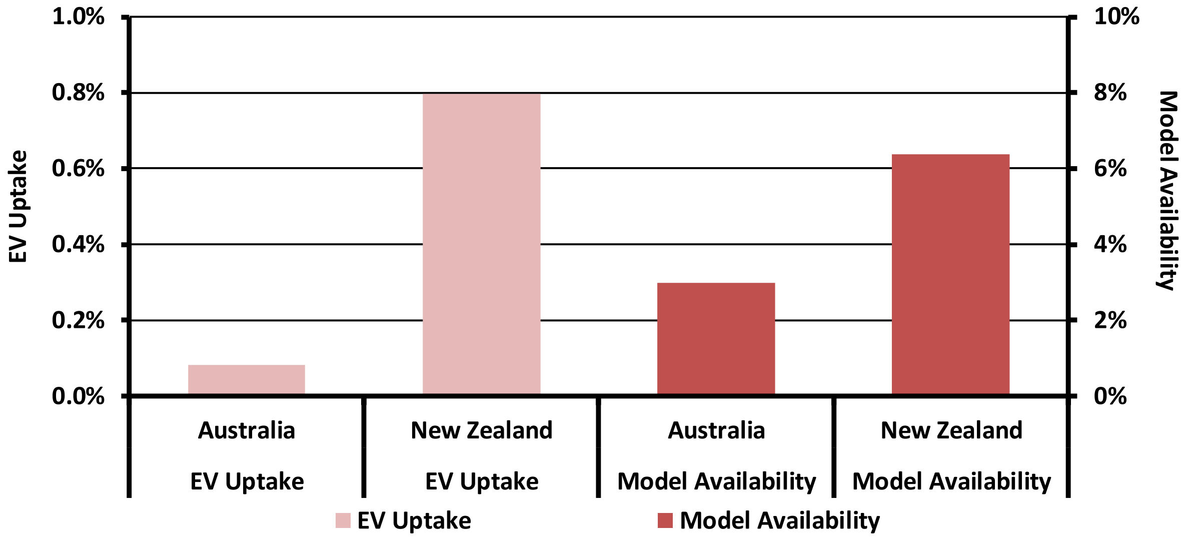
As well as market size, another difference to comparable right-hand drive markets is Australia's restriction on the third-party importing of motor vehicles for sale. The relevant comparator market is New Zealand, which is a smaller market than Australia, with no history of domestic vehicle manufacture. New Zealand's restrictions on third party car imports were removed in the late 1980s, and more than two-thirds of the cars now sold in New Zealand are "grey market" vehicles imported by brokers. The majority of imports by third-party are near-new, second-hand vehicles.

The ostensible rationale behind import restrictions in Australia was to protect the domestic car manufacturing industry, however, the 2015 Harper Review of Competition Policy, completed for the Productivity Commission, recommended a relaxation of third-party import restrictions given the decline in motor vehicle production. In 2016, the Federal Government partly adopted the recommended measures, allowing individuals to import a single near new (less than 12 months old and 500km mileage) motor vehicle without incurring customs import duties[13].

As shown in Figure 7, New Zealand has over two times the PEV model choice than Australia, despite having similar policy and regulatory settings with regard to PEV subsidies (i.e. almost no direct financial incentives), and over eight times the PEV uptake. Energeia's research has identified that model choice is a key driver of PEV uptake (refer to Section 6.3.1), and the effects of greater choice in NZ on uptake can be seen in the data.

[13] The Hon. Paul Fletcher, MP, February 2016 Ministerial Press Release: "More choice for car buyers and less red tape for the car industry under planned Government reforms to motor vehicle laws". Access from: http://minister.infrastructure.gov.au/pf/releases/2016/February/pf017_2016.aspx

Figure 7 – Model Uptake vs. Availability (2016) – Australia compared to New Zealand



Source: Energeia Analysis

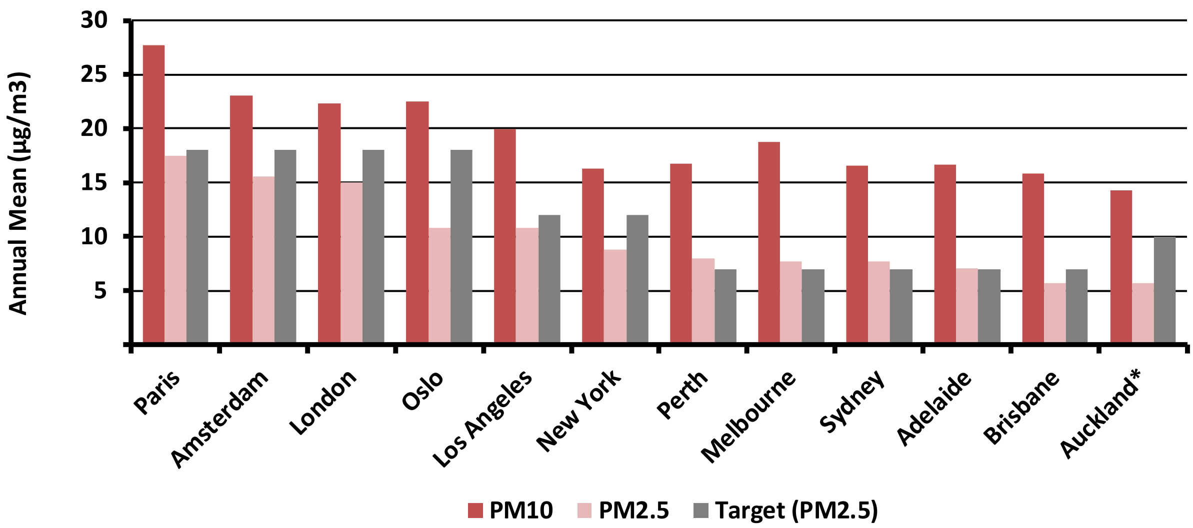
Should the Federal Government adopt further Harper Review recommendations and allow a secondary market in imported PEVs to emerge, then Energeia would expect model availability and overall uptake in Australia to increase in line with the New Zealand experience reported in Figure 7.

5.1.2.4 *Vehicle Efficiency Regulations*

Internal Combustion Engine (ICE) vehicle emissions include CO_2, SO_x, NO_x and particulates including PM10 and PM2.5. The transportation sector is typically the largest or second largest source of emissions in most OECD countries, making it a prime target for emissions reduction efforts (see P2.5 targets for major international cities in Figure 8). The impact of vehicle emissions on human health has been a key driver of emissions regulation in Europe and the US, and in particular, by the California Air Resource Board (CARB).

Energeia's research for this project identified vehicle emissions regulations as a key policy lever driving PEV uptake in leading overseas jurisdictions. Although policymakers have targeted CO_2, SO_x, NO_x and PM10 and PM2.5 emissions for their negative environmental and human health impacts, Energeia found that the key emissions regulations programs pertinent to transportation largely focused on fuel efficiency standards.

Figure 8 – Air Quality Targets and Actuals for Major International Cities



Source: Energeia Analysis

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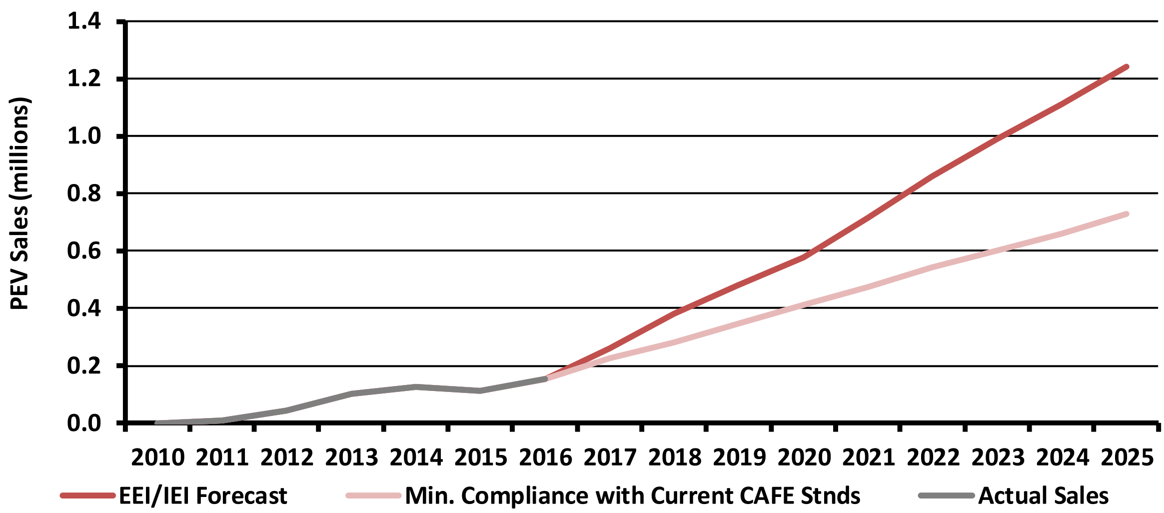
Fuel Efficiency – US Experience

The Corporate Average Fuel Efficiency (CAFE) standards were initially adopted in the US in the mid-1970s as a response to multiple spikes in oil prices. Congress passed the CAFE standards in 1975, which mandated manufacturers to increase fuel economy over the next decade to 1985 (achieving targets of 27.5 miles per gallon). The standards were tightened again over the last decade (fuel efficiency targets were increased in 2007 to a target of 35.5 mpg by 2016 and in 2011 to reach 54.5 mpg by 2025[14]).

The CAFE standards enable OEMs to drive PEV sales in lieu of improving the fuel efficiency of their ICE fleet. OEM's are free to choose the most cost-effective approach to achieve compliance. The estimated impact of the CAFE standards on PEV sales is shown in Figure 9. The numbers suggest that CAFE standards will be responsible for driving 53% of total PEV sales in the US by 2025.

Energeia's research found that the trend in US CAFE standards is representative of moves over the last decade to improve energy security, human health and greenhouse gas emissions globally. The number of countries with fuel economy standards has increased from 4 to 10, and standards now cover 80% of all new vehicles sold[15] in over two thirds of the world's vehicle markets. There is also increasing harmonisation of standard design, monitoring and enforcement.

Figure 9 – Impact of Energy Efficiency Standards (US Example)



Source: Edison Electric Institute (2017). 'PEV Sales Forecast through 2025 and the Charging Infrastructure Required'

Fuel Efficiency – California Experience

CARB is responsible for the development and promotion programs to mitigate the effects of climate change. Importantly, they are the leading state agency in protecting California's residents from the dangers associated with air pollution.

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[14] Regulation of the CAFE standards was moved from the Department of Transport to the Environmental Protection Agency in 2007. The EPA introduced the concept of "emissions credits" for the introduction of new technologies, including BEVs and PHEVs. The credits from high efficiency vehicles, such as PEVs, can be used to off-set the overall fleet average across any given manufacturers sales, allowing the manufacturer to meet the standard whilst still selling low mileage vehicles.

[15] ICCT (2017), '2017 Global Update: Light-Duty Vehicle Greenhouse Gas and Fuel Economy Standards'. Accessed from: https://www.theicct.org/sites/default/files/publications/2017-Global-LDV-Standards-Update_ICCT-Report_23062017_vF.pdf

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In response to scientific studies demonstrating the linkage between tailpipe emissions and negative human health impacts, particularly in the Los Angeles Air-Quality Control District, CARB has set increasingly stringent standards for vehicle emissions in California over the last 40 years.

CAFE standards finally caught up with CARB standards in 2004, and CARB has accepted compliance with CAFE standards as satisfying California emissions standards.

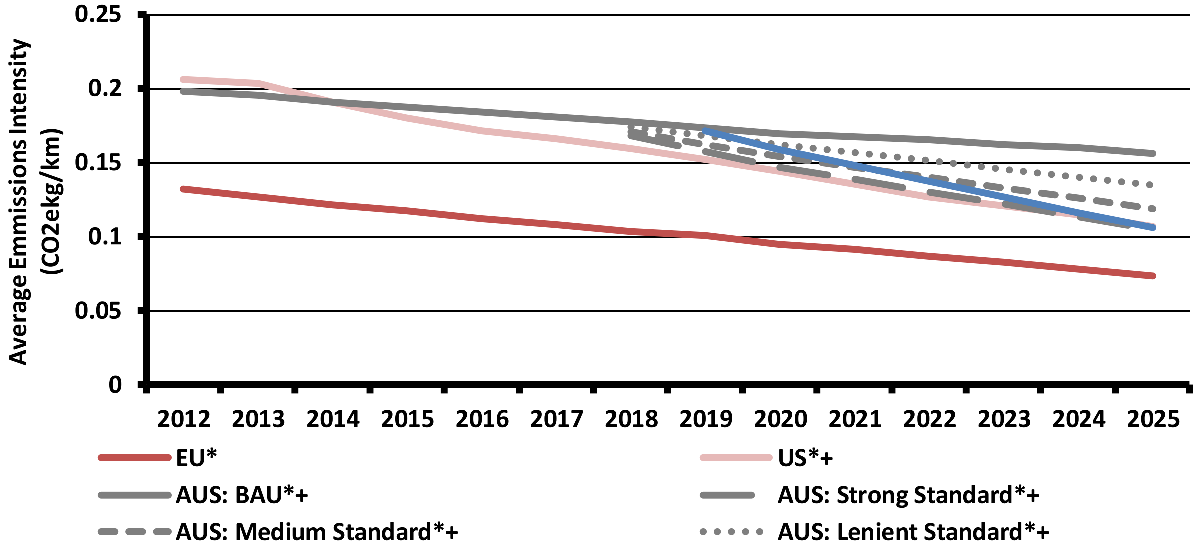
Fuel Efficiency – Australian Experience

A range of potential emissions pathways was proposed by the Climate Change Authority (CCA) in 2014[16], as outlined in Figure 10.

The Ministerial Forum on Vehicle Emissions is currently considering adopting the 105g/km standard, and released a Draft Regulation Impact Statement in 2016[17] that examined a range of 2025 fleet average efficiency targets – 105, 119 and 135 gCO_2/km. A target of 105g/km had the lowest cost of abatement of the three options considered and would bring Australia into line with US targets for 2025 (comparable to the CCA's Strong Standard), whilst saving motorists in excess of $500 p.a. in fuel usage.

Based on the above research and analysis, Energeia expects that implementation of the 105g/km would underpin a significant increase in PEVs in Australia driven by OEMs more aggressively marketing their PEVs in order to meet their compliance targets at least cost. In terms of the overall effect in Australia, we expect a similar impact to the US forecast presented in Figure 10 in percentage terms, after the US' higher level of direct financial subsidies and PEV model availability are taken into account.

Figure 10 – Current Australian Vehicle Emissions Policy



Source: Climate Change Authority (2016), 'Light Vehicle Emissions Standards for Australia Research Report'; Note: * = Passenger Vehicles; + = Light Vehicles

[16] Climate Change Authority (2014), 'Light Vehicle Emissions Standards for Australia'. Accessed from: http://climatechangeauthority.gov.au/files/files/Light%20Vehicle%20Report/Lightvehiclesreport.pdf

[17] Department of Infrastructure and Regional Development (2016), 'Improving the efficiency of new light vehicles: Draft Regulation Impact Statement'. Accessed from: https://infrastructure.gov.au/roads/environment/forum/files/Vehicle_Fuel_Efficiency_RIS.pdf

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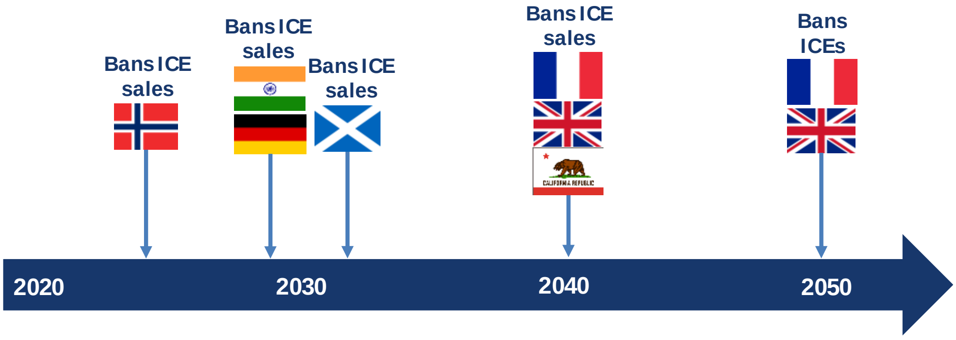
5.1.2.5 *ICE Bans*

Countries around the world are increasingly setting timeframes for sunsetting ICEs in their vehicle fleets, placing bans firstly on the sale of new ICEs as of a given date, before banning ICEs from the road entirely. Figure 11 shows new ICE sales are typically banned 10 years prior to completely banning ICEs on the roads. This implies a curtailing of vehicle lifetimes, which are 20 years in Australia, as the sales ban approaches.

Figure 11 – ICE Bans – Globally



Source: Energeia Research

The importance of the growing number of countries banning sales of ICEs for Australia is most likely due to the impact of the bans on OEM strategy. If the trend continues, and other major jurisdictions including China, the US and Japan follow-suit, then OEMs are increasingly likely to consider either removing ICEs from their vehicle portfolio, or at the very least stop investing in them, leading to increasingly inferior products.

5.1.3 Charging Infrastructure Deployment Levers

Energeia's review of the policy and regulatory framework of leading international jurisdictions by PEV market share identified publicly funded rollout programs, regulated rollout programs, matching grants, and concessionary loans as the key policy levers for ensuring public infrastructure availability.[18]

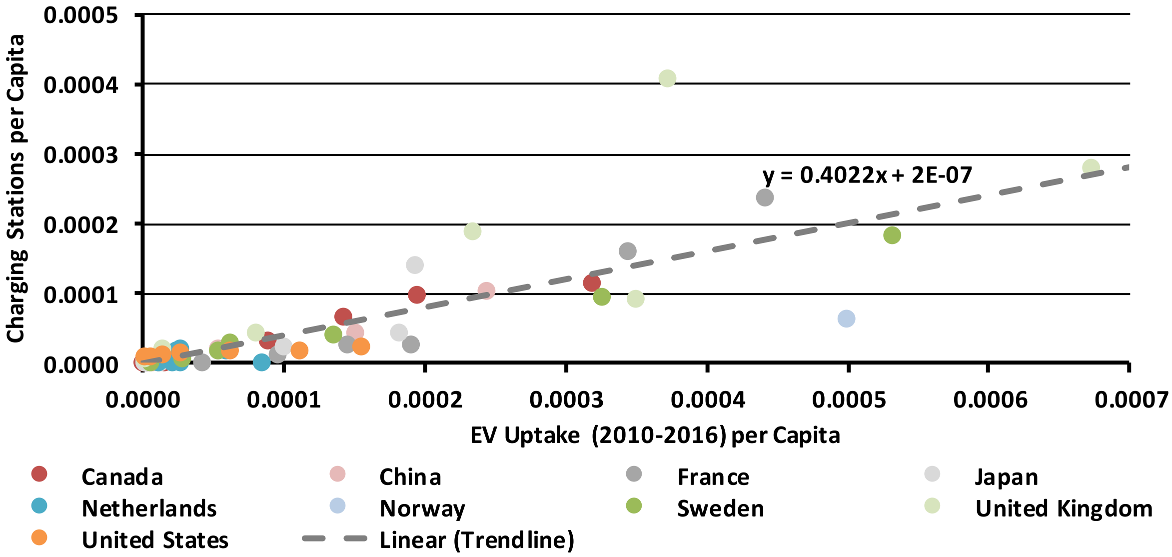
5.1.3.1 *Public Infrastructure Availability*

Energeia's research and analysis of international jurisdictions found that public charging infrastructure was a necessary but not sufficient factor in PEV adoption. In other words, the lack of public charging infrastructure will hold back PEV adoption, but it will not, by itself, driver greater levels of PEV adoption.

Figure 12 displays the relationship between per capita public charging stations and PEV adoption. The relationship is there, but it is not strong. The UK example sees the relationship evolve over time, with the right most data point falling on the industry average line. France's experience is closer to the industry average.

[18] See Glossary for definition of policy levers.

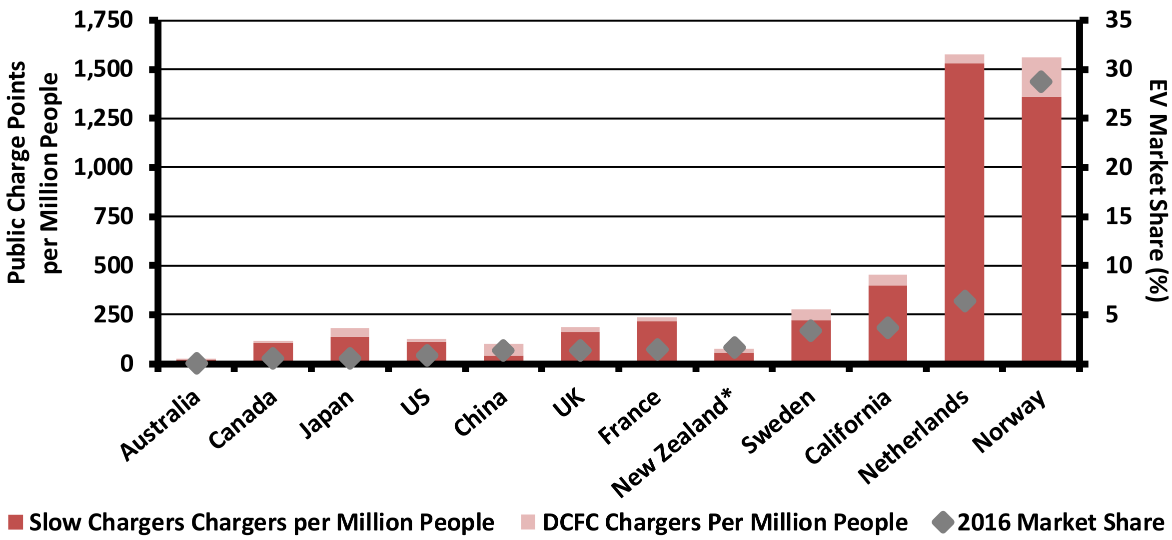
Figure 12 – Per capita relationship between EVSE Deployment and PEV Uptake



Source: IEA (2017), OECD, Energeia Analysis

Energeia investigated whether the mix of public charging infrastructure might also play a role in its impact on PEV adoption. The data shown in Figure 13 is noisy, but Energeia notes that Norway, which is the international leader in PEV adoption, has a much higher level of DCFC than the Netherlands. Sweden, the number three jurisdiction by annual sales percentage, also has a relatively high percentage of DCFCs.

Figure 13 – Public Chargers vs. PEV Uptake



Source: IEA (2017); Note: * The third-party import market largely drives New Zealand's adoption rate.

5.1.3.2 *Public Charging Infrastructure Support Mechanisms*

Energeia's research found virtually all public charging infrastructure deployed to date has been government subsidised. Differences in the number of Electric Vehicle Supply Equipment (EVSE) per PEV between various jurisdictions reported in Figure 13 were found to be due to differences in program targeting and the overall level of support.

Table 2 lists the sponsor of public charging infrastructure deployment programs across a range of overseas jurisdictions and reports on their mechanism of support.

Table 2 – International Public Infrastructure Deployment Programs Funding Sources and Mechanisms

Country	Deployment Investment Source	Mechanisms of Support
China	• National government owned utility • Automaker	• Utility programs • Grants to local governments
France	• National Government • National government owned utility	• Local governments apply for grants
Germany	• Federal government	• Subsidies for 60% of costs for all eligible businesses
Japan	• Government-automaker partnership	• Grants to local governments and highway operators
Netherlands	• National Government • State government owned utilities	• Contracts tendered to businesses • Contracts tendered to businesses
Norway	• Federal Government organisation	• Quarterly calls for proposals for targeted projects
United Kingdom	• National Government	• Municipalities apply for grants; installers reimbursed • Grants and tenders administered by public body
United States	• Federal Government	• Matching grants for local governments

Source: ICCT (2017)

Program targeting included deployment of DCFC networks to address range anxiety and enable nation-wide PEV access, and deployment of L2 chargers for drivers without a permanent place to park. Programs targeting range extension networks tended to develop projects and tender for this work, while programs targeting drivers without a permanent place to park offered rebates and incentives to incentivise establishment of chargers in response to employee or resident requests for access a charging station to be installed.

In the case of the two leading jurisdictions in terms of EVSE per PEV, Norway and the Netherlands, Norway's deployment was primarily driven by the state funded Enova, which developed a national public charging infrastructure plan and tendered for private companies to build and operate it. The Netherlands adopted a different, more decentralised approach which included major initiatives by state owned utilities, national and regional governments.

5.1.4 Australian Benchmarking

Energeia reviewed PEV policy and regulatory frameworks and settings across Australian State and Federal Governments to identify their alignment with international best practice and each other.

Table 3 presents the results of our research, which shows states other than VIC and WA implementing more PEV support mechanisms than the Federal Government. Energeia's research has found that in most cases, there are generally more supportive PEV policies and regulatory settings at the state level than at the federal level.

Table 3 – Australian Government Policy Actions and Impacts – Federal and State

Policy Type		AUS	ACT	SA	VIC	NSW	QLD	WA	Score
Sales	Sales per 10,000 vehicles (2016)	7	18	9	8	7	5	3	
Regulation	Building Code Changes (EVSE)*	✗	✓	✗	✗	✗	✗	✗	1
	Vehicle Emission Standards	✗							0
Financial Incentives	Direct Vehicle Incentive	✓	✗	✗	✗	✗	✗	✗	1
	Stamp duty/registration discounts **	✗	$2,110	✗	$100	<$250	$660	✗	4
	Charging Infrastructure Incentives***	✓	✓	$5,000	✗	✓	✓	✗	5
	Government Fleet Incentives	✓	✗	✗	✗	✗	✗	✗	1
	Toll Lane Exemption		✗	✗	✗	✗	✗	✗	0
	Discounted Parking		✗	100%	✗	49%	50%	✗	3
	Private Charger Install Rebate (L2)	✗	✗	✓	✗	✗	✗	✗	1
	Private Charger Install Rebate (L3)	✗	✗	✓	✗	✗	✗	✗	1
	Free Govt Charging (L2)	✗	✗	✓	✓	✓	✓	✓	5
	Free Govt Charging (DCFC)	✗	✗	✓	✓	✗	✓	✓	4
Non-Financial Incentives	Govt Fleet Trial/Initiative	✓	✓	✓	✗	✓	✓	✓	6
	Vehicle Lane Privileges		✗	✗	✗	✗	✗	✗	0
	Information and Education	✓	✓	✓	✗	✗	✗	✗	3
Score		5	5	8	3	5	6	3	35

Source: Energeia Research; Notes: * Building code changes to require conduit in all parking areas in new buildings to support charging; ** Estimated discounts are for a $60,000 electric vehicle in comparison to a $60,000 medium sized petrol or diesel vehicle; *** SA charging incentive not available outside of Adelaide City, maximum incentive shown for installing level 3 charger

The following sections discuss current Australian policy and regulator settings in light of the practice of leading international jurisdictions.

5.1.4.1 *PEV Uptake Support Levers*

Australian PEV purchase incentives range from zero, offered by the Federal Government and WA, to over $2,000 by the ACT. Most of the states, however, fall between $100 and $700.

While Australia's direct, upfront incentives are relatively small compared to leading jurisdictions, the Australian Tax Office's (ATO) work related tax deduction policy for individuals does offer an indirect incentive by assuming an ICE operating cost.

The government has simplified the car expense deductions for 2015–16, to a fixed 66 cents per kilometre for all motor vehicles, regardless of the size of the engine (or the type of drive train), with a maximal mileage of 5,000 work related kilometres in a tax year. Energeia estimates that this policy would represent a saving to a driver on the top income tax bracket of $1,485, assuming they were able to claim at the kilometres cap.

Only South Australia currently has a firm government PEV vehicle purchase target, although other states have been considering implementing a target.

5.1.4.2 *Public Infrastructure Deployment Levers*

Support for public charging infrastructure is the strongest in South Australia, where Adelaide is offering up to $5,000 to encourage the installation of public charging infrastructure within the city. ACT, New South Wales and Queensland are also offering incentives for public charging infrastructure.

Energeia's research found examples of electricity distribution network operators in the ACT and Queensland rolling out public charging infrastructure, but on an unregulated basis only. Other DCFC network rollouts, such as those by the NRMA., have been completed independent of government support.

Most states are offering free charging at government public charging stations, except the ACT. However, Energeia was unable to identify any government policy statements regarding the number of government owned public charging stations that would be deployed over what timeframe.

5.1.4.3 *Vehicle Regulations*

The regulation of third-party vehicle imports and the setting of vehicle fuel efficiency standards and emissions regulations are the realm of the Federal Government, which are currently considering changes to existing importation and fuel efficiency regulations that could see them align to New Zealand and US settings, as discussed in Sections 5.1.2.3 and 5.1.2.4, respectively.

5.2 Demand for Public Charging

Energeia's research and analysis of the international industry literature has found that future demand for charging in Australia is likely to be a function of the number and type of PEVs on the road, PEV driving and parking behaviour, and the availability, convenience and cost of public charging infrastructure.

Charging convenience is defined here as the amount of effort required by the driver to ensure that their vehicle battery is sufficiently charged to meet 100% of their travel requirements. The two main types of inconvenience include extra driving required to locate a free charger and extra time spent waiting for a recharge.

The following sections report on the results of Energeia's research and analysis of the key drivers of Australian demand for public charging infrastructure, overseas benchmark estimates, and public domain forecasts.

5.2.1 Drivers of Charging Behaviour

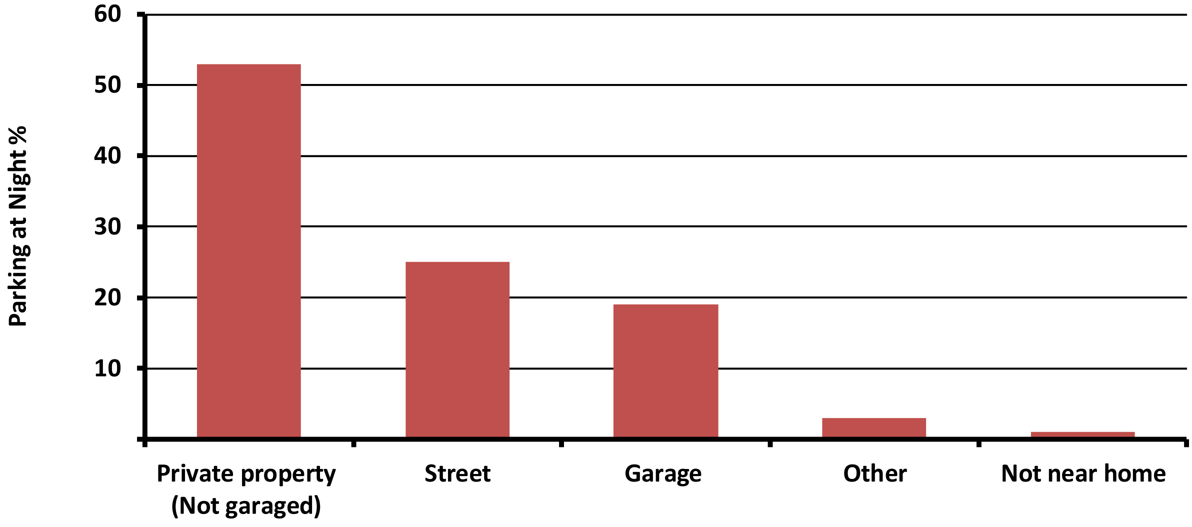
Energeia's research into drivers of charging behaviour found that PEV drivers prefer to charge in the most convenient way possible. This means that drivers will choose to charge at home as much as possible and use public charging options that are the most convenient when necessary. PEV driving range determines when and where PEV drivers charge in addition to dedicated home or workplace charging.

Drivers without access to home charging must rely entirely on public charging. The lack of a reliable public charging infrastructure limits PEV uptake to drivers with access to a dedicated parking spot, which is typically at home, but may also be at work for commercial vehicles. The establishment of public charging infrastructure in overseas markets is enabling drivers without dedicated charging posts to begin adopting PEVs.

5.2.1.1 *Access to Private Parking*

Figure 14 shows the percentage of drivers that do not have access to dedicated parking overnight. Assuming that drivers could install charging on their own private property as well as their garage, then around 25% of drivers would require public charging infrastructure for all their charging needs.

Figure 14 – Overnight Parking Availability



Source: UK National Travel Survey (2016). Access from: https://www.gov.uk/government/statistics/national-travel-survey-2016

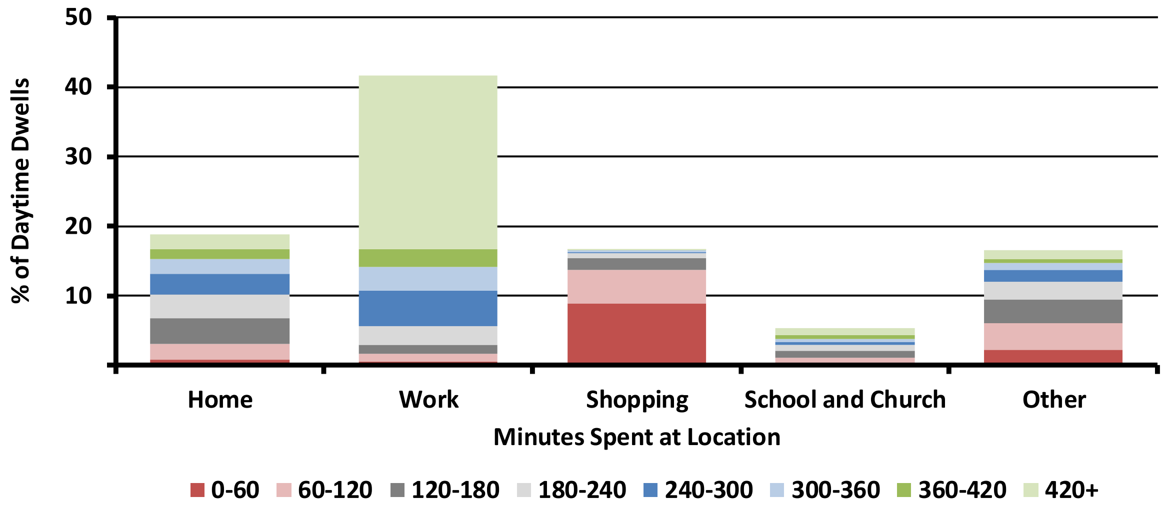
No comparable data was identified for the Australian market, and one of our key recommendations is for ARENA and the CEFC to consider funding research to determine Australia's need for public charging infrastructure for drivers without access to a dedicated parking spot. For those without access to dedicated home charging, demand for public infrastructure will be determined by their driving and parking patterns, and the availability and performance of public charging infrastructure, which are discussed in the following sections.

5.2.1.2 *Parking Patterns*

Vehicle parking is the key driver of charging behaviour because it determines the viable options for recharging a PEV. The shorter the parking duration, the lower the amount of recharge possible. At today's battery sizes and L2 charge rates, recharging an 80% depleted battery will require 6-8 hours. For drivers without a dedicated home or workplace parking spot, the data shows public workplace charging to be the next best option.

Figure 15 displays data from a University of Monash study of parking behaviour, which confirms that the workplace is the only viable location for PEV drivers to fully recharge their vehicles.

Figure 15 - Daily Parking by Location and Minutes

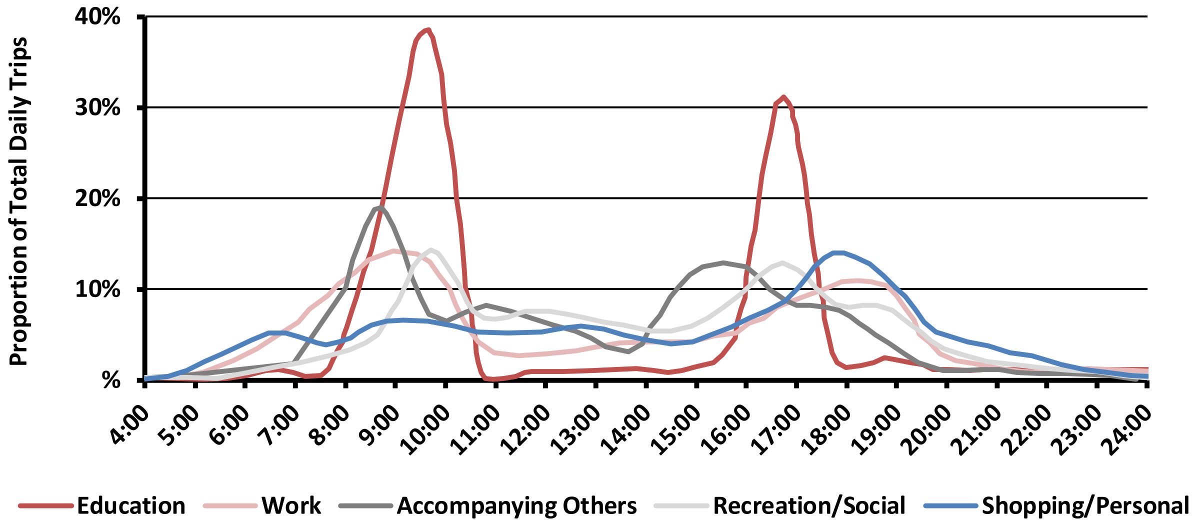


Source: Institute of Transport Studies, Monash University (2014), 'A spatial study of parking policy and usage in Melbourne, Australia'

Most of the other typical parking locations in a given day are for much shorter duration. Even with widespread Level 2 chargers[19] available, drivers would need to be plugging in at almost every stop to keep their vehicles charged.

Figure 16 presents data from the Queensland Travel Survey, which captures the distribution of parking by time of day. This dataset helps inform charging network requirements by identifying the timing of demand for public Level 2 charging. Estimates of chargers per Level 2 charging network customer can be developed based on utilisation models, which rely on assumptions of daily driving distances, arrival times and recharge rates.

Figure 16 – Cars Parked as a Proportion by Arrival Time – Queensland Regional Town Example



Source: 2014 Rockhampton Region Household Travel Survey. Accessed from: https://data.qld.gov.au/dataset/2014-rockhampton-region-household-travel-survey/resource/9fae882b-6976-436d-ae0e-5c6f0c477654

Energeia's research of leading overseas markets found a heavy emphasis on where vehicles are parked during the day to inform targeting for L2 public charging. However, our view is that the focus on L2 public charging to date in leading overseas markets has been driven by the state of charging technology at the time, with up to 7.4 kW L2 public charging being more convenient than frequent stops at a public 40 kW DCFC equipment.

As charging technology has evolved, and DCFC has reached 350 kW levels and is increasingly being rolled out, it has become more competitive in terms of cost-to-serve, and convenience, as drivers become more confident they can easily find an open DCFC location than an open L2 charger location. This discussion is revisited in 5.3.2 on charging business models.

5.2.1.3 *Driving Patterns*

Travel requirements relative to PEV driving ranges determine the level and timing of demand for DCFC public charging by all PEV drivers regardless of their access to dedicated parking. Long distance travel can realistically only be served by public DCFC charging due to the length of time L2 charging takes.

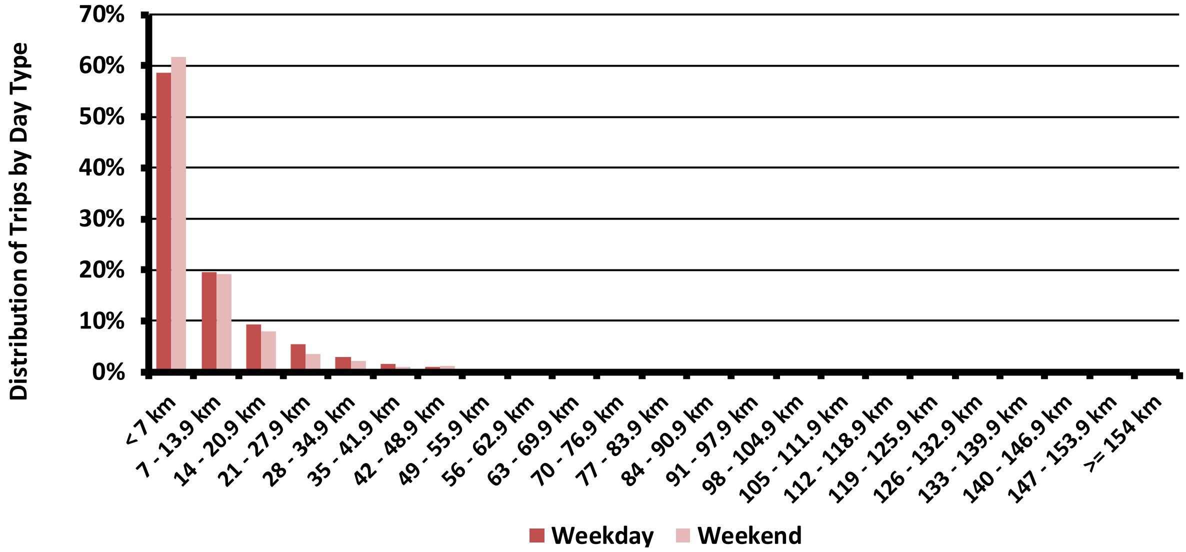
Travel distance is ideally specified as the distance travelled between charging, however, data limitations mean that travel is more typically discussed in terms of single trip distances, and daily average travel distances. In reality, several trips may be tied together into a 'tour', and a driver may make several tours per day.

One of Energeia's recommendations to ARENA and the CEFC is to consider funding research of detailed travel requirements to enable optimal design and development of Australia's public charging infrastructure.

[19] Charger types are defined in Table 13 in Section 5.3.3.1.

Figure 17 displays data from a Victorian travel study from 2013, which shows that more than 99% of daily trips were under 50 km, implying a round trip distance of 100 km, which is well within the range of new PEVs. Actual demand for public charging infrastructure will be higher due to drivers forgetting to charge their vehicles prior to making larger trips or tours.

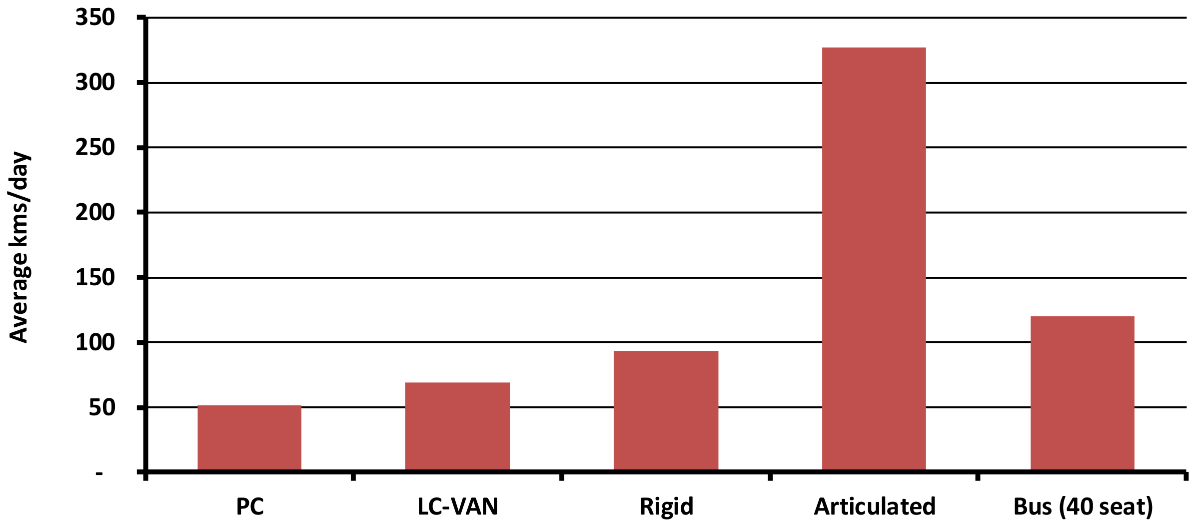
Figure 17 – Distribution of Individual Weekday/Weekend Trips



Source: Victorian Integrated Survey of Travel & Activity (2013), Melbourne Metropolitan Example

Distributions in Figure 17 mainly cover passenger vehicles, which the ABS reports travel an average of 50 km per day across Australia. Other types of vehicles, particularly commercial vehicles, travel greater distances on average, as shown in Figure 18. While most are likely to have larger ranges to reduce the need for frequent recharging, longer distance vehicles such as articulated trucks and busses, are may rely on inter-day charging.

Figure 18 – Average Driving Per Day – By Driver Type

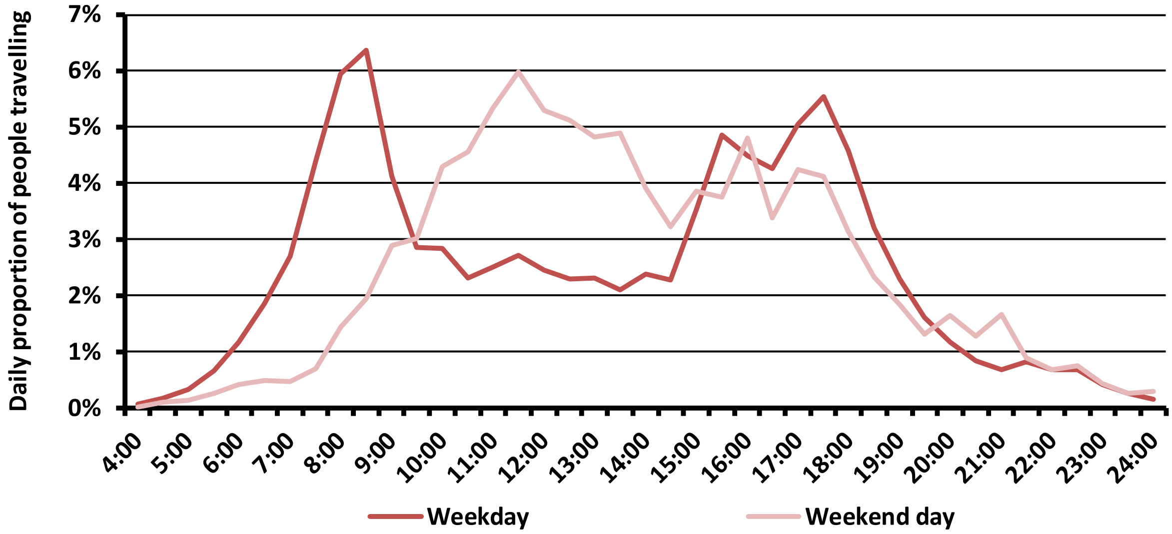


Source: ABS (2016), 92080DO001_1231201610 Survey of Motor Vehicle Use, Australia; Energeia Analysis; Abbreviations: PC = Passenger Car, LC-VAN = Light Commercial Van

In addition to access to private parking and daily driving distances, trip timing is a key driver of demand for DCFC charging, as drivers are more likely to be looking for a DCFC when they are on the road.

Energeia's research of Australian driving patterns found data for Victorian drivers, which is presented in Figure 19. The data shows a significant difference between the shape of demand by day type.

Figure 19 – Cars on the Road – Melbourne Week and Weekend Days



Source: Victorian Integrated Survey of Travel & Activity (2013), Melbourne Metropolitan Example

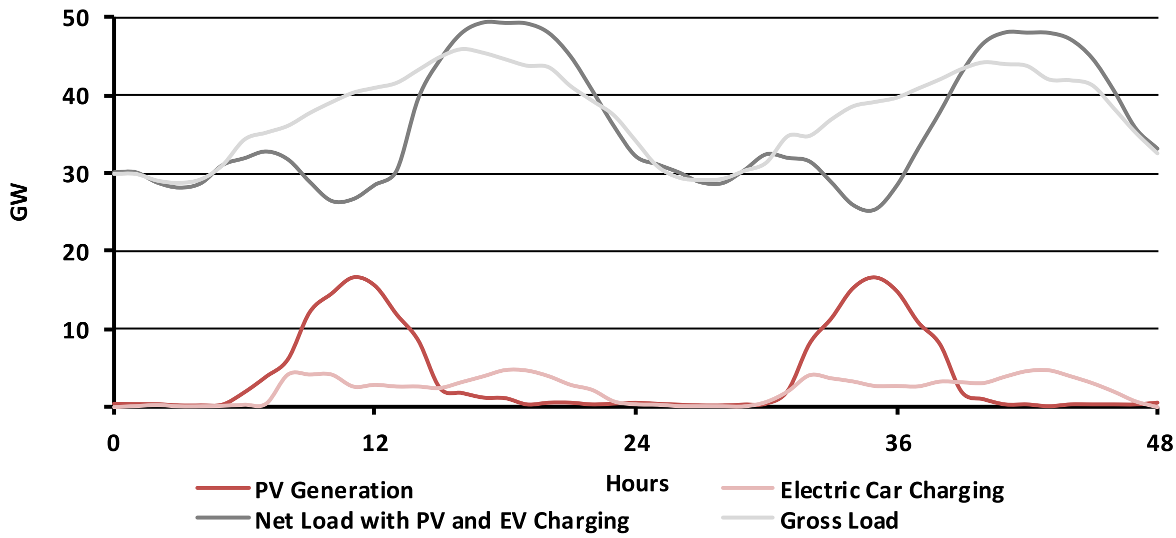
Energeia used the data on the timing of cars on the road in Figure 19 to inform its model of demand for DCFC, which is discussed in Section 6.3.3.

5.2.1.4 *Power Grid Interactions*

As the largest single residential load, PEVs could have a significant cost impact on electricity grids. However, they could also help keep costs when used to help manage peak demand or over-generation of solar PV. Energeia expects strong economic drivers will increasingly lead to management of PEV charging loads where possible. We expect this to mainly impact L2 charging, as we do not expect DCFC charging to be flexible.

Figure 20 displays a typical power system load pattern (gross load) over the course of a typical 48-hour period given unmanaged PEV charging. The timing of PV generation and PEV consumption are out of alignment, resulting in higher peaks and steeper load ramps.

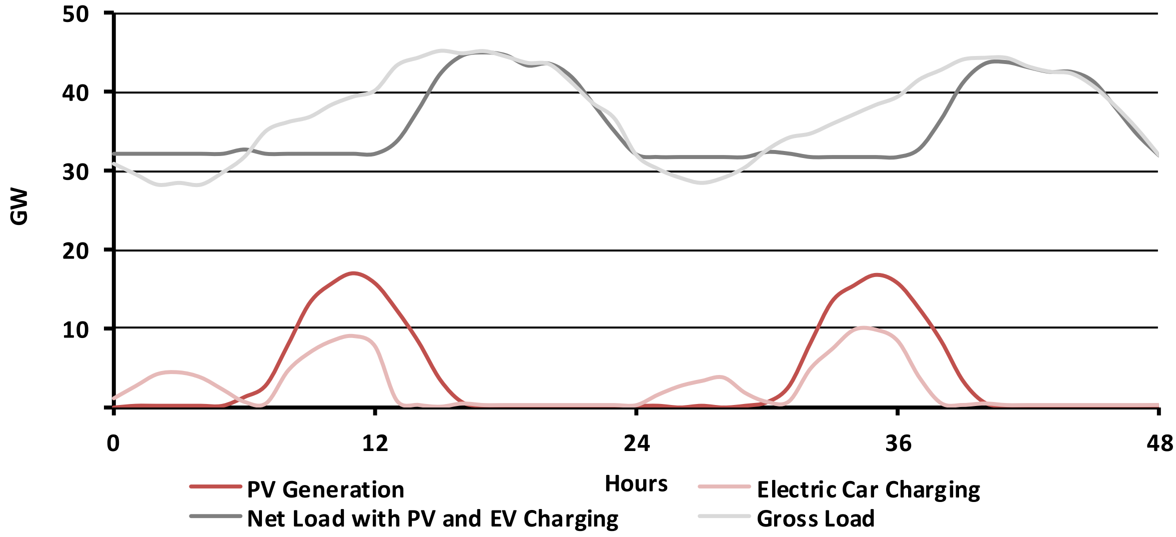
Figure 20 – Unmanaged Solar PV Interactions



Source: IEA (2017), 'Global EV Outlook 2017'

Managing the charging load, through either price or control signals, can keep net system load and ramping rates lower, while increasing minimum demand and utilisation, as shown in Figure 21. The result for the power system is significantly lower costs, which will create a strong industry incentive to implement PEV charging management solutions.

Figure 21 – Managed Solar PV Interactions

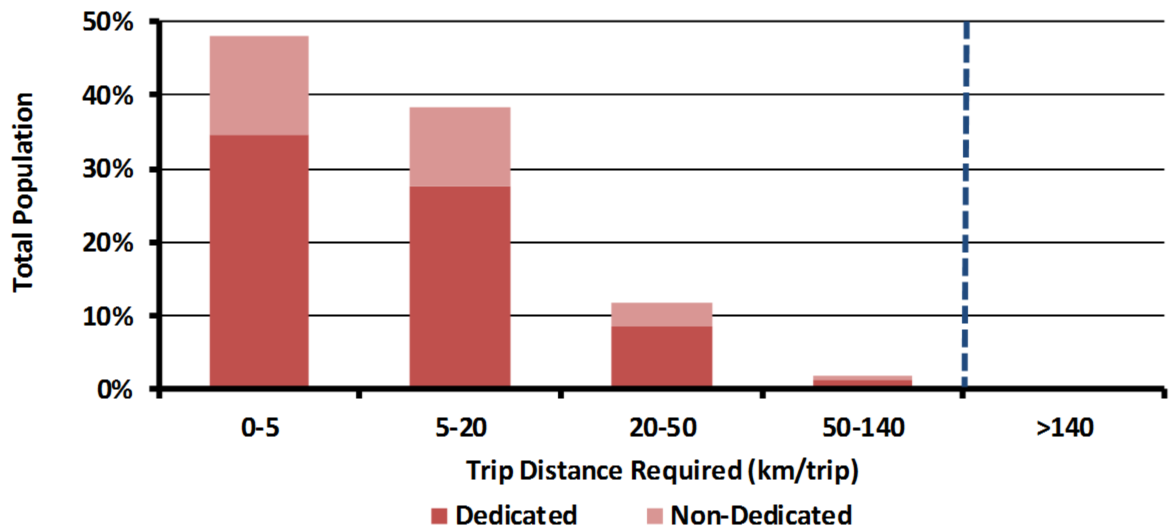


Source: IEA (2017), 'Global EV Outlook 2017'

5.2.2 Key Charging Segments

Based on the research and analysis carried out for this project, Energeia developed a charging market segmentation framework, which is shown in Figure 22.

Figure 22 – Australian Charging Market Segmentation



Source: Energeia analysis

This framework uses trip distance and dedicated parking to segment the charging market into the following key segments and associated charging requirements:

1. **Drivers with Access to Dedicated Charging** – This segment represents around 70% of the vehicle transportation market and will require public charging for around 1% of long-haul trips.
2. **Drivers without Access to Dedicated Charging** – This segment represents around 30% of the market and will require public charging for 100% of their charging requirements. 99% of their trips could be satisfied using L2 public charging at work, or public DCFCs.

The ultimate level of demand is driven by the number of PEVs, which is in turn a function of total annual vehicle sales, and the rate of PEV uptake.

5.2.3 Drivers of Future Demand for Charging

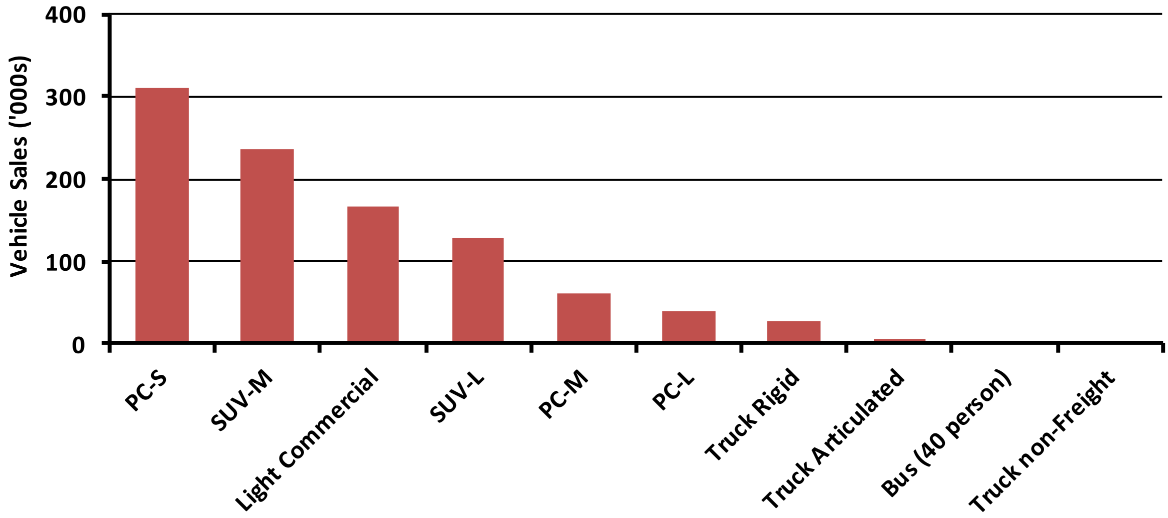
Energeia research carried out for this project found that future demand for charging in Australia will depend upon a number of key factors impacting on PEV adoption and vehicle technology evolution, which are analysed in the following sections.

5.2.3.1 *New Vehicle Sales (Addressable Market)*

Energeia's previous research and analysis found that uptake of PEVs is driven by annual vehicle sales and the uptake rate of PEVs within the vehicle fleet.

New vehicle sales totalled almost a million vehicles per year in 2016, as shown in Figure 23, with the leading categories being Small Passenger Cars (PC-S), Medium Sports Utility Vehicles (SUV-M), Light Commercial, which together accounted for over 70% of all sales.

Figure 23 – Vehicle Sales by Class (2016)



Source: Federal Chamber of Automotive Industries (2016), VFACTS; Abbreviations: PC = Passenger Car – Small, Medium and Large; SUV = Sports Utility Vehicle – Medium and Large

Growth in passenger vehicles sales have remained relatively constant over the past 10 years at 1.2% per annum.[20] There have been some noteworthy inter-category trends in Australia's annual vehicle sales data including transitioning from large passenger cars to sport utility vehicles.

[20] ABS, Sales of New Motor Vehicles, Australia, December 2017

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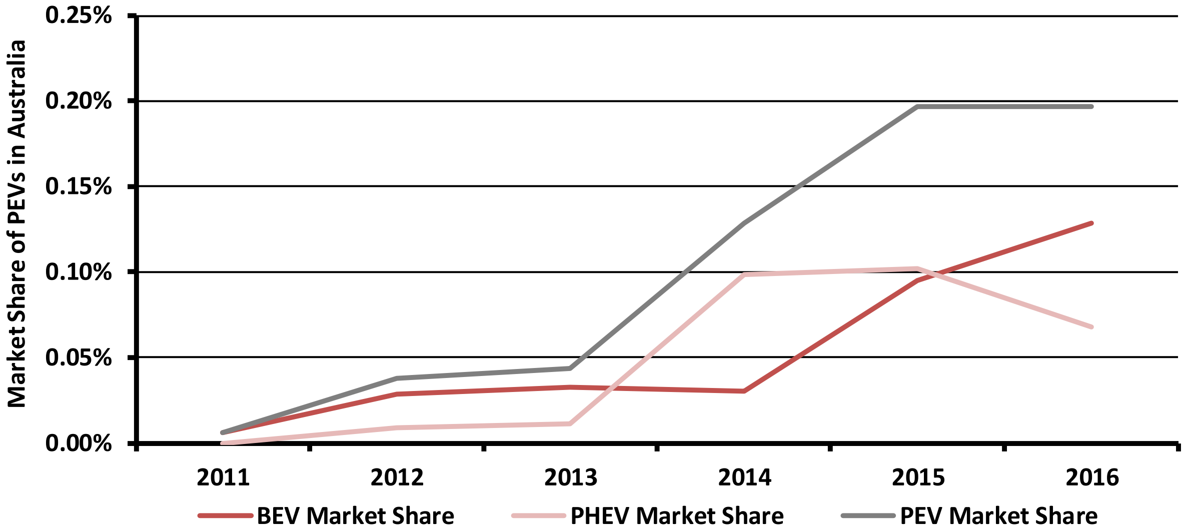
5.2.3.2 *PEV Adoption Rate*

The rate of PEV adoption in Australia over time is shown in Figure 24.

Figure 24 – Australian PEV Adoption Rate by Year



Source: Federal Chamber of Automotive Industries (2016), VFACTS; Energeia Research

Current trends show Australia's rate of PEV adoption is rising, albeit from a very low base. The key drivers of forecast vehicle adoption rates are analysed in the following sections. Energeia's forecast of adoption rates over time by scenario is discussed in Section **Error! Reference source not found.**.

5.2.3.3 *PEV Cost Premiums*

Energeia's analysis of Australia's historical vehicle technology adoption rates, and analysis of international PEV adoption rates found cost premiums were a key inhibitor of demand.[21] Energeia's research of long-term PEV price premiums to comparable PEVs identified research from Navigant, which forecasts PEVs being 20% cheaper than comparable ICE vehicles to manufacture. Navigant's premiums exclude the cost of the lithium-ion battery, so the actual premium paid by consumers would be higher.

Navigant's estimate is based on an analysis of the underlying cost to build, which showed the BEVs are lower cost to produce on the basis of raw materials, and a less complex drive-train than an ICE. Navigant's view is that these cost savings are likely to occur once economies of 1 million vehicles are reached by OEMs, i.e. by the mid-2020s.

It is worth noting that PEV's purchase premium will only become lower than a comparable ICE once the incremental cost of batteries falls below the PEV manufacturing cost discount. The timing of this therefore depends not only on the forecast manufacturing discount, but also the forecast cost of lithium-ion batteries. Figure 25 displays historical lithium-ion battery prices for PEV applications. Energeia and BNEF are largely agreed that the forecast price of lithium-ion batteries is likely to follow its historical average rate of annual cost declines.

The assumptions regarding the PEV manufacturing and lithium-ion battery costs made for modelling purposes are described in Section 6.2.

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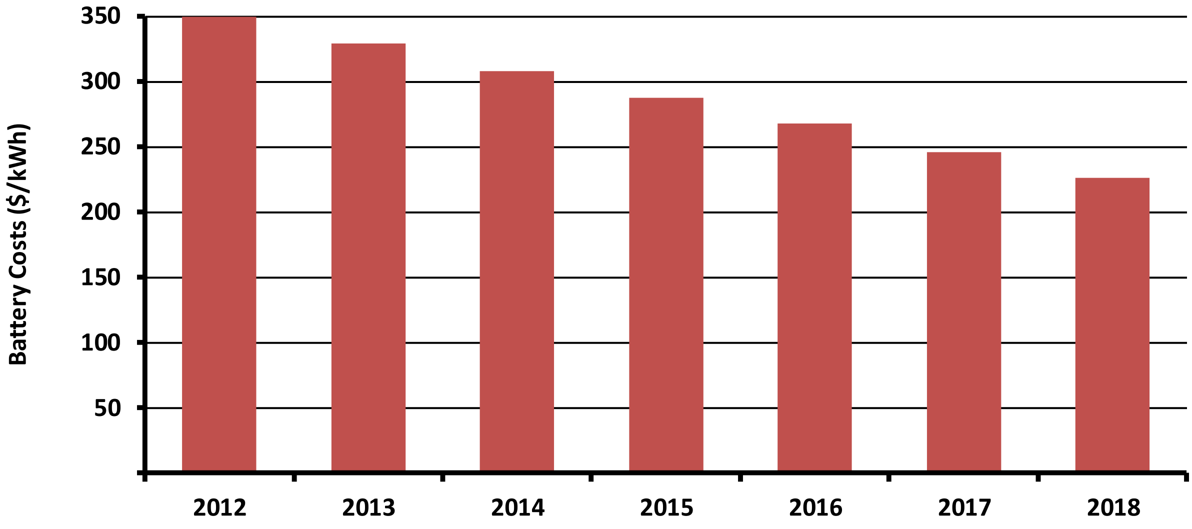
[21] Energeia (2015) 'Review of Alternative Fuel Vehicle Policy Targets and Settings for Australia, prepared by Energeia for the Energy Supply Association of Australia'. Access from: http://energeia.com.au/wp-content/uploads/2016/03/Energeia-Report-for-ESAA_-Optimal-AFV-Policy-Targets-and-Settings-for-Australia.compressed.pdf

Figure 25 – Trends in Lithium-Ion Battery Costs for PEV Applications



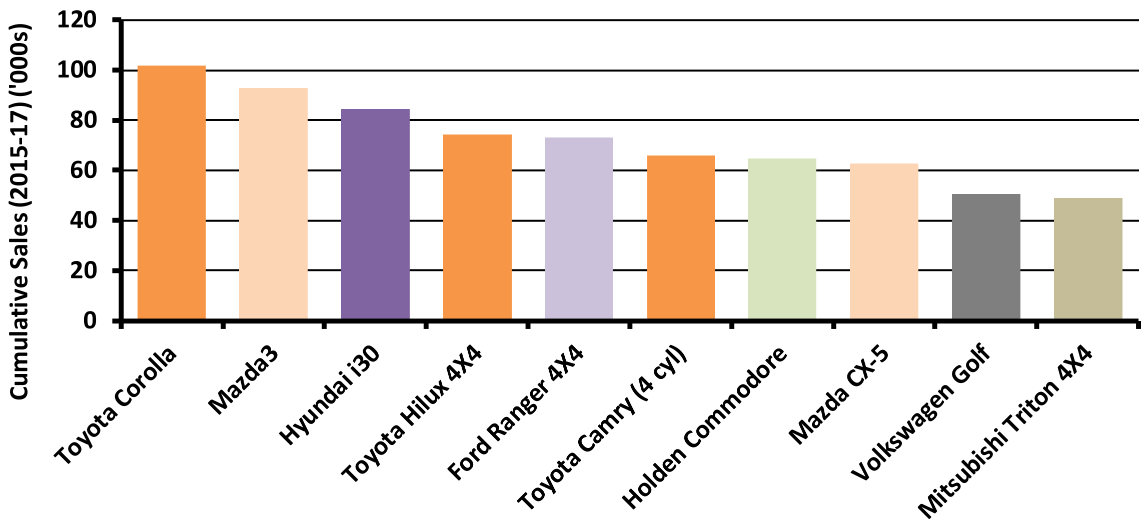
Source: Energeia Research

5.2.3.4 *PEV Model Availability*

Energeia's analysis of Australia's historical vehicle technology adoption rates, and analysis of international PEV adoption rates found vehicle model availability was a key inhibitor of demand.[22]

The expected number of models offered by OEM's in the future is therefore a key driver of future PEV demand in Australia. Australia's top selling vehicles over the last 5 years are shown in Figure 26. Energeia notes that none of these vehicles are offered in a PEV version.

Figure 26 – Australia's Top Selling Passenger Vehicles

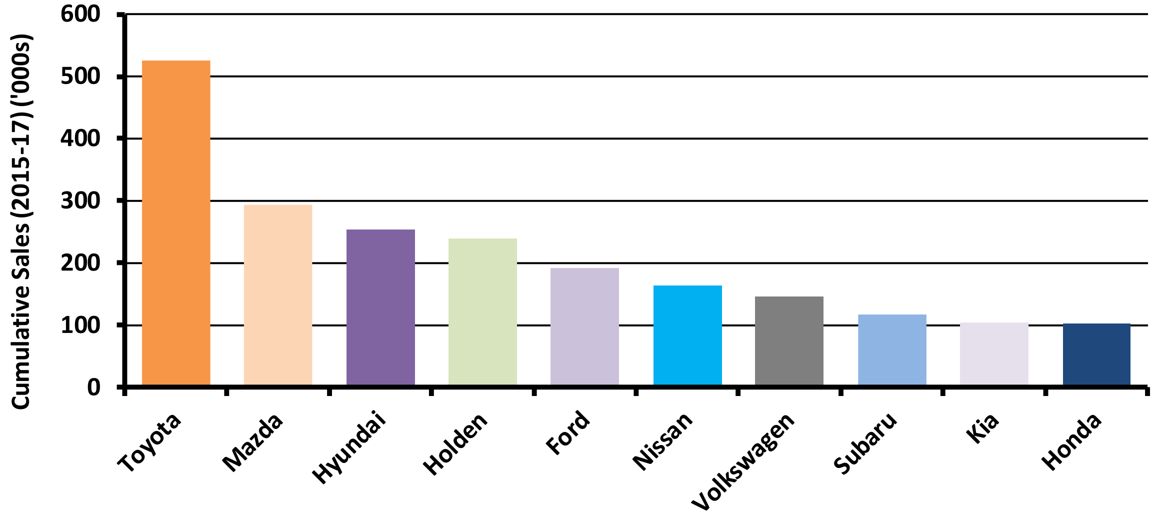


Source: Federal Chamber of Automotive Industries (2016), VFACTS

[22] Energeia (2015) 'Review of Alternative Fuel Vehicle Policy Targets and Settings for Australia, prepared by Energeia for the Energy Supply Association of Australia'. Access from: http://energeia.com.au/wp-content/uploads/2016/03/Energeia-Report-for-ESAA_-Optimal-AFV-Policy-Targets-and-Settings-for-Australia.compressed.pdf

Toyota is a dominant player in Australia with 3 out of the top 10 selling vehicles, and the largest sale volumes by make, as shown in Figure 27.

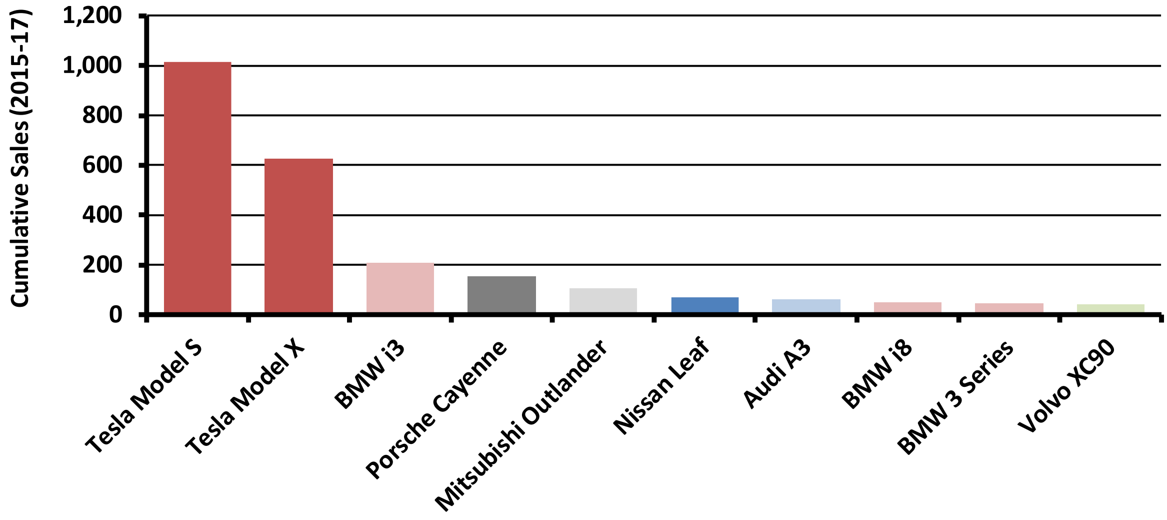
Figure 27 – Australia's Top Passenger Vehicle OEMs by Sales



Source: Federal Chamber of Automotive Industries (2016), VFACTS

The top-10 selling PEVs in Australia are shown in Figure 28. Tesla's vehicles are far more popular than all the other PEV sales combined. Energeia notes that most of the available PEVs are considered luxury models, mainly due to their pricing. The Model X and the Outlander are the only SUVs available.

Figure 28 – Australia's Top Selling PEVs – Passenger Vehicles

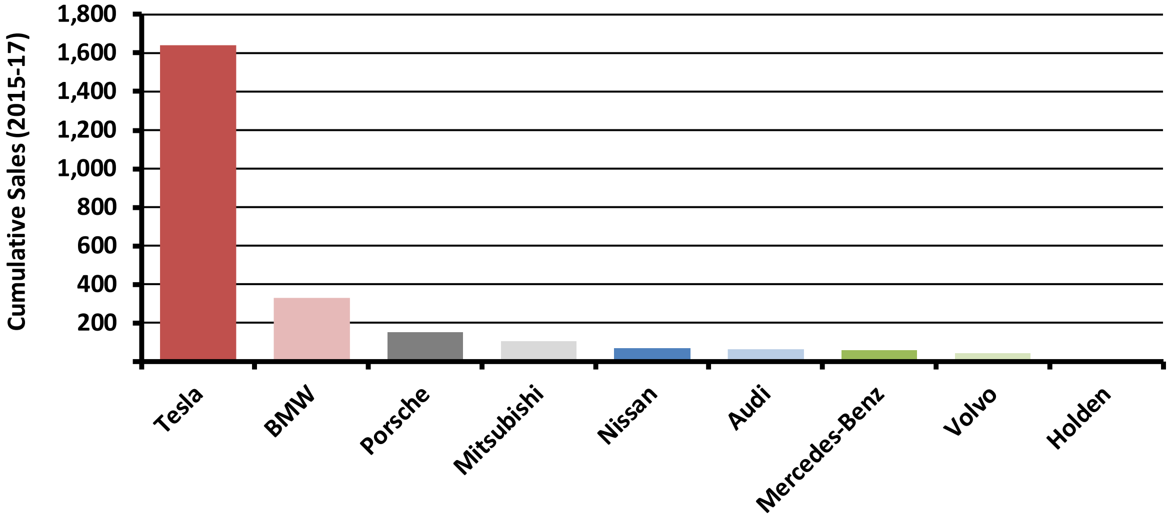


Source: Federal Chamber of Automotive Industries (2016), VFACTS; Energeia Research

The list of Australia's top PEV OEMs shown in Figure 29 is very different from its overall ranking. In Energeia's view, this reflects the OEMs' near-term PEV strategy, rather than signalling a longer-term shift in OEM rankings as more PEVs are adopted over time. In other words, Energeia expects long-term PEV OEM rankings to reflect the overall vehicle rankings, once the leading OEMs start offering more PEVs into Australia.

The main potential exception to this rule may be Tesla, who has managed to deliver PEVs that are in high demand, and who may be able to parley this into a long-term position of sales leadership. The relative performance of the Nissan Leaf, Model 3 and GM Bolt will inform the discussion as to whether Tesla's early lead over the major OEMs will translate into a long-term competitive advantage.[23]

Figure 29 – Australia's Top Selling PEV OEMs – Passenger Vehicles



Source: Federal Chamber of Automotive Industries (2016), VFACTS; Energeia Research

Energeia updated its research for this project to identify the likely rate of new PEV model availability over time and by OEM. The results of our research are summarised in Table 4, which displays announcements by major OEMs regarding the timing of major changes to their PEV model availability.

Table 4 – Global OEM PEV Availability Announcements

Target Year	OEM	Parent	HQ	Target No. of Models	Target % Models
2018	Honda	Honda	Japan	2	-
2019	Volvo	Geely	China	-	100
2020	Toyota	Toyota	Japan	10	-
	Mazda	Mazda		10	100
	Jaguar Land Rover	Tata	India	-	-
2021	Ford	Ford	USA	13	-
2022	Mercedes-Benz	Daimler AG	Germany	10	-
	Nissan	Nissan	Japan	12	-
	Mitsubishi	Mitsubishi	Japan	12	-
	Renault	Renault	France	12	-
2023	General Motors	GM	USA	20	-
	PSA	PSA	France	-	80
2025	Audi	VW	Germany	-	33
	Volkswagen			30	-
	BMW	BMW		25	-
	Hyundai	Hyundai	South Korea	38	-
	Kia			16	-

Source: Energeia Research

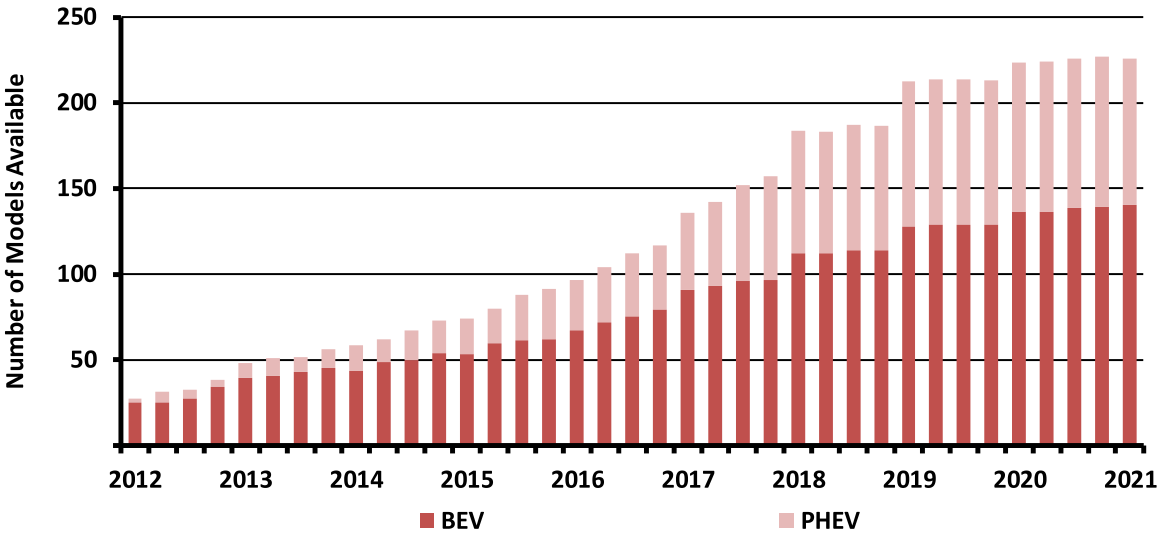
[23] Comparing the 3-year cumulative sales data Figure 29 with the analysis in Section 5.1.2.2 that all PEV models sold in Australia, with the exception of the Tesla Model S, are selling less than 200 units per year, this suggests that these models are at risk of being discontinued on volume grounds by OEMs (as per Figure 5)

The data shows that some, smaller manufacturers like Volvo, Land Rover and Jaguar are rapidly moving towards complete electrification of their vehicles in the next few years, most of the other players are promising relatively meagre additional PEV models in the future. For example, Volkswagen is promising 30 PEVs by 2025, which is around 10% of their roughly 300 models worldwide.

The key question is whether the major OEMs will be driven to accelerate their PEV transition or not, and what the catalysts for this might be. In Energeia's view, the most likely driver of additional PEV models is likely to be the performance of each company's PEV offerings, competition from companies like Tesla, government pressure exerted through future bans on ICEs, and the pace of alternative options, and in particular, fuel cells.

Figure 30 displays a 2017 forecast of PEV model availability by BNEF, which shows BEV models continuing to increase to 2021 but at a slower rate than over the 2016 to 2018 period. Interestingly, BNEF is expecting the number of Plug-in Hybrid Electric Vehicles (PHEVs) to continue growing, albeit at a slower rate than BEVs.

Figure 30 – Global OEM PEV Availability Forecast – BNEF



Source: Bloomberg New Energy Finance (2017)

In addition to examining international OEM strategies and public statements regarding PEV availability moving forward, Energeia also researched Australian specific statements by OEMs to inform our own modelling of Australia's future PEV model availability, which is presented later in Section 6.3.1.

Table 5 shows OEM statements related to the Australian PEV market and/or their intentions, where available. Energeia was unable to find a single statement by market leaders Mazda and Subaru. Tesla, Hyundai and Holden were the only OEMs to mention an Australian specific PEV strategy or intention.

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Table 5 – OEM Statements on Australian PEV Uptake and Requirement for EVSE Deployment

Rank		OEM	Date	Statement
Australian Top-5 ICE Vehicle OEMs	1	TOYOTA	8/01/18	***"…there are unique Australian requirements as well in terms of regulations, and also demand. We have vast distances to travel compared to places such as Europe and industries which require those vehicles to perform as tools of trade as well."***
	2	mazda	6/08/15	*[no statement]*
	3	HYUNDAI	14/12/17	*"**We want all three (variants of the Ioniq in Australia in 2018)**, because we think we have a unique proposition in terms of setup, with three completely different experiences and drivetrains…"*
	4	HOLDEN	4/10/17	*GM Holden will be at the forefront of these technological changes, with the local brand already testing infrastructure requirements for electric vehicles with **two Bolts currently in Australia**.*
	5	Ford	31/12/16	*"Many Asia Pacific countries (such as **Australia**, China, India, South Korea, Taiwan, and Vietnam) are developing or enforcing fuel efficiency or labeling targets." (Could signal view on rising Australian interest)*
Australian Top-5 PEV OEMs	1	TESLA	24/04/17	*"In 2017, we'll be **doubling the Tesla charging network**, expanding existing sites so drivers never wait to charge, and broadening our charging locations within city centers."*
	2	BMW	9/01/18	*BMW Australia's CEO […] said **Australia's emissions levels were "shocking"** and suggested "financial and non-financial incentives. Incentives that will put these low-emission vehicles within the reach of more Australians"*
	3	PORSCHE	-	*[no statement]*
	4	MITSUBISHI	29/09/17	*City of Adelaide and the South Australian Government joining Mitsubishi Motors Australia to open a first-of-its-kind, fast direct current (DC) charging station in the city's CBD.*
	5	NISSAN	4/10/17	***"I don't think today there is anything to lead us to think that Australia is going to see, soon, electric cars"***

Source: Energeia Research

Overall, the statements ranged from mildly negative or non-committal to more aggressive and positive statements, from both current incumbents in the conventional market and from challengers in the PEV space. These statements may be misleading as to the true strategic intent of different company's statements, such as BMW's and Renault's, should be viewed in the light of their current lobbying efforts to impact government policy.

5.2.3.5 *PEV and EVSE Technology Improvements*

The rate of technological change across the PEV value chain is continually accelerating, with vehicle and infrastructure OEMs racing to improve:

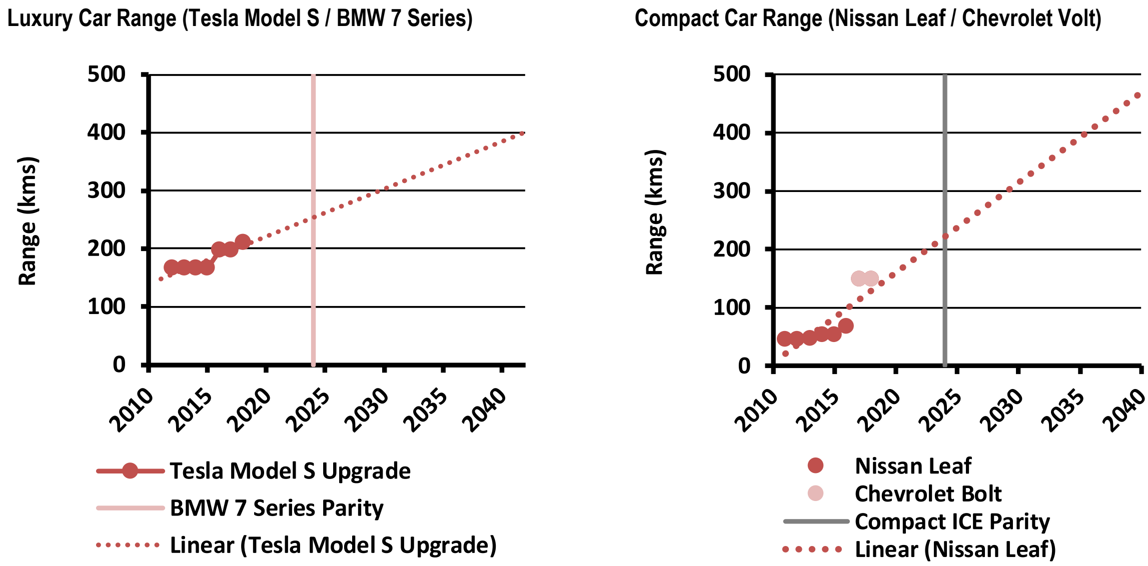
- **Driving Range** – The first-generation Leaf had a range that was less than one third of a comparable ICE vehicle. The second-generation Leaf's range is now about half that of a comparable ICE vehicle.
- **Refuelling Time** – First generation DCFCs offered in 2013 were 40 kW and took 30 mins to recharge a Leaf. The latest DCFCs are 350kW and can recharge a 30kWh Leaf in less than 5 mins.
- **Charging Convenience** – Wireless charging technology is emerging that can recharge PEVs while parking as well as while driving, eliminating the need to plug-in at all.

Improvements in these factors will impact on demand for current charging technology in different ways, which is discussed in the following sections.

Driving Range

Figure 31 reports on the trends in range for Tesla's Model S, and compact passenger vehicles like the Nissan Leaf and the Holden Volt. Our research and analysis suggest that PEVs will reach ICE equivalent driving ranges by 2024, closing a key gap in PEV performance relative to ICE vehicles.

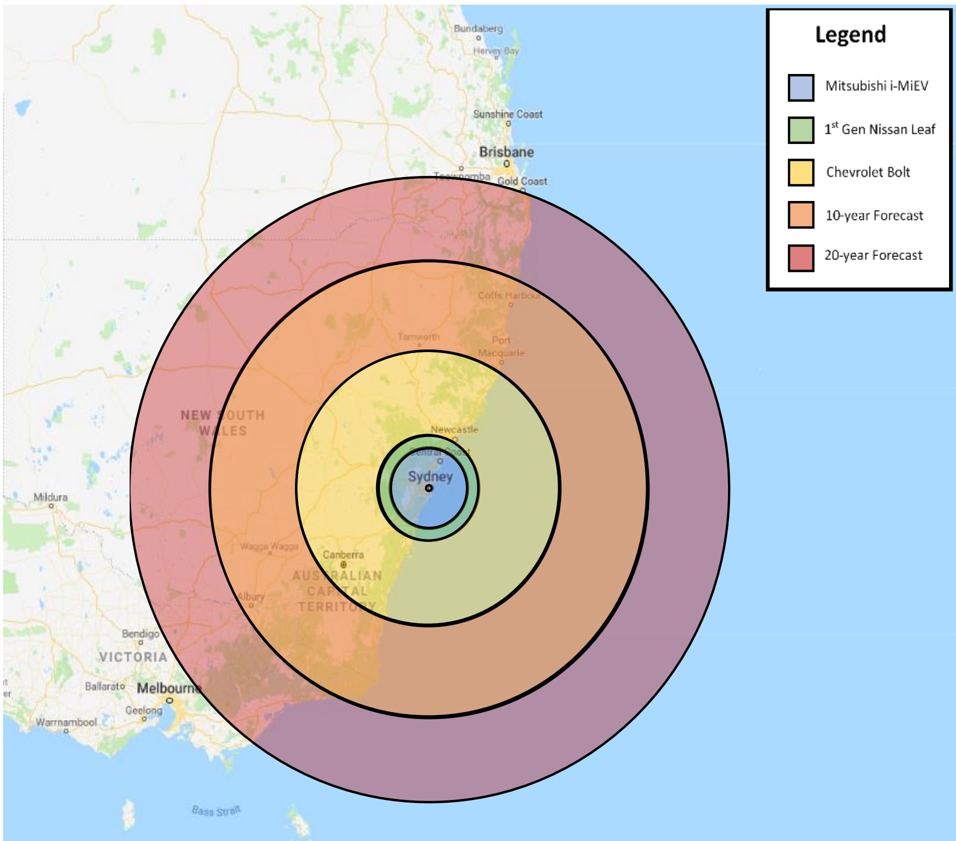
Figure 31 – Trends in PEV Range by Vehicle Type and Outlook to 2030



Source: Energeia Analysis

The impact of the introduction of the second generation PEVs such as the Model 3, Nissan Leaf and Chevy Bolt will dramatically increase driving range in Australia, as shown graphically in Figure 32. The figure also projects the range of PEVs in Australia over the next ten and twenty years.

Figure 32 – Map of Historical and Future PEV Ranges from Sydney



Source: Energeia Analysis

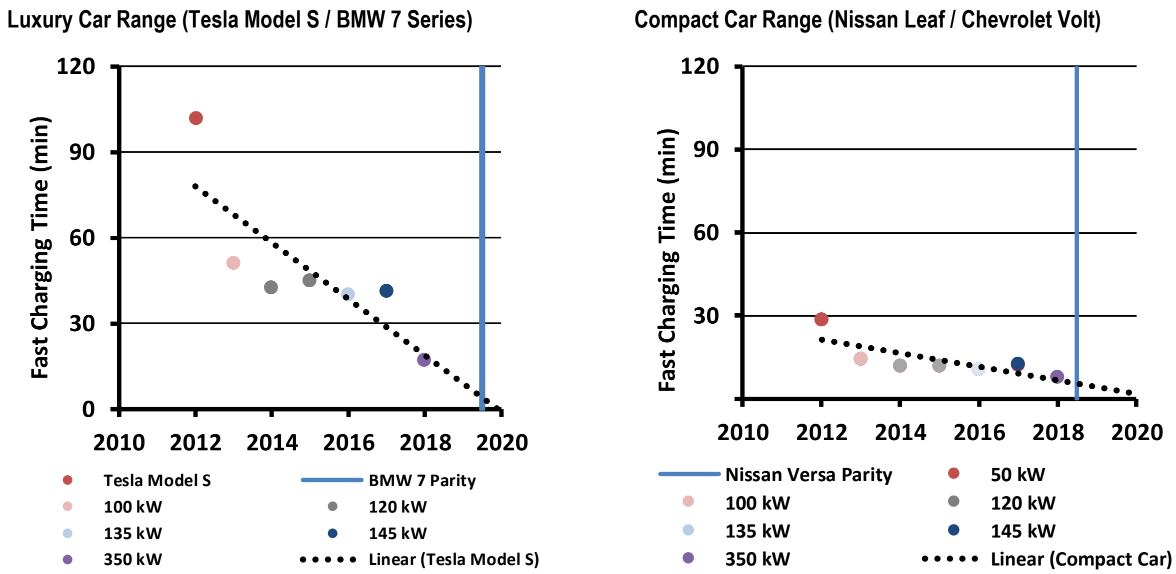
The impact of longer driving ranges will mainly impact on DCFC public charging infrastructure requirements. As range increases, the distance between DCFCs will be able to be increased. However, drivers will continue driving the same distances, so the overall number of hoses needed to support the traffic will remain constant.

Refuelling Time

Similarly, future outlooks for public recharging requirements need to account for the reduced refuelling times, as PEV recharging rates increase. Energeia's research into trends in vehicle recharging rates is reported in Figure 33 for luxury and compact vehicles.

The research shows that PEVs will hit ICE parity as early as 2019 if current rates continue. Taking the projected changes in vehicle range (i.e. the implied increase in battery size) into account, refuelling parity is likely to be pushed back a few years. Energeia expects the implications of higher DCFC recharging rates on public recharging infrastructure to include fewer DCFCs needed to refuel a given number of vehicles as each vehicle will take less time. All else being equal, a 10-minute DCFC EVSE will be able to handle twice as many PEVs as a 20-minute DCFC EVSE.

Figure 33 – BEV Charging Times – Outlook to 2020



Source: Energeia Analysis

Charging Convenience

Studies have consistently shown that drivers will choose the most convenient recharging options. Wireless charging offers a more convenient recharging option as PEV drivers do not have to plug-in.

There are two main types of wireless charging:

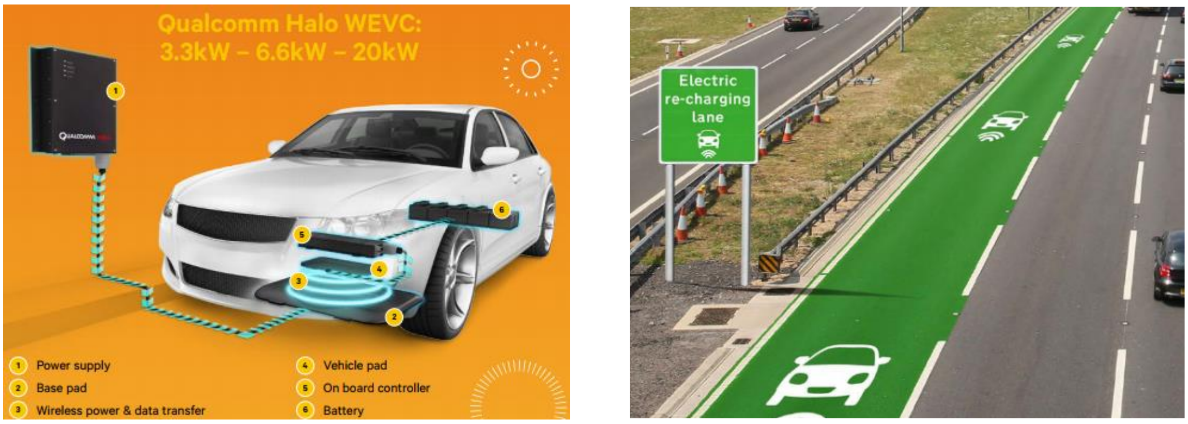
- **Static** – PEVs are recharged wireless using inductance (magnetic) coupling while they are parked. Charging rates of up to 20 kW, equal to our better than conventional L2 chargers.
- **Dynamic** – PEVs are recharged as they drive using inductance coupling. They are able to be charged at 20 kW while driving up to 100 km/h.

Wireless charging power transfer efficiencies depend on the distances involved. Static wireless charging is around 95% efficient, while dynamic wireless charging is between 80-90% efficient.

Figure 34 displays Qualcomm's Halo wireless charging system on the left. Wireless charging is currently a third party retrofit option as OEMs do not yet offer it themselves. Energeia expects the technology to catch on rapidly for home charging, however, and for OEMs to offer it as an added feature initially, and then as standard.

Figure 34 – Wireless Charging

Stationary **Dynamic**



Source: Energeia Analysis

A pilot of dynamic charging is shown in Figure 34 on the right. A key limitation of dynamic charging is the need to install the equipment in the road. This may be relatively low cost at the time the road is built but will be prohibitively expensive as a retrofit.

Prices for static chargers vary according to the capacity but the premiums over L2 charging products are declining. The cost of the dynamic charging equipment does not appear to be in the public domain. In any case, they are likely to be driven more by the installation costs more so than the cost of the equipment.

Energeia sees the impact of dynamic wireless charging on future demand for public charging infrastructure to be limited over the next 10-20 years due to the high cost of embedding it into the road system. We see wireless L2 charging to potentially be the L2 charging technology of choice when the current crop is replaced in 10 years.

5.2.3.6 *Competing Vehicle Technologies*

Competing vehicle technologies, specifically Fuel Cell Electric Vehicles (FCEV), could reduce future demand for public charging infrastructure by reducing demand for PEVs. Energeia's previous research and analysis[24] of Australian's adoption of new vehicle technologies over time including diesel, hybrid electric and plug-in electric technologies found that cost, model choice and performance were the key drivers of technology switching.

Performance Comparison

Although PEVs are forecast to displace ICEs over time on a cost and performance basis, a competing technology with superior performance could in turn supplant PEVs. In some quarters, FCEVs are seen as a potential challenger to PEVs for the following reasons:

- FCEVs currently offer a higher driving range, which has been a major buying objection against PEVs.
- FCEVs can use hydrogen as a fuel directly, which some expect to be the long-term energy storage medium of choice.

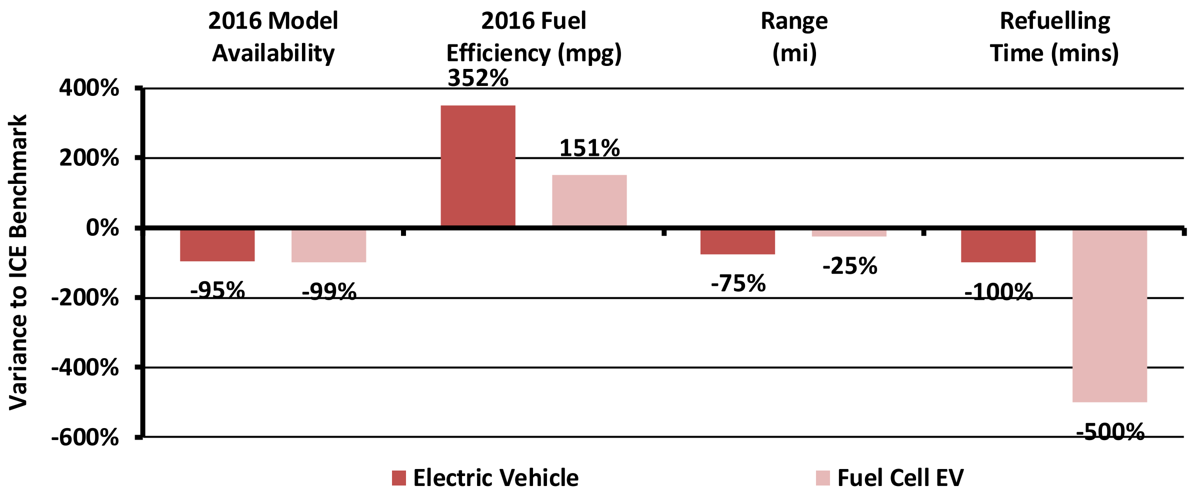
On the downside, FCEVs might require an entirely new hydrogen infrastructure to be developed, compared to PEV's which can rely on the existing electricity network for energy delivery.

[24] Energeia (2015) 'Review of Alternative Fuel Vehicle Policy Targets and Settings for Australia, prepared by Energeia for the Energy Supply Association of Australia'. Access from: http://energeia.com.au/wp-content/uploads/2016/03/Energeia-Report-for-ESAA_-Optimal-AFV-Policy-Targets-and-Settings-for-Australia.compressed.pdf

A comparison of current technology performance against key criteria is presented in Figure 35 for PEVs and FCEVs compared to ICEs. It is worth noting that FCEV development has progressed at a slower pace than PEVs, and model availability is limited.

The key question for FCEVs then is when FCEV costs, model availability and refuelling time will come down to benchmark levels, keeping in mind the rate of PEV improvement in driving range and refuelling time. In Energeia's view, recent PEV announcements by FCEV stalwarts including Toyota and Honda signals that even they are finally accepting that PEVs may become the dominant technology longer-term.

Figure 35 – PEV and FCEV Performance Relative to ICE



Source: University of Michigan (2016), 'The Relative Merits of Battery-electric Vehicles and Fuel-cell Vehicles'

FCEV Model Availability

The model availability for FCEVs is highly constrained with just 3 models available globally, as shown in Table 6. However, IHS Markit is forecasting model availability will treble to 10 by 2022 (i.e. the addition of 7 new models over the next 4 years, as shown in Figure 36).

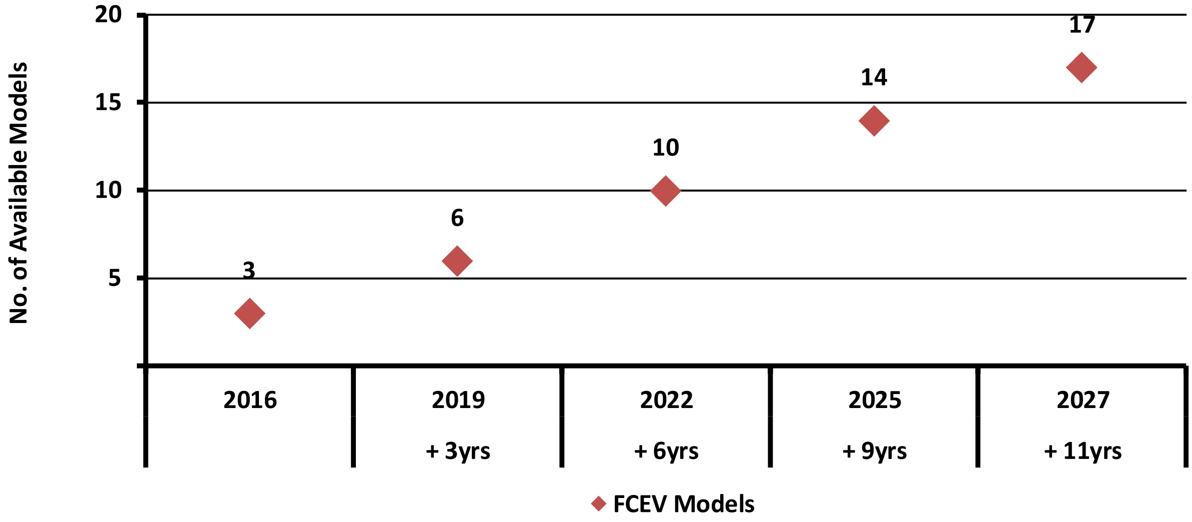
Table 6 – 2017 FCEV Models

Commercially Available FCEVs – 2015 Activities and 2016 Plans			
Automaker	**Model**	**2015 News**	**Specs**
Hyundai	Tucson Fuel Cell (North America) ix35 Fuel Cell (South Korea, Europe) 	The first Tucson Fuel Cell vehicles were delivered to customers in Vancouver, Canada. 70 vehicles delivered in the US through May 2015.	50 miles/gallon gas equivalent (gge) 265 mile range 100 kW stack
Toyota	Mirai 	Mirai sales were started in California, The U.K., Belgium, Denmark and Germany. 200 vehicles delivered in the U.S. in 2015.	67 miles/gge 312 mile range 114 kW fuel cell stack
Honda	Clarity Fuel Cell 	Honda unveiled its new FCEV, the Clarity Fuel Cell, at the Tokyo Motor Show.	300 mile range (preliminary range estimate determined by Honda) 100 kW stack

Source: US DOE (2015), 'Fuel Cell Technologies Market Report 2015'

Energeia notes that fuel cell policy support remains high in key jurisdictions like California, who are continuing to support it in the expectation that a 100% renewable energy based economy will rely on hydrogen rather than battery storage to store and transport energy in the long-term.

Figure 36 – Forecast FCEV Model Availability



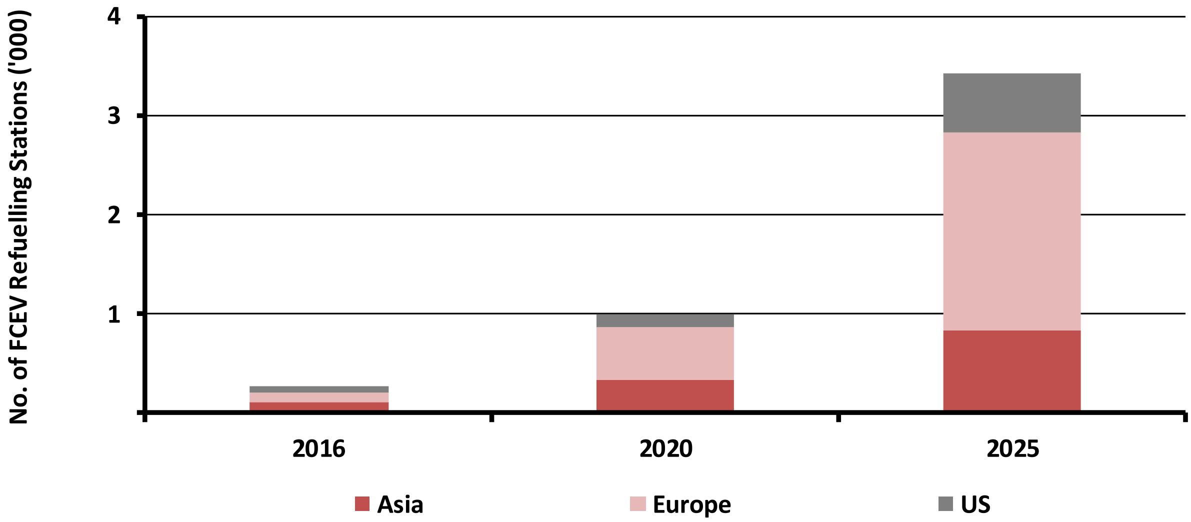
Source: IHS Markit (2016)

The FCEV model availability forecast in Figure 36 should be considered in light of the PEV forecast presented in Figure 30, which showed 225 PEVs models by 2021. In other words, even by 2027, the number of FCEV models forecast to be available is likely to be less than 5% of available PEV models.

FCEV Infrastructure Deployment

Public refuelling stations will need to be deployed to allow FCEV vehicles to operate beyond their home. There are limited forecasts available for FCEV infrastructure deployment, but the Hydrogen Council forecasts a significant ramp-up in refuelling infrastructure in the 2020-2025 period, particularly in the US, as shown in Figure 37. However, as is the case with FCEV model choice forecasts, the forecasts for public refuelling infrastructure is tiny compared to the expected PEV public charging infrastructure.

Figure 37 – FECV Charging Station Availability - High-Level Forecast



Source: Hydrogen Council (Jan 2017), 'How hydrogen empowers the energy transition'

FCEV Uptake Forecasts

Given the early stage of the FCEV adoption, forecast sales vary widely between source, with a variance of 10 times between two different recent estimates for 2025 FCEV sales, as shown in Figure 38 and Figure 39.

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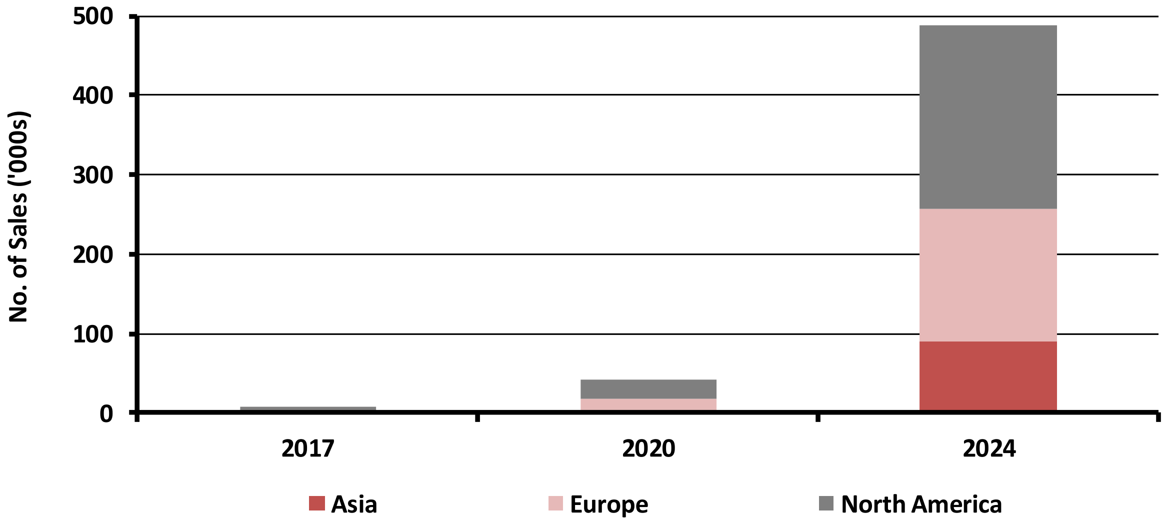
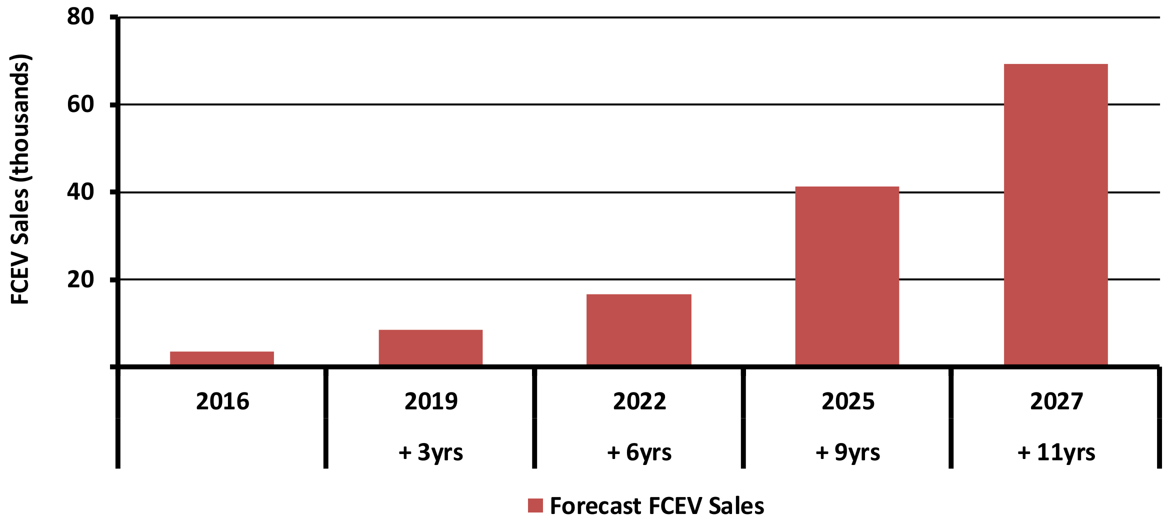
Figure 38 – FCEV Uptake Forecast – Navigant, 2015



Source: Navigant (2015)

Figure 39 – FCEV Uptake Forecast – IHS Markit, 2016



Source: IHS Markit (2016)

5.2.3.7 *Transport Sector Transformation*

Shared Autonomous Electric Vehicles (SAEVs) could impact on future demand for public charging infrastructure by requiring automated refuelling technology and by reducing the number of cars on the road due to the impact of pooled vehicle based business models such as corporate motor pools, as well as emerging public models including Transport-as-a-Service (TaaS).

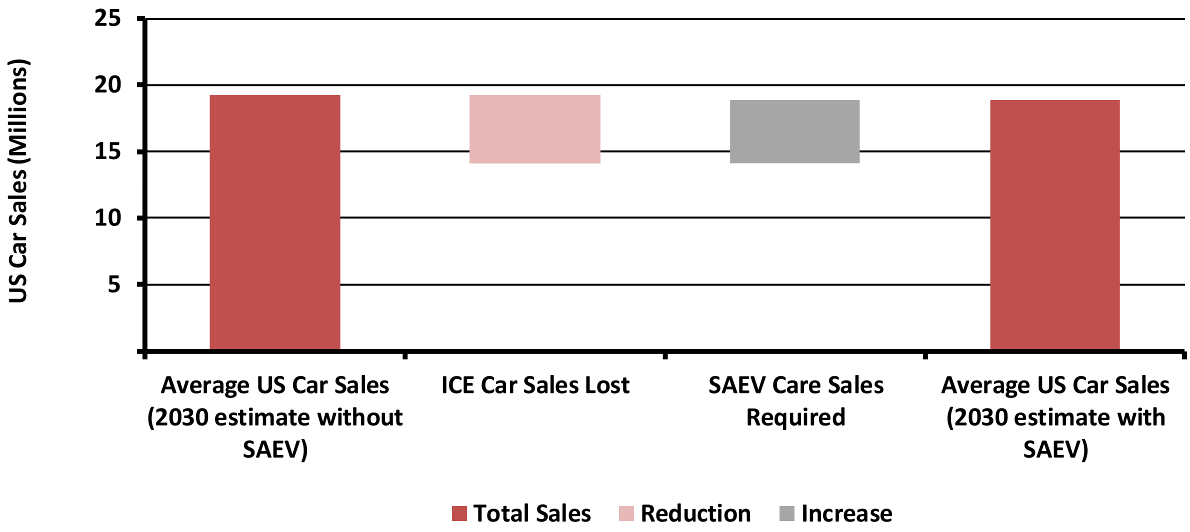
Pooled SAEVs are also expected to impact on public charging infrastructure requirements by increasing the average km driven per TaaS vehicle. Highly utilised vehicles are likely to value the speed of DCFC or dynamic wireless charging over stationary L2 or wireless charging options.

Some futurists are predicting up to 95% of all vehicle-kilometres travelled in 2030 will be by SAEVs[25], assuming current technologies and learning curves. The RethinkX think-tank has developed an aggressive forecast of an average net benefit per US household of $5,000 per annum, as:

- **Car ownership will decline** – TaaS will be between 5 and 10 times cheaper than buying a new car by 2021, mainly driven by the lower capital costs of pooled vehicles.
- **Passenger fleet size will decline** – The US fleet will reduce from around 250 million in 2020 to less than 50 million in 2030, as fewer shared vehicles travel more, increasing utilisation rates tenfold.

In contrast to these bullish views, the current consensus (as represented by an April 2017 BCG study) is for 25% of overall vehicle-kilometres travelled in 2030 to be completed in SAEVs. They see savings in vehicle numbers through sharing balanced out by increasing km travelled, reducing fleet size by 5%, as shown in Figure 40.

Figure 40 – Forecast 2030 Impact of SAEV on Vehicle Sales – BCG Analysis



Source: BCG (2017). Accessed From https://www.bcg.com/d/press/10april2017-future-autonomous-electric-vehicles-151076TaaS – Outlook

Energeia's view is that the long-term impact of SAEVs and TaaS is likely to fall somewhere in between the two views presented in Figure 40. There is not enough experience with SAEVs or TaaS to develop a firm view either way.

Outlook

Automotive sector expert IHS Market forecasts that full autonomous SAEVs will hit the market in 2019, firstly for TaaS in the US[26], where sales will increase to over 50,000 autonomous vehicles by 2021, leading to global sales in excess of 1 million autonomous vehicles by 2025, as shown in Figure 41.

Energeia's research has found that TaaS and SAEVs could have a material impact on demand for public charging infrastructure in the medium term, but that there is limited overseas or Australian research into the potential impacts on vehicle numbers, total km travelled and public charging technology requirements. Energeia therefore recommend that ARENA and the CEFC consider detailed research into SAEVs and TaaS.

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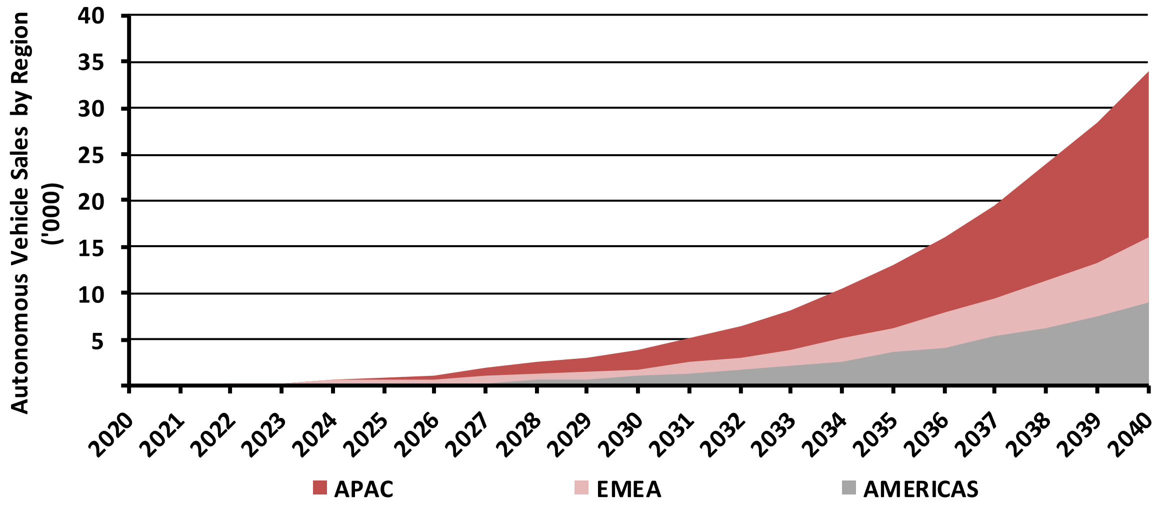
[25] Source: RethinkX (2017), 'Rethinking Transportation 2020-2030: The Disruption of Transportation and the Collapse of the ICE Vehicle and Oil Industries'

[26] From IHS Market: "Announcements from General Motors, Waymo and Uber contribute to early projected mobility fleet volumes in 2019 before personal autonomous vehicles become available as early as 2021."

Figure 41 – Global Autonomous Vehicle Forecast



Source: IHS Markit (2018). Accessed from: https://ihsmarkit.com/research-analysis/autonomous-vehicle-sales-to-surpass-33-million-annually-in-2040-enabling-new-autonomous-mobility-in-more-than-26-percent-of-new-car-sales.html

5.2.4 PEV Adoption Forecasts

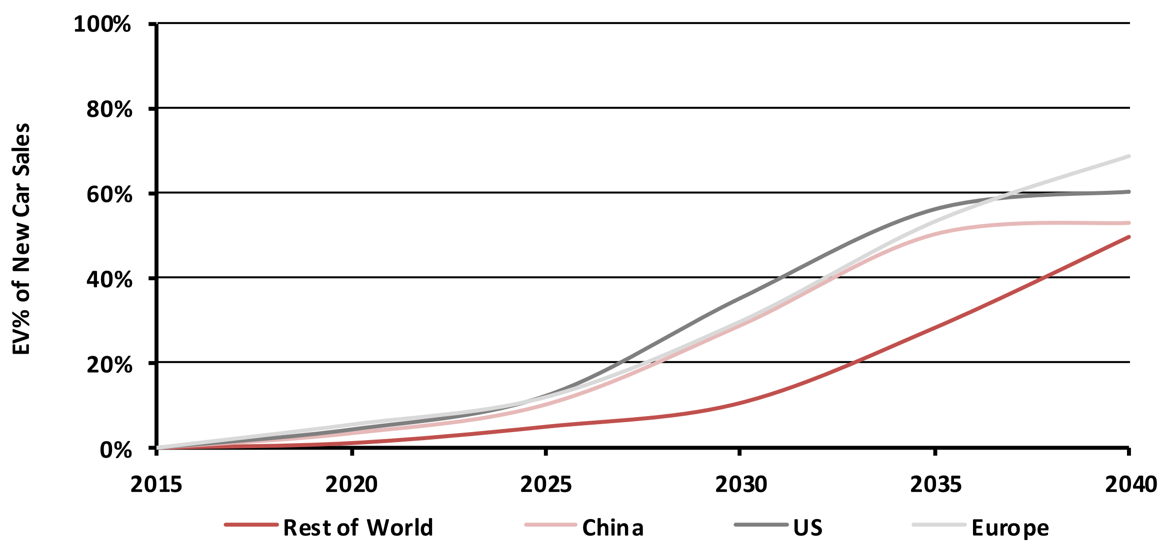
This section reports on the latest international and Australian forecasts of PEV adoption. Public domain forecasts of public charging infrastructure are presented in Section 5.2.5.

5.2.4.1 *International Benchmarks*

There is a wide variation in near and longer-term forecasts in the public domain, as can be seen be inspection of Figure 42 and Figure 43, which show global forecasts by BNEF and DNV GL, respectively.

BNEF sees global PEV adoption ramping from 2025 onwards in China, Europe and the US, but reaching a cap of approximately 60% in most markets (with the exception of Europe) due to the lack of public charging infrastructure for the 40% of people without access to dedicated charging. BNEF sees Europe providing adequate public charging infrastructure, which enables PEV market share there to rise beyond 60%.

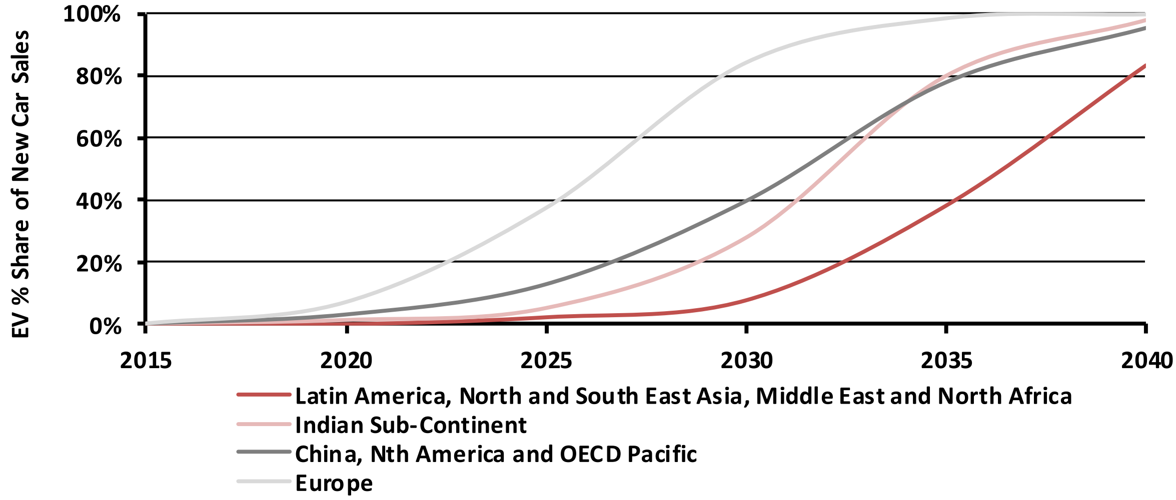
Figure 42 – Global PEV Adoption Forecasts by Region – BNEF, 2017



Source: Bloomberg New Energy Finance (2017), 'Electric Vehicle Outlook 2017'

DNV GL expects PEV adoption will ramp in Europe from 2020 onwards, with the Indian Sub-Continent, China, US, Canada, Mexico and Australia ramping up from 2025, resulting in PEV saturation between 2035 (Europe) and 2040 (Indian Sub-Continent, China, US, Canada, Mexico and Australia).

Figure 43 – Global PEV Adoption Forecasts by Region – DNV GL, 2017

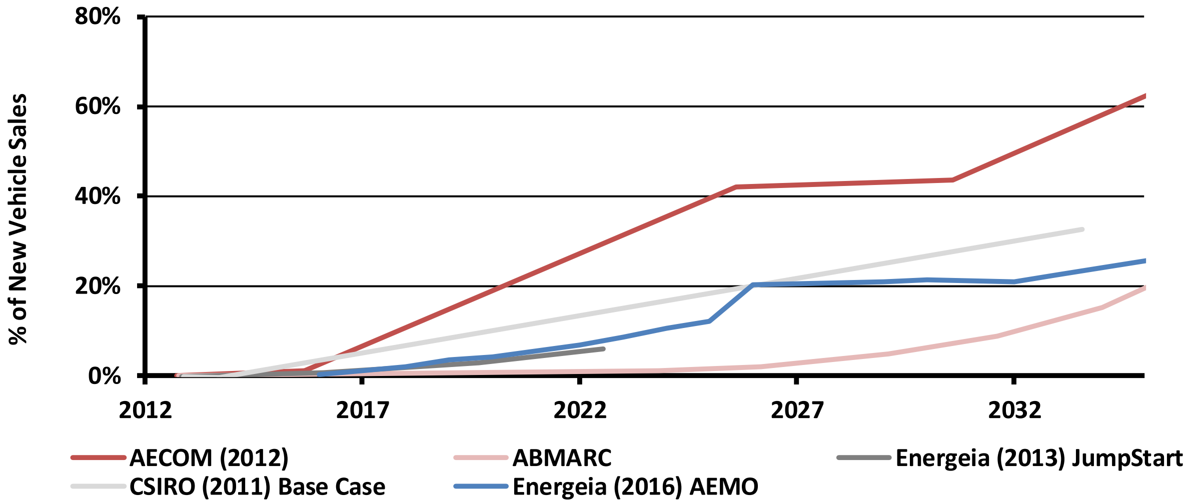


Source: DNV GL (2017), 'Energy Transition Outlook'

5.2.4.2 *Australian Forecasts*

Australian PEV forecasts have varied widely, with initial forecasts at the start of this decade expecting 10% saturation by 2018 (AECOM's 2012 and CSIRO's 2011 forecasts). More recent forecasts, as shown in Figure 44, have been less aggressive over the medium term, and the current Energeia forecasts completed for AEMO's Electricity Forecasting Insights program of work forecast PEV uptake of 20% of new vehicle sales by 2030.

Figure 44 – Selected Historic Australian PEV Uptake Forecasts



Source: Energeia Analysis; Note: above forecasts represent the middle scenario where multiple scenarios were available.

5.2.5 Charging Infrastructure Requirements

This section reports on international and Australian forecasts of charging infrastructure requirements. These are largely based on modelled estimates of charging requirements per forecast PEV by charging segment.

5.2.5.1 *International Benchmarks*

Energeia reviewed the most current studies available across a range of comparable jurisdictions to form a view on the potential charging requirement in Australia at different levels of PEV adoption.

Energeia's research found that most international forecasts of future charging infrastructure requirements may be broken into the following three types of networks:

- **Private charging** – Dedicated charging infrastructure available at home or the workplace. One charger is required for each PEV.
- **Public L2 charging** – Non-dedicated charging infrastructure available near homes and workplaces, where vehicles are parked for long periods. A ratio of chargers per non-dedicated PEV is estimated.
- **Public DCFC** – Non-dedicated charging infrastructure available on major roads to ensure dedicated and non-dedicated PEVs can drive anywhere. A ratio of chargers per PEV is estimated.

The focus of Europe and the US over the past few years has been on Level 2 workplace charging to meet the charging needs of those without dedicated parking, and on DCFC networks for range extension. However, with DCFC performance improvements, the latest studies are showing a higher public DCFC charging rates.

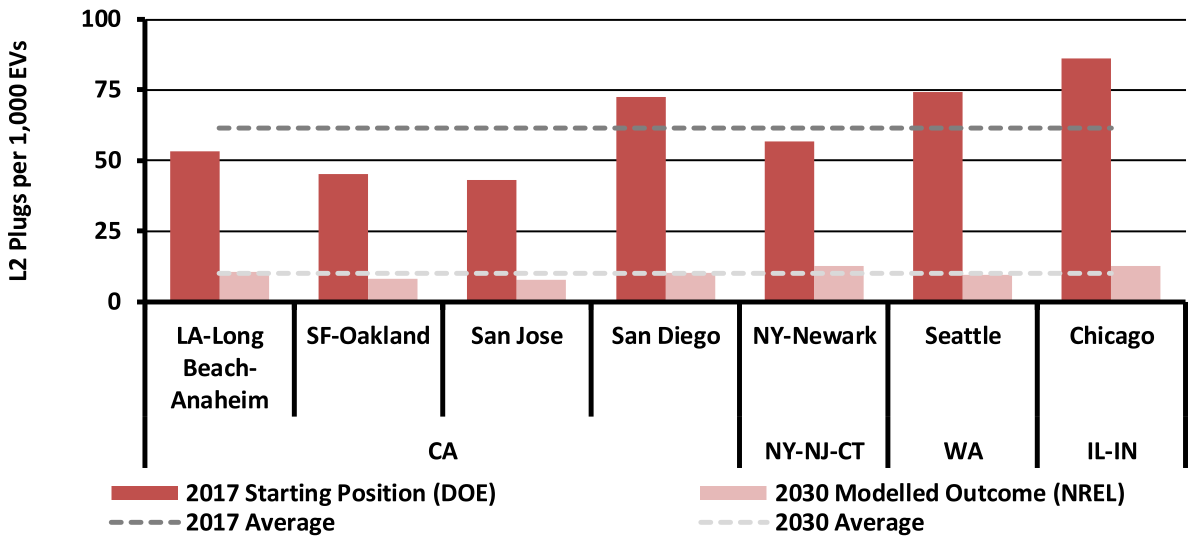
NREL US-wide Charging Requirements Simulation

The following figures compare baseline data from 2017 (IHS Markit) with modelled 2030 outcomes for public Level 2 (Figure 45) and DCFCs (Figure 46) in major US markets.

The modelled case is based on a range of key assumptions, including:

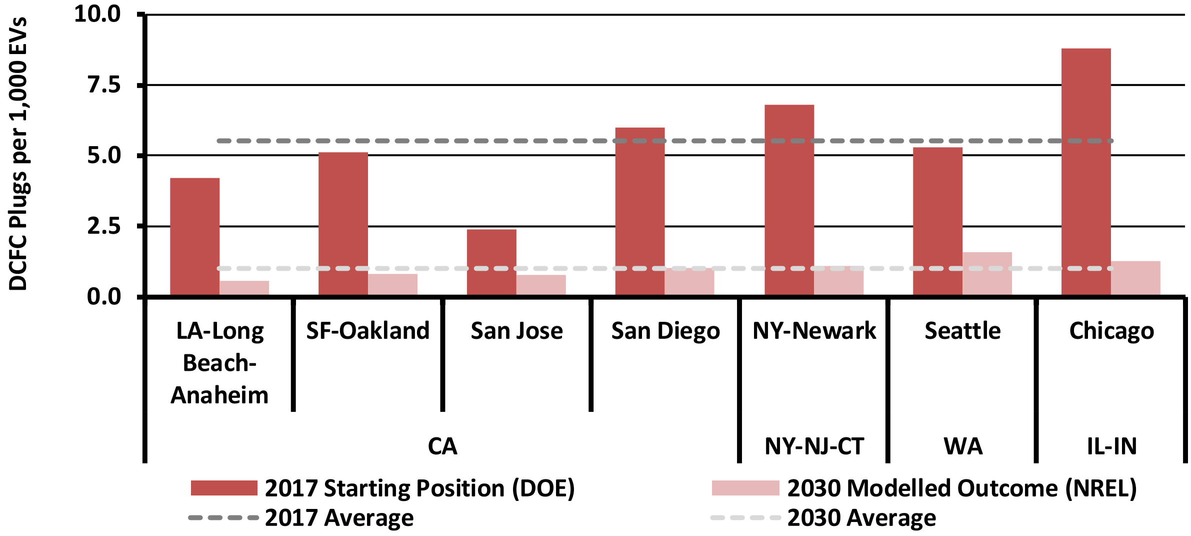
- **PEV Sales** – linear growth to 20% of light duty vehicle sales in 2030
- **PHEV/BEV ratio** – 50% of all PEVs are PHEVs
- **PHEV ICE support** – 50% of all possible vehicle miles travelled are battery powered
- **Home Charging** – 88% of all PEVs
- **Corridor DCFC Spacing** – 70 miles
- **DCFC Charge Time** – 20 minutes (150 kW)

Figure 45 – Public Level 2 Chargers per PEV – Forecasts to 2030



Source: NREL (2017), 'National Plug-In Electric Vehicle Infrastructure Analysis'

Figure 46 – Public DC Fast Chargers per PEV - Forecast to 2030



Source: NREL (2017), 'National Plug-In Electric Vehicle Infrastructure Analysis'

The variance in results for each location is due to difference in simulated driving patterns in each metro centre, given the above assumptions. Sensitivity analysis completed on the results showed the most sensitive variables for Level 2 and DC Fast Charger deployment ratios to PEVs were:

- **Level 2** – PHEV ICE support, assumed driving patterns and % home charging
- **DCFC** – assumed driving patterns, BEV/PHEV ratio and % home charging

The above analysis suggests significant economies of scale are expected to emerge as the level of PEV adoption rises over time. L2 charger per PEV requirements start at 50:1,000, and fall to around 10:1,000 by 2030, while DCFC start at around 5:1,000 and fall to around 1:1,000 over the same period.

European Commission EVSE Siting Study

The European Commission recently (2016) completed a study on the locational criteria for siting EVSE, with selected graphics from that report shown in Figure 47. The study identified a range of relevant criteria, including:

- Population Density
- Parking Places and Parking Lots
- Electrical Power Grid Net Costs
- Public Transport Stations
- Public Access Buildings (hospitals, museums, universities, etc.).
- Shopping / Food Areas (stores, malls, restaurants, etc.)

The modelling concluded that the number of Level 2 chargers required to service a targeted 4 million vehicles was 8 million (at an approximate 2:1 ratio of L2 chargers to PEV), comprised of 7.2 million home and workplace chargers, and 0.8 million publicly accessible chargers, located either on street or in car-parking. The modelled roll-out of publicly accessible chargers equates to a ratio of 200 public chargers per 1,000 PEV.

The above analysis represents a significantly higher forecast requirement of public chargers per PEV than US studies. Energeia also identified a different, EU commissioned study of future public charging infrastructure requirements, which is displayed in Figure 47. This study is closer to the US estimates of around 100 L2 public chargers and 130 DCFCs per 1,000 PEVs in 2017, with L2 requirements falling to 30 per 1,000 PEVs by 2040.

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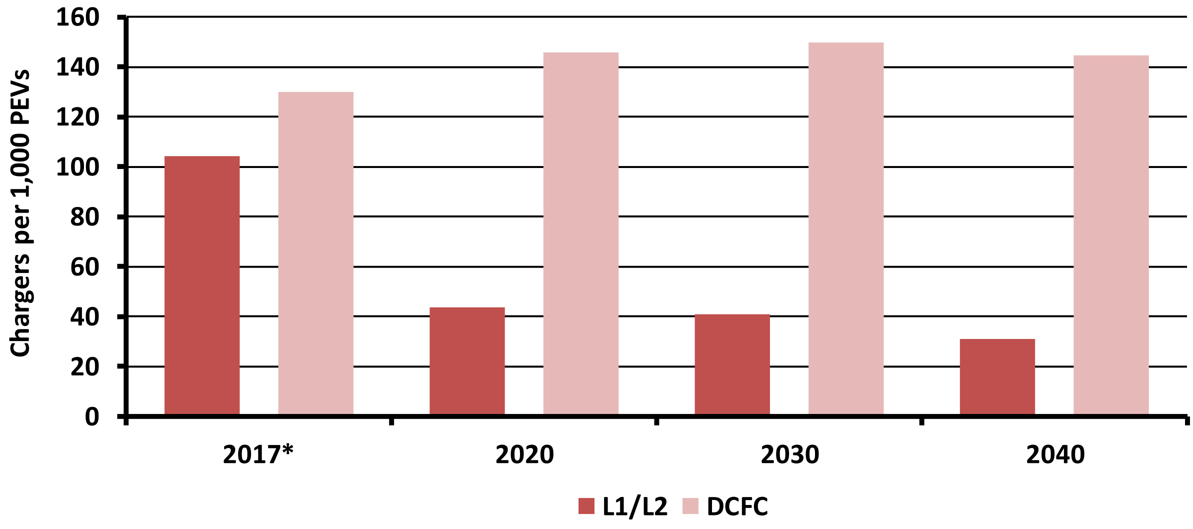
Figure 47 – EU Scenario Modelling of Public Charging Requirements



Source: Sia Partners (2017), 'Energy Outlook'

In summary, European and US estimates of public charging requirements per PEV by 2030 vary by an order of magnitude. Given the large discrepancy between the two jurisdictions, and the significant impact this has estimates of future charging infrastructure requirements, Energeia recommends that the CEFC and ARENA consider further detailed analyses to better understand the key differences between the various approaches.

Energeia's approach to estimating the future public charging requirements in Australia are detailed in Section 6.3.3.

5.3 Supply of Public Charging Infrastructure

This section addresses the key questions raised by the CEFC and ARENA regarding charging infrastructure business models, technology costs, standards, competitive dynamics and potential players.

5.3.1 Charging Solutions, Scaling and Economics

5.3.1.1 *Public Charging Solutions*

Energeia research carried out for this project found that there are primarily two public charging infrastructure solutions:

- **Level 2** – Level 2 charging can provide charging for the daily driving needs of PEVs without a dedicated parking space. It can also be used for range extension of trips where the vehicle will be parked long enough to recharge. This extends it to trips of 100%-160% of a PEV's range.
- **DCFC** – DCFC can provide the daily charging and range extension. Its key drawback is it is relatively inconvenient to abundant Level 2 charging at 20 min refuelling rates (150kW), where drivers never have to worry about finding a space near their house or work.

Table 7 maps the two charging solutions to charging requirements by charging segment.

Table 7 – PEV Charging Solutions and Applications

Charging Requirement	Daily	Range Extension
< 80% Range	✓	
80-160% of Range	✓	
> 160% of Range	✓	✓

Source: Energeia Analysis

5.3.1.2 *Public Charging Infrastructure Scaling*

Energeia's research found that leading overseas jurisdictions follow a common approach to scaling their charging infrastructure, which is summarised in Table 8.

Step 1 targeted first generation PEVs, which did not have the driving range to meet common commuting distances. Stage 1 networks targeted public charging near workplaces to enable commuters to purchase and use first generation PEVs. Second generation PEVs have sufficient range for commuting, and Step 1 is therefore no longer required for this segment (and chargers can be used to address Step 3).

Step 2 focused on establishing a network of DCFC to enable PEVs to 'access' the road network, particularly inter-region and long-haul destinations. The number of DCFCs depending on PEV range. Early range extending access networks targeted at least 1 DCFC every 40-50 miles, consistent with the maximum range of first generation PEVs. New range extension networks can be spaced further apart as PEV ranges have increased.

Table 8 – PEV Charging Network Scaling

Step	Segment	Solution	Locations	Targets	Impacts
1	Dedicated Residential - Daily Commuter	L2	Workplace	Long-Distance Commutes	20% of Commuters
2	All	DCFC	Main Roads, Destinations	Road Trips, Regional Tourism	Less than 1% of trips
3	Non-Dedicated Residential	L2 or DCFC	Public Parking	Daily Commutes	20% of All Res Drivers
4	All	L2 or DCFC	Non-Dedicated	Congestion	Non-Dedicated + Long-Haul

Source: Energeia Analysis

Step 3 public charging networks have focused on the roughly 20% of drivers without access to dedicated parking and therefore their own Level 2 charger. To date, for reasons discussed in previous sections, public charging infrastructure deployment targeting this segment has focused on public L2 chargers near work and home. However, the most recent studies also include petrol station style DCFC solutions for this segment.

The final stage, **Step 4**, in public infrastructure scaling that Energeia research identified is the scaling up of the network as the number of PEVs rise. This infrastructure layer is volume driven to address rising congestion in Step 2 and Step 3 layers. It is therefore typically targeted at metropolitan and urban areas with the highest population density, and at major thoroughfares, which see the most traffic.

5.3.1.3 *Public Charging Economics*

While Step 1 and Step 2 charging has to date been heavily subsidized by leading overseas jurisdictions, charging infrastructure is expected to eventually become a stand-alone business. Energeia therefore analysed the economics of each of the main public charging solutions, and the results are shown in Table 9.

The analysis reflects new cost input assumptions taken from research conducted for this report. Key updates to our assumptions since we released our briefing note in 2017 are the expected costs of 500-1,000 kW DCFCs and the associated electricity network interconnection costs, which are discussed in Section 5.3.3.3.

Despite increasing our assumed cost of DCFC, our modelling still shows that DCFC is likely to be the longer-term public charging infrastructure winner, mainly due to its superior utilisation characteristics. L2 workplace and destination charging suffers from relatively low levels of utilisation due to weekends and weekdays, respectively.

Table 9 – PEV Charging Models – Economic Comparison

	Public Workplace (Parking Lot)	Public Destination (Parking Lot)	Public Transit (Gas Station)
Equipment Capex	$2,000	$2,000	$60,000
Electricity Connection Capex	$4,000	$4,000	$30,000
Electricity ($/kWh)	$0.15	$0.15	$0.10
Daily Fixed Cost	$2	$2	$36
Per 100 kWh Charge Cost	$17	$19	$11
Power (kW)	9.6	9.6	1,000
Usage Profile	Weekdays	Weekends	7 Days
Charges per Day (Weekly Avg)	1.4	0.6	25.2
Mins per Charge	240	240	5
Total kWh/Day/Charger	55	22	2,099

Source: Energeia Analysis

In the next 10 years, Table 9 is suggesting that PEVs could expect to pay around $11 to fill up their 100 kWh tank at the local DCFC station in about 5 minutes or less. We estimate the same fill-up would take 4 hours (parked at work during the day or at home overnight) and cost $17-19 using a L2 solution.

Importantly, the above analysis is assuming DCFC prices for 500-1,000 kW chargers reported later in this report fall to prices closer to todays 50 kW chargers through economies of scale and competition. Also, public L2 chargers may still need to play a role in Australia in the near-term until DCFC performance and costs improve.

5.3.2 Charging Revenue Models, Networks and Pricing

5.3.2.1 *Public Charging Revenue Models*

Energeia's research has identified a range of public charging infrastructure revenue models, which have underpinned the deployment of public charging infrastructure to date.

Table 10 displays the main types and sub-types of public charging infrastructure revenue models that Energeia has identified and their estimated market shares in Australia and overseas. Most public charging revenue is estimated to come from government and business subsidies. Government subsidies and user pays business models are more prevalent in Europe and the US, while Australian public charging is more reliant on businesses paying for the cost of chargers to enable PEV drives to patronise their locations.

Table 10 – Public Charging Revenue Models and Market Shares

Type	Sub-Type	Australian Market	Overseas Market	Examples
User Pays	Subscription	0%	10%	Not yet identified in Australia
	Ad-Hoc	10%	20%	Few for-profit chargers exist
Embedded	OEMs	5%	10%	Tesla, etc.
	Associations	5%	0%	NRMA
	Commerce	60%	10%	Most free charging currently
	Advertising	0%	0%	Not yet identified
	Data	0%	0%	Not yet identified
Subsidies	Government	25%	50%	Many

Source: Energeia Analysis

Energeia was unable to identify public charging infrastructure revenue models based on advertising or access to PEV recharging data.

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5.3.2.2 *Public Charging Networks and Pricing*

Energeia researched international public charging networks in the US, EU and Australia to understand their relative size, business entry drivers, and pricing approach.

International

Internationally, Energeia's research found public charging infrastructure deployment is being led by a mixture of utilities, new entrants and PEV OEMs. Table 11 reports our findings for selected players in Europe and the US.

Table 11 – Charging Networks and Service Pricing – Leading International Jurisdictions

Charging Service and Pricing	Network Operator											
	Tesla	Charge Point	New Motion	Ionity*	essent	RWE	LYSE	Enel	Sema Connect	NVEnergy	nrg	KCP&L
Player												
Region	Global		EU						US			
	-	-	-	-	NL	DE	No	IT	-	NV	TX	KS
No. of Charging Stations **	1000	45k	50k	400	1k	2.8k	NA	1.6k	2k	150	350	1k
Start of Program	2012	Pre-2010	2009	2017	2011	2009	2011	2008		2015	NA	2015
Free Charging	✓	✓				✓			✓	✓	✓	✓
Subscription Plan			✓		✓	✓	✓	✓	✓		✓	
c/kWh (Level 2 charging)		✓	✓		✓	✓			✓	✓		
c/hr (Level 2 charging)		✓	✓						✓		✓	
c/min (DC charging)	✓	✓	✓		✓						✓	
$/charge			✓				✓		✓			

Source: Energeia Research; Note: * Ionity is a very recently founded company whose pricing model is not public knowledge at the moment. ** Number for Tesla is 100% DCFC, for all other legacy players total is mix of L2 and DCFC chargers

Energeia's analysis shows that public charging network operators, which mainly operating public L2 chargers, have not yet settled on a common approach to pricing public charging services.

Australian

In Australia, there is a wider range of charging infrastructure network operators than we have found overseas, as shown in Table 12. This is mainly due to the entry of national and state-based vehicle associations including, including the NRMA and RAC, which we have not seen emerge as a player overseas. There is also a larger role being played by state governments like South Australia, who are seeking to establish their state as a leader in electric vehicle mobility technology and manufacturing.

Energeia's review of Australian networks has found that free charging is being gradually phased out in favour of a user pays (ChargeFox, ChargePoint, SA Government and Everty) or embedded revenue model (NRMA/RAC and Tesla).

Energeia notes that Australia has not yet followed the $/minute model, which is popular overseas due to providing a better incentive for users to move-on once they have reached their desired charging amount.

Table 12 – Australian Charging Networks and Service Pricing

Service / Pricing	Charging Network Operator							
Player	Tesla	NRMA	RAC (WA)	Energy Qld	ChargeFox (JetCharge)	chargepoint	City of Adelaide	Everty
Type of Player	EV OEM	Motoring Association		Utility	EVSE Operator	EVSE Operator	Local Govt	EVSE Operator
Region	AU	NSW	WA	QLD	AU	AU	SA	NSW
Charging Stations	20* (DCFC)	1**	12 (DCFC)	1*** (DCFC)		350 (3 DCFC)	40 (DCFC)	N/A****
Charging Hardware	Tesla L3	-	Circontrol Trio	Tritium Veefill	Wallpod / EV Box	chargepoint CT4000	Tesla L3	N/A
Charging Software	Tesla	-	ChargeStar		EV Connect		Tesla	N/A
Payment Method	Cloud	-	RFID card	RFID card	Cloud	RFID card	Cloud	Cloud
Start of Program	2014	-	2015	2017	-	Pre-2010	2016	2017
Free Charging	1st 400 kWh	-	✗	1st 12 months	Owners Discretion	Owners Discretion	Until end of 2017	✗
c/kWh (Level 2)	✗	✗	$0.75/kWh ++	✗	✓	✓	✗	✗
c/hr (Level 2)	✗	✗	✗	✗	✓	✓	✗	$1-3/min
c/kWh (DCFC)	$0.35/kWh +	-	$0.75/kWh ++	✓	✓	✓	$0.30/kWh	✗

Source: Energeia Research; Notes: * Tesla has announced an additional 18; ** NRMA is planning to roll-out 40 chargers at a cost of $10m as part of their Social Dividend Investment Strategy; *** Energy Queensland is rolling out an Electric Super Highway of 18 superchargers up the Queensland coast from the Gold Coast to Cairns; **** Everty is a P2P charging network, offers PEV owners a platform for listing and monetising their home charger to fellow PEV drivers; + Tesla; ++ Included in this charge is a flat 30c/kWh fee to a payments handling company (Braintree)

5.3.3 Charging Technology, Standards and Costs

5.3.3.1 *Charging Technology*

PEV recharging technology has evolved rapidly from when it was first introduced in 2010 into Australia. First generation chargers, called Level 1, took supply directly from wall outlets, and took hours to recharge first generation PEVs, which has very small batteries.

DCFC and L2 chargers appeared in the next few years, initially at relatively lower charging capacities. Over the last couple of years, DCFCs have increased from 22 kW to 40 kW, then to 150 kW and are now available in 350kW sizes. Level 2 chargers have increased their capacity from 3.7 kW initially to up to 22 kW today.

Wireless charging has emerged over the last few years to offer an alternative to plug-in charging. Power capacities for wireless capacities are now comparable to Level 2 chargers, and wireless power transmission losses are no longer a major performance consideration.

The final major charging technology frontier is vehicle-to-grid (V2G), which will allow vehicles to discharge their batteries into the electricity network. Although V2G technology has been around almost from the start, it has made little progress, and remains limited to bespoke technology pilots and trials.

V2G refers specifically to power transfer from a PEV back into the network and should not be confused with charging management systems. PEV charging management systems seek to control charging and provide utility demand response, but do not actually cause electricity to travel from a PEV back into the network.

Table 13 summarises the key charging technologies in terms of their voltages, power ratings and connectors.

Table 13 – EVSE Characteristics by Charger Type

Type	Definition	Voltage	Rating	Connectors	Examples
L1 Charging (AC)	Level 1 charging in the equivalent of plugging your car into an ordinary household outlet	120 V	1.4 kW to 1.9 kW		
L2 Charging (AC)	Level 2 chargers are used mainly at private premises for personal use or for public destination-based charging locations to attract drivers	240 V	3.7 kW to 17.2kW		
DC Fast Charging (DCFC/L3)	DC fast chargers are typical used by public charging networks to enable rapid recharging along major long-distance thoroughfares	480 V	22 kW to 350 kW		
Wireless Charging	Transfers energy between a charging pad on the ground and a receiving pad on the underside of the vehicle, allowing PEVs to charge without plugging in	240 V	3.6 kW to 11 kW		
Vehicle to Grid (V2G)	Connects vehicles to the grid allowing for bidirectional flow to assist networks with demand response	220 V	7.4 kW		

Source: Energeia Research

5.3.3.2 *Charging Standards*

Charging standards have also developed rapidly over the past five years, and there are now standards for each of the key charging technologies listed in Table 14.

Table 14 – PEV Charging Standards

Classification	Level	Current	Power	Type		
				China	Europe	Japan
Slow Chargers	Level 1	AC	≤3.7 kW	Devices installed in private households, the primary purpose of which is not recharging electric vehicles		
	Level 2	AC	>3.7 and ≤22kW	GB/T 20234 AC	IEC 62196 Type 2	SAE J1772 Type 1
	Level 2	AC	≤22 kW	Tesla Connector		
Fast Chargers	Level 3	AC, 3-phase	>22 kW and ≤43.5 kW		IEC 62196 Type 2	
	Level 3	DC	DC Currently <200kW	GB/T 20234 DC	CCS Combo 2 (IEC 62196 Type 2 & DC)	CHAdeMO
	Level 3	DC	Currently < 150 kW	Tesla and CHAdeMO connectors		
Wireless	Level 2	AC	3.6 kW to 11 kW	NEMA 14 - 50		
Vehicle to Grid (V2G)	Emerging Standard: ISO 15118 (2013)					

Source: IEA (2017), 'Global EV Outlook 2017'; Note: No Australian Standard for EVSE currently exists

Key developments in standards include the CCS DCFC standard which will DCFC standards across Europe and the US. However, Japan and China continue to pursue their own DCFC standard. There are now common international standards for wireless charging and an emerging international standard for V2G charging, which has only recently emerged.

5.3.3.3 *Charging Infrastructure Costs*

Detailed public charging infrastructure costs are not widely disclosed. Energeia's research has nevertheless found several cost build-ups for the US and Europe, one of which is recently and includes 350 kW units. Energeia expects public infrastructure costs, particularly for DCFCs, to continue to fall as the market matures, industry capability developers and economies of scale increase.

Table 15 displays detailed cost data from a US study of public L2 and DCFC infrastructure deployment costs.

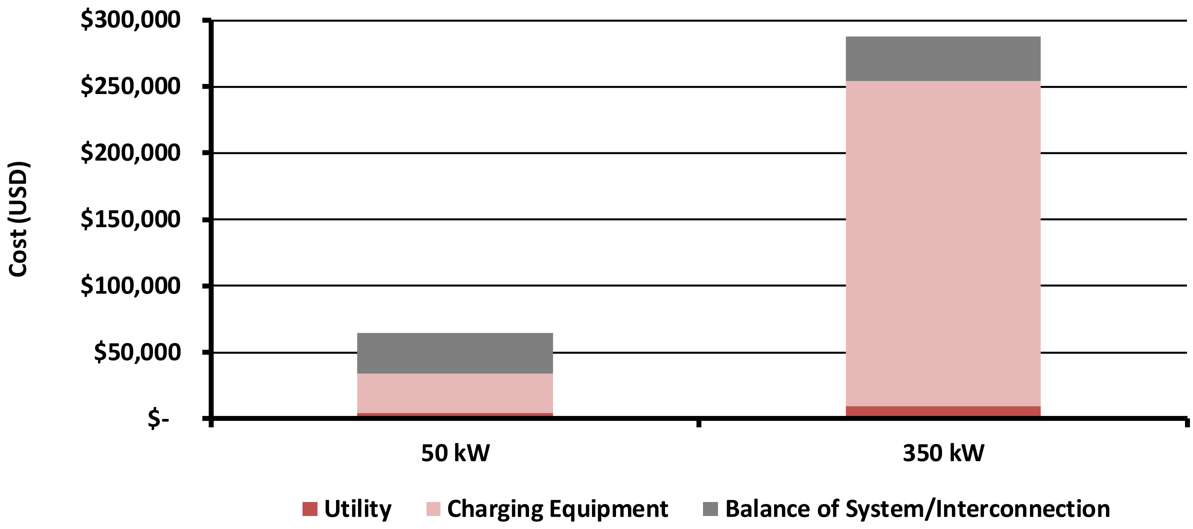
Table 15 – Published Level 2 and DCFC Installation Costs – US (USD, 2014)

		Public Level 2		Public DCFC	
		Low	High	Low	High
OEM	Charging Unit	$1,500	$3,000	$12,000	$35,000
Electrical	Materials	$150	$300	$300	$600
	Labour	$400	$800	$2,200	$4,200
Civils	Materials	$50	$150	$100	$400
	Labour	$2,500	$7,500	$5,000	$15,000
Network	Transformer	-	-	$10,000	$25,000
	Total	$4,600	$11,750	$29,600	$80,200
	Labour	63%	71%	24%	24%
	Charging Unit	33%	26%	41%	44%

Source: RMI (2014). Accessed from: https://rmi.org/news/pulling-back-veil-ev-charging-station-costs/

More recent data on DCFC costs for 50 kW and 350 kW by cost component are shown in Figure 48. Energeia notes that the 350 kW units are more than five times more expensive that the 50 kW chargers. However, the 50 kW charging technology is relatively mature, and Energeia expects the cost of the 350 kW units to fall to this level over time, on the basis of the underlying inputs are not substantially more expensive.

Figure 48 – Published DCFC Installation Costs – US (2017)



Source: Idaho National Laboratory (May 2017)

Another key insight from the cost structure reported in the 2017 study is the relatively low connection costs for the 350 kW systems. Energeia's own modelling suggests that this may be due to cost sharing by the utility in their new connection prices. The costs of connecting in Australia are charged to the electricity user upfront, and Energeia therefore expects these costs could be a higher percentage of construction costs in Australia.

Table 16 displays detailed data on public infrastructure costs from Europe. It shows costs for DCFC chargers that are at the higher range of the costs reported in the 2014 US study.

Table 16 – Published EVSE Installation Costs – EU (USD, 2014)

	Level 3 DC	Level 3 AC
Station Lifetime (Years)	10-15	10-15
Load Limit (V)	500	400 (3 phase)
Load Limit (A)	125	96 (3 x 32)
Current	DC	AC
Power Limit (kW)	62.5	50
Material Cost (A$)	61,600	61,600
Site Works (A$)	23,100	15,400
Total Cost - Installed	84,700	77,000

Source: Colmenar-Santos, A,et al (2014) 'Planning Minimum Interurban Fast Charging Infrastructure for Electric Vehicles: Methodology and Application to Spain'

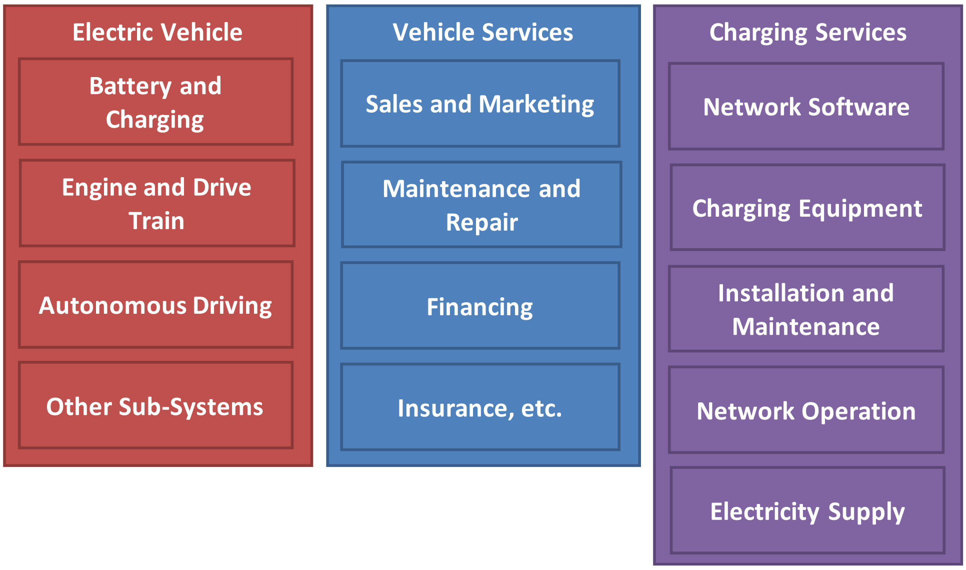
In summary, Energeia's review of international public charging infrastructure costs has found that L2 chargers can be expected to cost USD $5,000-$10,000, and DCFC can be expected to cost around USD $60,000-$80,000 in the medium term, once the industry has matured and is able to realise economies of scale. In the near-term, newly introduced, 350 kW DCFCs can be expected to cost as much as five times more than 50 kW DCFCs.

5.3.4 Value Chain and Player Analysis

5.3.4.1 *Electric Vehicle and Charging Value Chain*

The Australian PEV value chain may be segmented in vehicle manufacturing, vehicle services and charging services, and their associated major sub-components, as shown in Figure 49.

Figure 49 – PEV and EVSE Industry Value Chain



Source: Energeia Analysis

The following sections focus on current and potential future player positioning within the charging services value chain segment.

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5.3.4.2 *Key Player Positioning*

The findings from Energeia's research into key player positioning across the public charging infrastructure value chain are reported in Table 17.

Most of the major players in Australia are locally focused, with Tesla and GreenLots the only major players with overseas operations. Tesla, Chargepoint and GreenLots develop charging software and hardware, while Qualcomm only makes hardware at the present time. All included companies are developing their own public charging networks except for Chargepoint and GreenLots, who rely on third party, largely independent, developers. Finally, EnergyQLD and ACtewAGL also participate in energy retailing and electricity distribution.

Table 17 – Charging Value Chain – Key Player Positioning

Company	Regions				Technology Development						Network Dvlp.		Electricity	
	ANZ	Europe	N.A.	Asia	PEV	L2	DCFC	Wireless	V2G	Software	L2	DC	Retail	Distribution
Tesla	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		
RACV	✓											✓		
EnergyQLD	✓										✓	✓	✓	✓
ACTewAGL	✓										✓	✓	✓	✓
SA Gov't	✓										✓	✓		
ChargePoint	✓	✓	✓	✓		✓				✓				
GreenLots	✓		✓	✓		✓				✓				
Tritium	✓		✓				✓							
Qualcomm	✓	✓	✓	✓				✓						

Source: Energeia research

Energeia does not expect Qualcomm, Tritium, ChargePoint or GreenLots to change their business positioning to include development of public charging networks in the near to medium term. Longer-term, we think that ChargePoint and potentially GreenLots may move into DCFC and wireless charging as those markets grow.

5.3.4.3 *Charging Winners/Losers and Critical Success Factors*

The results of Energeia's research into the key winners and losers in the public infrastructure charging market, and the associated key lessons learned and critical success factors, is reported in Table 18.

Two major public charging infrastructure players, BetterPlace and ECOtality, have gone out of business over the past five years. Our view is that BetterPlace failed due to insufficient capitalisation to see through their vertically integrated business model. Our view is that ECOTality failed due to a lack of management capability, which cause it to declare bankruptcy before it had completed its $100M grant for the US government.

Our research has identified a number of clear winners in the public charging infrastructure market including ChargePoint, SemaConnect and New Motion, all originally independent players focused on L2 charging technology development that have leveraged revenue from government grants and third party charging infrastructure owners and operators to address the high capital requirements of infrastructure deployment.

While OEMs other than Tesla have been slow to establish their own charging networks, a number of new consortiums have emerged in the last couple of years focused on deploying DCFC networks. Ionity is one such consortium in Europe, which is planning to roll out 400 350 kW charging stations to enable its mainly European OEM backers to compete with Tesla's DCFC network. It remains to be seen if this is a long-term play for them.

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Table 18 – Charging Network Developers – Key Winners, Losers and Risks

Player	Type	Stations	Location	Winner / Loser	Critical Success Factor	Key Future Risks
Charge-Point	Equipment	41,000 (US)	AU / US	Winner	Viable business model (host pays) to date	Change to DCFC for public charging, no DCFC products
ECOtality	Equipment	12,450 (L2), 110 (DCFC)	US	Loser	$100M government grant, unviable business model	N/A
Sema-Connect	Equipment	2,000 (L2)	US	Winner	Viable business model (host pays) to date	Change to DCFC for public charging, no DCFC products
New-Motion	Equipment	30000	EU	Winner	Positioned for petrol station model, based on German experience	Private charging to date, could lose out to Public DCFC networks
Utilities	Utility	'000s	US / EU	Winner	Added to rate base, upstream selling benefits	Migration to public DCFC network with better location/tech
BetterPlace	OEM	16 (Battery Swap)	AU / US	Loser	Under-capitalised, unviable business model	N/A
Tesla	OEM	20 (DCFC)	AU / US / EU	Winner	Upstream selling benefits, free charging	Migration to public DCFC network with better locations
Ionity	OEM	400*	EU	TBC	Carmaker backed, 350 kW DCFC network	Unproven business model

Source: Energeia Analysis

To date, petrol station operators have not established large DCFC networks. However, this may be about to change with the UK's proposed legislation requiring petrol stations to offer DCFC[27], and Shell's recent acquisition of New Motion, the largest public charging infrastructure operator in Europe.

5.3.4.4 *Potential Public Charging Infrastructure Developers*

Based on our review of the key players in Australia and overseas, key lessons learned and critical success factors, Energeia developed an assessment framework for considering the strengths and weaknesses of potential developers of Australia's public charging network.

The framework and our assessment results are reported in Table 19. Based on this framework, Energeia concludes that petrol station operators, major domestic operators, automotive associations, regulated electricity networks and energy retailers are in the strongest positions to deploy Australia future public charging network.

[27] Automated and Electric Vehicles Bill 2017-19. Access from: https://services.parliament.uk/bills/2017-19/automatedandelectricvehicles.html

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Table 19 – Potential DC Fast Charging Developers – Strengths and Weaknesses

Category	Examples	Key Strengths								
		Software / Hardware	Infrastructure Development	Asset Management	Regulatory Backing	Access to Capital	Energy Risk Management	Existing Locations	Cost Sharing	Score
Major Petrol Station Operators	Shell, BP	×	✓	✓	×	✓	✓	✓	✓	6
Major Energy Retailers	Origin, AGL	×	✓	✓	×	✓	✓	×	✓	5
Regulated Electricity Networks	Ausgrid, TransGrid	×	✓	✓	✓	✓	×	×	✓	5
Automobile Associations	RACV, NRMA	×	✓	✓	×	✓	✓	×	✓	5
Major Overseas Operators	NewMotion	✓	✓	✓	×	×	✓	×	×	4
Major Infrastructure Developers	CMIC, Lendlease, etc.	×	✓	✓	×	✓	×	×	×	3
Unregulated Electricity Networks	Ausgrid, TransGrid	×	✓	✓	×	✓	×	×	×	3
Car OEMs	Tesla, etc.	×	×	×	×	✓	×	×	✓	2

Source: Energeia Analysis

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6 Part B: Market Review of Electric Vehicle Sales, Stock and Infrastructure

This section of the report details the quantitative modelling methodology and results, including forecast PEV sales, OEM market shares, infrastructure requirements and network impacts. The results are shown for the 'Moderate Intervention' scenario unless otherwise specified and focus on an Australia-wide outlook to 2040.

6.1 Overview

The PEV forecasts consider impacts from PEVs taken up within the passenger vehicle and commercial sectors, excluding articulated trucks and speciality vehicles such as bucket trucks. The passenger sector includes passenger cars (PC) and sport utility vehicles (SUV). The commercial sector includes light commercial (vans and trucks), buses, and rigid vehicles. PEV forecasts include both BEVs and 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.

Energeia has used its fifth generation PEV forecasting model (detailed in Appendix E), updated to align with the latest industry consensus assumptions regarding electricity prices as well as market and policy settings, to derive the results. Further specific PEV assumptions were set in conjunction with the CEFC as described in Section 6.2.

6.2 Scenarios and Key Assumptions

Three forecast scenarios were modelled that represent the expected pathway for Australia's PEV outlook across a Moderate Intervention scenario, and book ending No Intervention and Accelerated Intervention scenarios, where the technical barriers/capabilities, consumer sentiment, policy and regulatory outlooks aligned with each forecast scenario.

- **No Intervention Scenario:** assumes no additional action by any stakeholders in Australia, and uptake is driven solely by the economics of PEVs manufactured overseas and shipped to Australia.
- **Moderate Intervention Scenario:** Assumes an unco-ordinated mix of policy support, across several layers of government, including potential federal policy changes to luxury car tax, fringe benefits tax and vehicle emissions standards, and a mix of the most likely state and local government PEV support from the list below. This scenario assumes no long-term decarbonisation target.
    - Australian states with net-zero targets and a history of policy action to support this in power generation introduce policies to support PEV uptake in their states. Policies include stamp duty and registration exemptions.
    - Local and state government fleets are pushed to increase fleet purchases of PEVs where there is a comparable PEV in the class.
    - Removal of restrictions on import of second-hand PEVs drives a larger second-hand market.
    - Preferential parking and use of transit lanes.
    - Assumes that a range of actors (governments, motoring associations, private companies) accelerate the roll-out of charging infrastructure which removes range anxiety, e.g. QLD Superhighway and the NRMA network.
    - Assumes OEMs react to this policy support by increasing PEV model availability.
- **Accelerated Intervention Scenario:** assumes the unco-ordinated policy and OEM actions in the Moderate Intervention scenario occur earlier and to a higher level of support, representing a more aggressive push to support PEVs. In addition, it is assumed that as foreign-produced ICEs model availability decreases that a total ban in ICE sales is implemented towards the end of the projection period.

Key macroeconomic drivers of relevance to PEVs are kept consistent between the three modelled scenarios and are shown in Table 20.

Table 20 – Macroeconomic PEV Drivers

Driver	No Intervention	Moderate Intervention	Accelerated Intervention
Population Growth	ABS projection B		
Economic Growth	Neutral		
Electricity Network Charges, 5 Years	Current AER determinations, fixed after 5 years		
Electricity Retail Costs and Margin	Assume current margins throughout		
Oil Prices	USD60/bbl. (BR) over 5-year glide path		

Source: Energeia Modelling

In addition to the macroeconomic PEV drivers, the PEV Forecast includes the additional assumptions listed in Table 21.

Table 21 – Additional PEV Scenario Drivers

Driver	Impact	No Intervention	Moderate Intervention	Accelerated Intervention
PEV Policy Incentives	Used to improve PEV cost of ownership. Includes indirect subsidies, e.g. from vehicle energy efficiency standards.	$0	$2,000	$3,000
Year Policy Incentive Applies	Determines when the incentive is applied.	Never	2021	2019
PEV Tariff Product	Drives cost of ownership through tariff structure and levels and charging impacts.	Controlled Load for non-DCFC	Controlled Load for non-DCFC	Controlled Load for non-DCFC
PEV Industry Incentives	Used to improve PEV cost of ownership. Includes upfront direct incentives.	$0	$1,000	$2,500
Year Industry Incentive Applies	Determines when the incentive is applied.	Never	2022	2019
Additional Negotiated Models	Drives uptake model via availability coefficient. Focuses on volume for model strategy.	0	3	6
Overseas Importation Policy	Increases model availability to NZ levels.	Never	2022	2019
Charging Infrastructure Availability	Will limit uptake of segments without access to dedicated charging, e.g. second cars	2026	2022	2019
Battery Prices (CAGR)	Drives PEV cost of ownership.	-8.00%	-8.00%	-8.00%
PEV Vehicle Price Parity (excl. Battery) in Years	Drives cost of ownership by reducing current differentials not explained by battery costs.	5	5	5
PEV Distance Parity (Years)	Drives cost of ownership by increasing size of battery and therefore costs.	5	5	5

Source: Energeia Modelling

Detailed assumptions underpinning the PEV scenarios are provided in Appendix E.

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6.3 Results

The results shown in this section describe forecast PEV uptake over the period 2018 to 2040, OEM market share by year, required charging infrastructure scaling and the corresponding contribution to energy consumption and maximum and minimum demand at the NEM level and by state. The results are presented for the Moderate Intervention scenario unless otherwise indicated.

6.3.1 EV Sales and Stock Uptake Forecast

Section 6.3.1 presents uptake of PEVs in terms of both annual sales and number of vehicles on the road (stock).

6.3.1.1 *Moderate Intervention*

PEV sales (both BEV and PHEV) are forecast to reach 611,800 vehicles per annum by 2030, increasing to 1.89 million annual new vehicle sales by 2040, or 49% and 100% of sales respectively as shown in Figure 50.

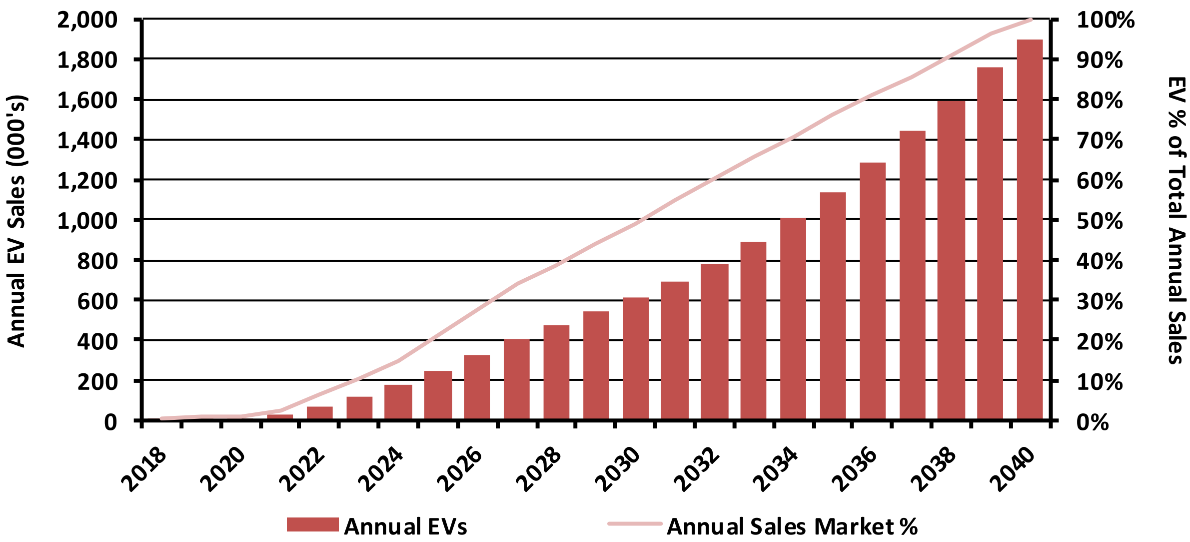
Detailed PEV modelling shows a relatively steady increase in PEV sales to around 28% per annum by 2026 driven by:

- falling PEV prices supported by falling battery prices,
- increased model availability by OEM, and
- an increasing differential between electricity and petrol prices.

Sales are forecast to see a step change in sales from 2021, when the first PEVs segments begin to see two-year paybacks, reaching a market tipping point.

From 2021 to 2040, annual sales growth is higher, driven by falling battery costs, increased driving range and charging infrastructure builds, but is constrained by transition of supply side manufacturing from ICE to PEV technology. In 2040, the market reaches saturation point with 100% of new car sales coming from PEVs.

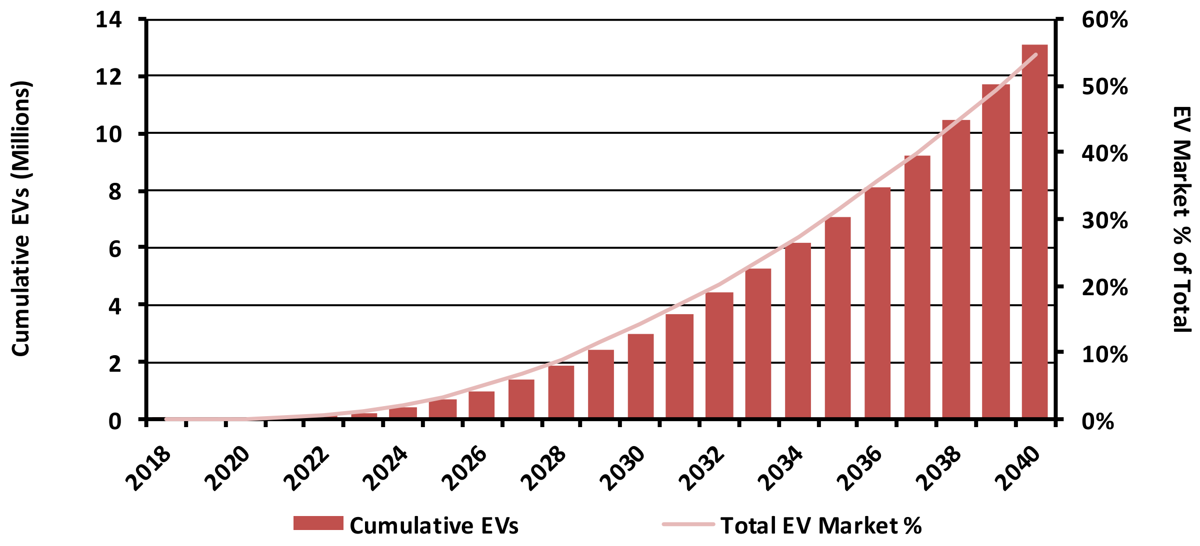
Figure 50 – Annual PEV Sales (Moderate Intervention)



Source: Energeia Modelling

As a result, total vehicles on the road are forecast to reach 3.01 million by 2030 or 14% of vehicles as shown in Figure 51. By 2040, PEV uptake reaches 13.08 million vehicles, or 54.5%.

Figure 51 – PEVs on the Road (Moderate Intervention)



Source: Energeia Modelling

6.3.1.2 *Scenarios*

PEV uptake forecasts vary significantly across scenarios as shown in Table 22 for the NEM. Detailed results by scenario are presented in Appendix D.

Table 22 – PEV Uptake by Scenario

Scenario	2018			2020			2030			2040		
	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)
No Intervention	0%	3	10	1%	12	30	22%	257	832	73%	1,045	6,775
Moderate Intervention	0%	3	10	1%	12	31	49%	612	3,010	100%	1,895	13,078
Accelerated Intervention	0%	3	10	4%	44	79	64%	857	4,927	100%	2,247	17,315

Source: Energeia Modelling

For the Accelerated Intervention scenario, PEV sales initially increase at a faster rate than both the No Intervention and Moderate Intervention scenario driven by the larger PEV incentive, which applies earlier, and earlier PEV price parity. The Accelerated Intervention scenario sale rates accelerate further from 2020 due to a faster ramp-up of model availability driven in part by higher incentives and OEM reaction to consumer demand.

As a result, forecast PEV stock under the Accelerated Intervention scenario reaches 4.93 million vehicles by 2030, 1.6 times higher than the Moderate Intervention scenario, and reaches 17.32 million vehicles by 2040, 1.3 times higher than the Moderate Intervention scenario.

In the No Intervention scenario, PEV sales increase slower over time due to a reduced decline in PEV price premiums and model availability. Under the No Intervention scenario, the first PEVs to reach the two-year pay-back do so in 2027, three years later than the Moderate Intervention scenario. As a result, forecast PEV stock in the No Intervention scenario reaches almost 832,000 vehicles by 2030, 3.6 times smaller than the Moderate Intervention scenario. Looking further ahead, the PEV stock under the No Intervention scenario reaches 6.78 million vehicles by 2040, 48% smaller than the Moderate Intervention scenario.

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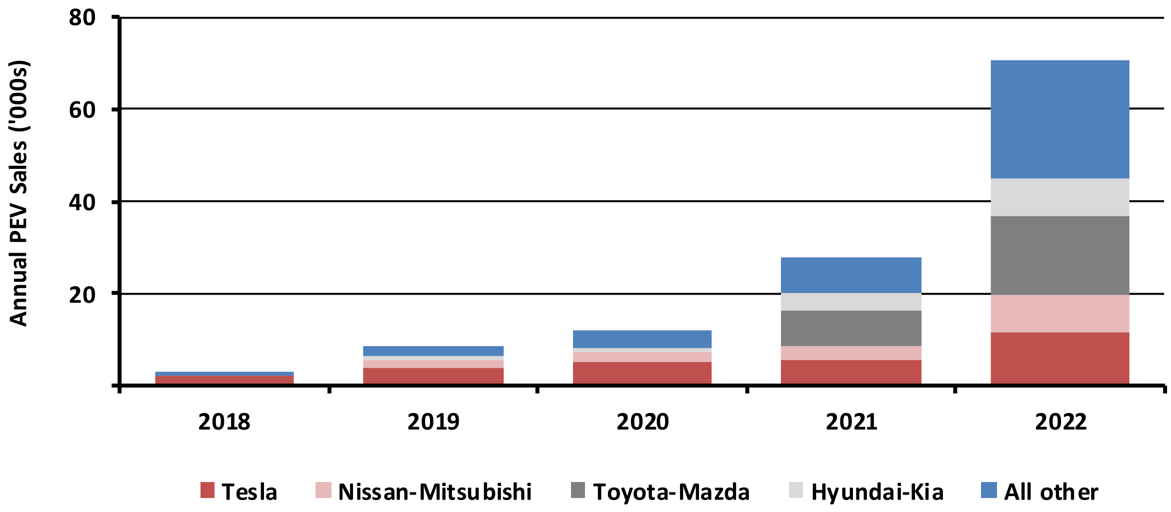
6.3.2 EV OEM Market Shares

Section 6.3.2 presents the short-term forecasts for OEM market shares from Australia's forecast PEV stock and the manufacturers likely to play a significant role on PEV adoption to 2022. Energeia's OEM market share forecast is based on the latest OEM announcements on their commitments to PEV model availability.

6.3.2.1 *Moderate Intervention*

Under the Moderate Intervention case, PEV sales are set to expand over the next five years from 3,100 to 70,700 electric vehicles sales. The rapid rise in uptake is based on a shift in PEV model availability from niche vehicles and non-leading OEMs to electric equivalent models of leading brands and models, this is highlighted in Figure 52.

Figure 52 – OEM PEV Market Share Forecast (Moderate Intervention)

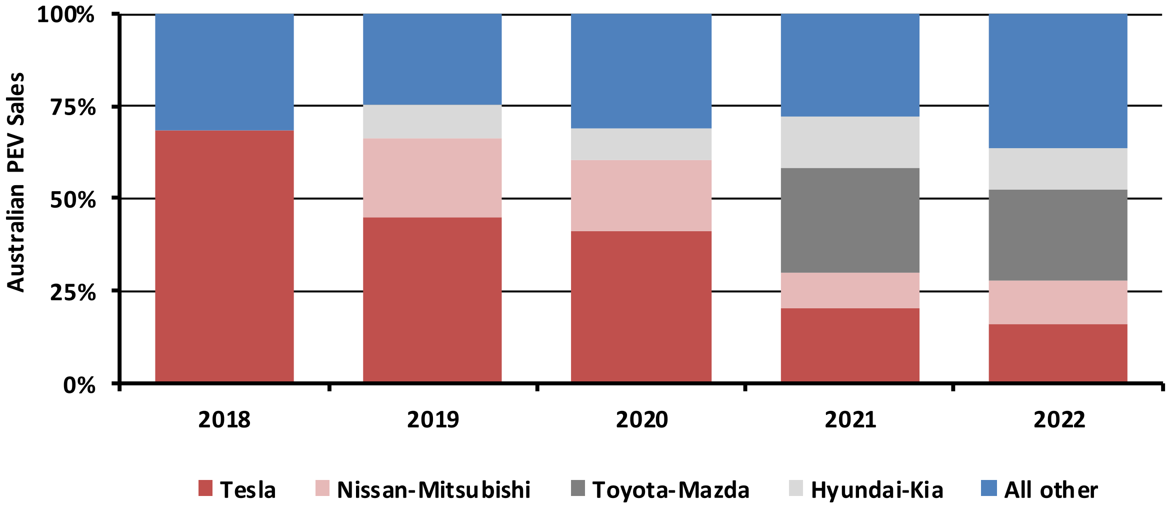


Source: Energeia Modelling

The step change in forecast sales result from high volume OEMs, specifically Mazda, Honda, Mitsubishi, Toyota and Hyundai, announcing and releasing PEV equivalents, both PHEV and BEV, of their most popular models as soon as 2019.

We expect the Nissan-Mitsubishi-Renault alliance to be an earlier mover, followed by the Hyundai-Kia group and Toyota-Mazda alliance. The next wave of PEV models will therefore shift the market shares from low to high volume OEMs as per Figure 53.

Figure 53 – OEM PEV Sales (Moderate Intervention)



Source: Energeia Modelling

6.3.2.2 *Scenarios*

OEM market share forecasts do not vary significantly across the No Intervention and Accelerated Intervention scenarios. Although the number of PEVs sold between scenarios varies, the assumed uptake of vehicle type and model are expected to maintain their uptake ratio between scenarios. OEM PEV sales forecast by scenario are presented in Appendix D.

6.3.3 EV Charging Infrastructure Scaling/Development

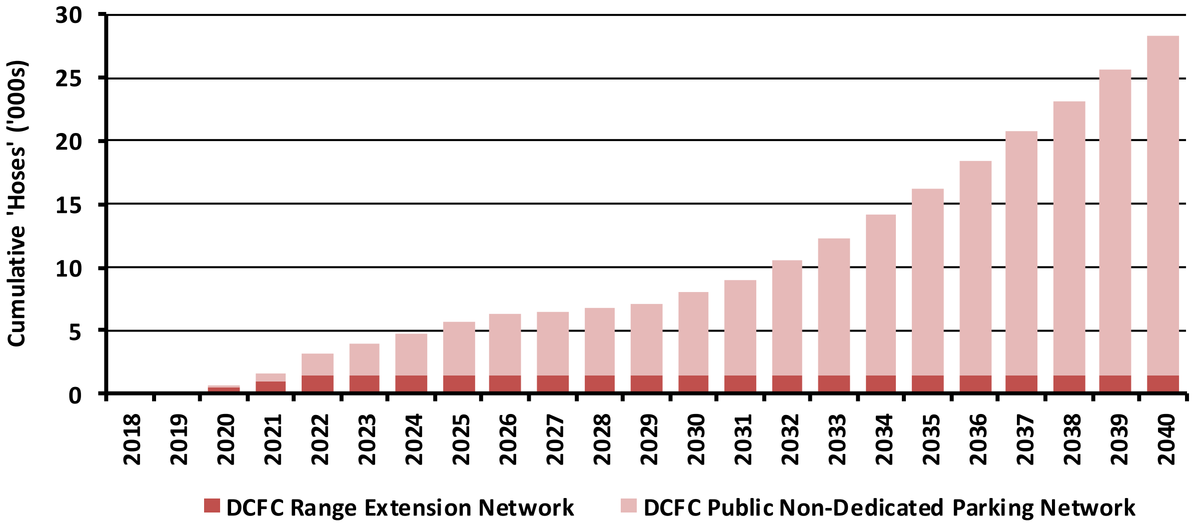
Charging infrastructure forecasts are based on the development of a DCFC network to enable universal access to 90% of the country's main and arterial roads.

6.3.3.1 *Moderate Intervention*

Under the Moderate Intervention case, public DCFC are required to meet charging demand from the majority of PEVs that do not have access to dedicated L2 charging at home or the workplace. These chargers are based on the gas station model with charge times below 5 minutes to avoid congestion, while range extension charges are required to supply the <1% trips required for inter-region driving over 150kms.

Australia will require over 28,370 DCFC hoses over the period to 2040, split by range extension chargers (1,440) which address range-anxiety and public non-dedicated parking chargers (26,930) which are the locally-accessible public chargers and become increasingly more important to avoid congestion at charge points as the number of PEVs on the road increase, as per Figure 54.

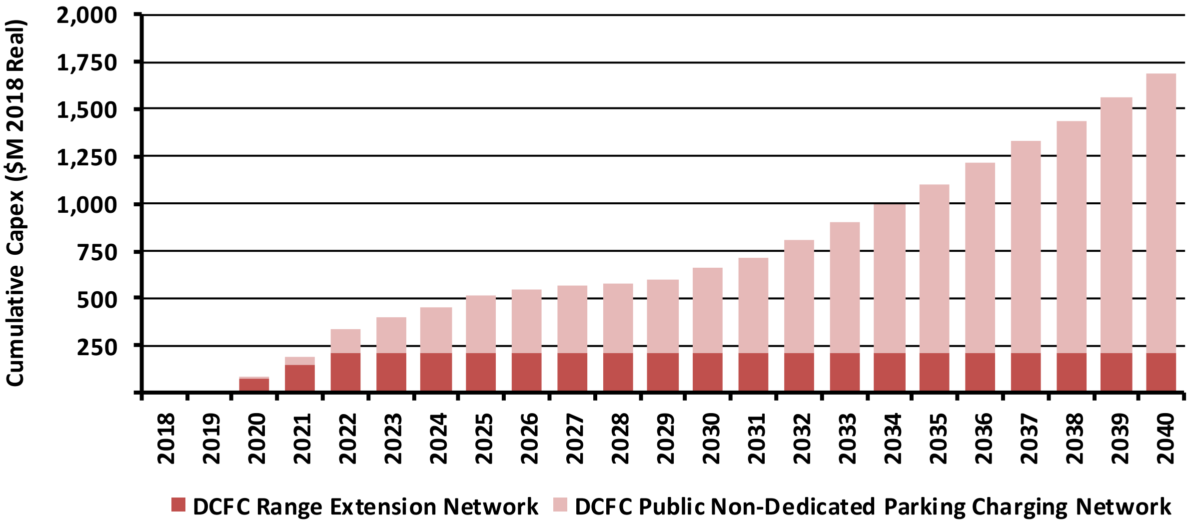
Figure 54 – Charging Connections Required by Type (Moderate Intervention)



Source: Energeia Modelling; Note: dedicated L2 charges not shown in order to avoid overwhelming the number of DCFCs.

The cumulative capital cost required to meet PEV demand from DCFCs is set to rise to just under $1,688 million by 2040. Of this, $214 million will be for range extending networks, and the remaining $1,474 million will be for a non-dedicated parking DCFC network as per Figure 55.

Figure 55 – Charging Capex Required by Type (Moderate Intervention)



Source: Energeia Modelling

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6.3.3.2 *Scenarios*

EV charging infrastructure forecasts vary significantly across scenario as shown in Table 23 for the Australian market.

Table 23 – PEV Charger Uptake by Scenario

Scenario	2018 Acc. DCFC (000s)	2018 Cong. DCFC (000s)	2018 Level 2 (000s)	2020 Acc. DCFC (000s)	2020 Cong. DCFC (000s)	2020 Level 2 (000s)	2030 Acc. DCFC (000s)	2030 Cong. DCFC (000s)	2030 Level 2 (000s)	2040 Acc. DCFC (000s)	2040 Cong. DCFC (000s)	2040 Level 2 (000s)
No Intervention	0.0	0.0	9.9	0.5	0.0	26.9	1.4	0.2	613	1.4	1.8	4,955
Moderate Intervention	0.0	0.0	10.0	0.5	0.0	27.6	1.4	0.8	2,189	1.4	3.4	9,520
Accelerated Intervention	0.0	0.0	10.1	0.5	0.1	70.1	1.4	1.3	3,528	1.4	4.4	12,449

Source: Energeia Modelling

For the Accelerated Intervention scenario, stronger uptake of PEVs require a faster transition to DCFC to avoid congestion and remove PEV range barriers. The Accelerated Intervention scenario requires 2.5 times the number of PEV chargers than the Moderate Intervention scenario to 2021, and No Intervention scenario to 2026. As a result, forecast PEV chargers under the Accelerated Intervention scenario reaches 2,700 DC fast chargers and 3.53 million L2 dedicated chargers by 2030, 60% greater than the Moderate Intervention scenario, and reaches 5,800 DC fast chargers and 12.45 million chargers by 2040, 30% greater than the Moderate Intervention scenario.

In the No Intervention scenario, the PEV charger requirement increases slower over time due to a reduced consumer demand. As a result, forecast PEV chargers in the No Intervention scenario reaches almost 1,600 DC fast chargers and 613,000 L2 dedicated chargers by 2030, 70% smaller than the Moderate Intervention scenario. Looking further ahead, the PEV stock under the No Intervention scenario reaches 3,200 DC fast chargers and 4.96 million L2 dedicated chargers by 2040, 50% smaller than the Moderate Intervention scenario.

6.3.4 EV Charging Electricity Network Impacts

EV impacts on transmission and distribution infrastructure assume managed charging in place for dedicated parking vehicles, while DCFC grid impacts are calculated based on driving and traffic patterns.

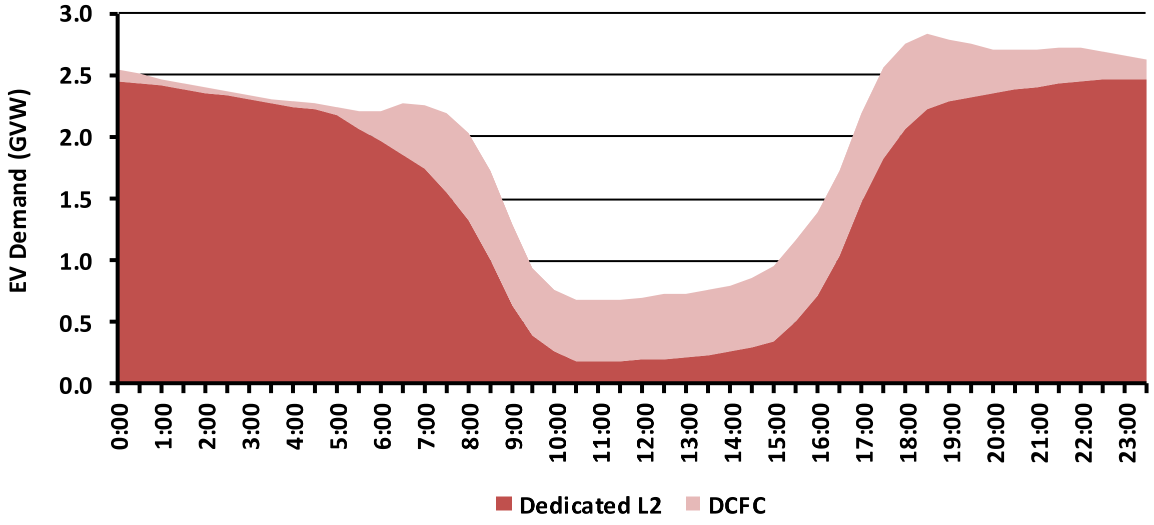
6.3.4.1 *Moderate Intervention*

This section describes Energeia's forecast of aggregate PEV demand including controlled PEV charging and uncontrolled DC fast charging.

Energeia's modelling shows PEV charge management avoiding any significant increase in maximum demand in the Moderate Intervention scenarios. DCFC is expected to occur in proportion to cars on the road and is therefore not amendable to managed charging. Overall, the impact of PEV charging on system peak demand is 2.8 GW by 2040, as shown in Figure 56.

While these results suggest an opportunity to encourage daytime PEV charging, a whole of system analysis is required to determine the optimal PEV charging profile. A key issue to be addressed is whether higher charging in the middle of the day will increase peak demand and augmentation costs for distribution networks, especially in commercial areas where peak demand is already set in the middle of the day. It should also be noted that some of the additional 2.8 GW of additional demand by 2040 may be able to be shifted further given additional analysis.

Figure 56 – PEV Charging by Segment in 2040 (Moderate Intervention)

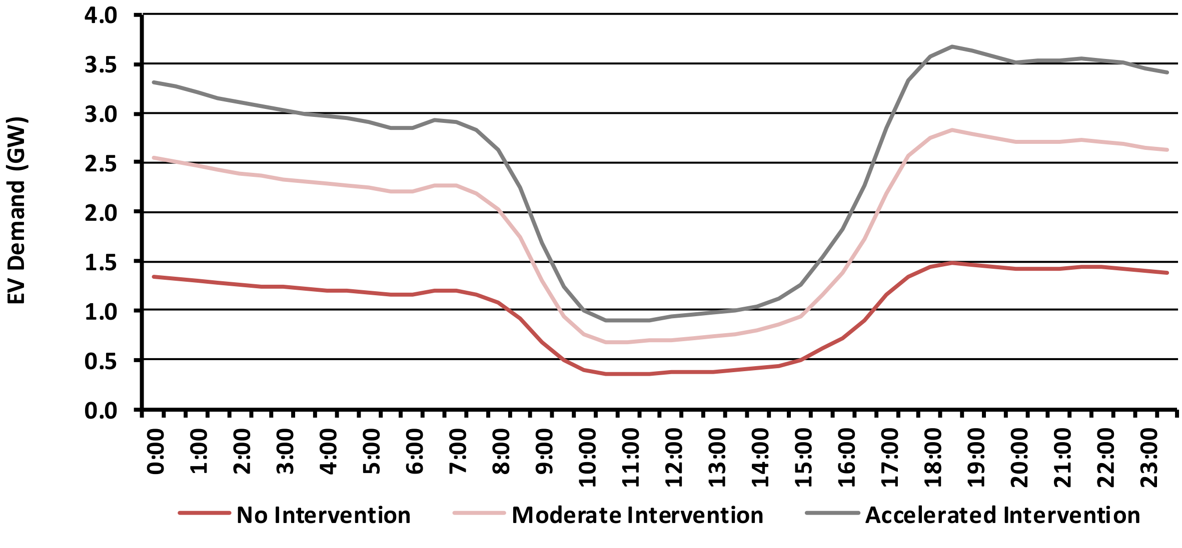


Source: Energeia Modelling

6.3.4.2 *Scenarios*

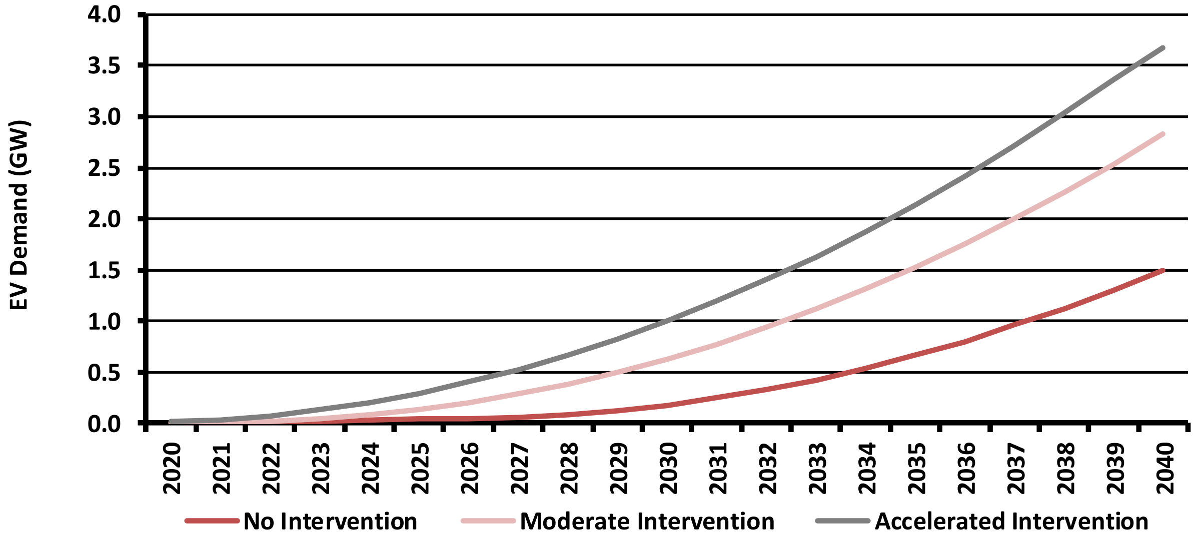
EV electricity demand forecasts vary significantly in magnitude, as a result of the factors detailed in Section 6.3.1, although load shapes stay consistent with the use of controlled charging between sensitives as shown in Figure 57 and Figure 58.

Figure 57 – PEV Charging Load by Scenario (2040)



Source: Energeia Modelling

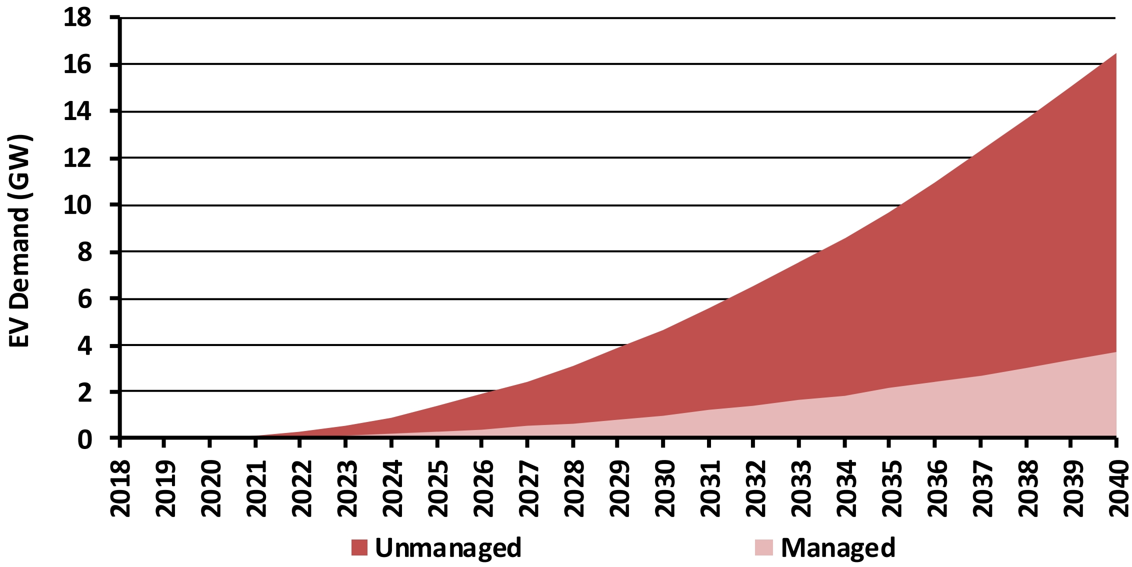
Figure 58 – PEV Charging Load by Scenario



Source: Energeia Modelling

Under the Accelerated Intervention scenario, PEV grid demand reaches 3.7 GW of additional non-coincident peak demand in 2040 with managed charging. If PEV demand remains unmanaged, forecast peak demand would increase to 16.5 GW, a 450% increase in demand, as shown in Figure 59. This is over double the demand when compared to the Moderate Intervention scenario, consistent with differences in uptake rates between the scenarios.

Figure 59 – PEV Electricity Demand (AUS, Accelerated Intervention)

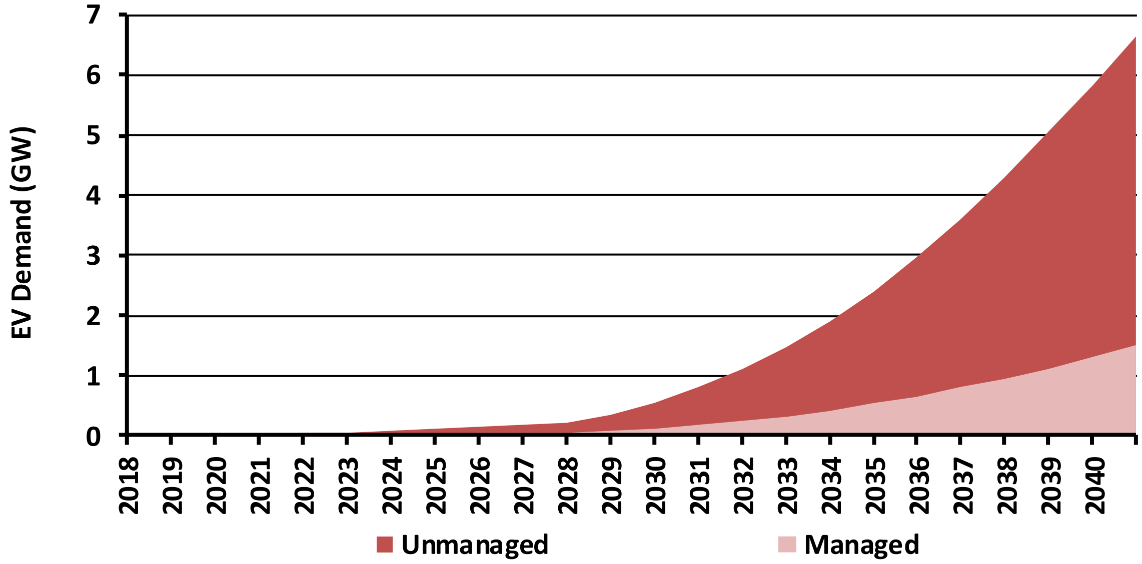


Source: Energeia Modelling

Under the No Intervention scenario, PEV electricity demand reaches 1.5 GW of additional non-coincident peak demand in 2040 with managed charging. If PEV demand remains unmanaged, forecast peak demand would increase to 6.6 GW, a 440% increase in demand, as shown in Figure 60.

This is 40% below the Moderate Intervention scenario, consistent with differences in uptake rates between the scenarios.

Figure 60 – PEV Electricity Demand (AUS, No Intervention)



Source: Energeia Modelling

7 Conclusion and Future Direction

7.1 Key Findings from Part A and B

Energeia's research review of PEV charging infrastructure, and market modelling of PEV sales and associated charging infrastructure requirements have uncovered the following key findings.

7.1.1 Strategic Review of Electric Vehicle Charging Infrastructure

7.1.1.1 *Policy and Regulation*

Energeia's benchmarking of international comparator markets identified the role of financial and non-financial incentives, and reviewed the case study of Norway, the world leader for PEV uptake. From that review, Energeia identified the following uptake levers that could be used to drive uptake of PEVs in Australia:

- **Purchase Incentives** – Any increase in direct Australian financial incentives for PEV adoption will drive improved PEV model availability, which in turn will drive demand.
- **Procurement Targets** – Limited numbers (200-500 cars per year) bought via a co-ordinated fleet buying program would be sufficient to attract OEM interest import new right-hand drive models not yet made available in Australia.
- **Import Regulation** – Adoption of parallel imports of PEVs would increase both model availability and overall uptake in Australia (in line with the New Zealand experience).
- **Fuel Efficiency Regulation** – Implementation of 105g/km fuel efficiency standard would underpin a significant increase in PEVs in Australia driven by OEMs more aggressively marketing their PEVs in order to meet their compliance targets at least cost.
- **Global ICE Bans** – OEMs are increasingly likely to consider either removing ICEs from their vehicle portfolio and replace those models with PEV alternatives over the 10 to 30-year timeframe.

Energeia found that investment in public charging infrastructure, and in particular DCFC, is correlated with high levels of PEV uptake globally.

In Australia, state level policy settings are more supportive than at the federal level, however both levels of government lag well behind leading international jurisdictions.

7.1.1.2 *Demand for Public Charging*

Energeia found that PEV drivers prefer to charge in the most convenient way possible, meaning at home where possible, and using the most convenient public charging options when necessary (determined mainly by trip destination and vehicle range). Based on our review of charging behaviour, Energeia develop a framework based on dedicated parking and trip distance to segment the market into two, namely:

- **Drivers with Access to Dedicated Charging** – This segment represents around 70% of the vehicle transportation market and will require public charging for around 1% of long-haul trips.
- **Drivers without Access to Dedicated Charging** – This segment represents around 30% of the market and will require public charging for 100% of their charging requirements. 99% of their trips could be satisfied using L2 public charging at work, or public DCFCs.

The ultimate level of demand for charging is driven by the number of PEVs, which is in turn a function of total annual vehicle sales, and the rate of PEV uptake. In Energeia's view, model availability is the key driver of future PEV demand in Australia.

The demand for charging infrastructure could be influenced on the downside (competing drive train) and upside (shared or pooled fleets) technology risks:

- **Fuel Cell Electric Vehicles** – Although PEVs are forecast to displace ICEs over time on a cost and performance basis, FCEVs could supplant PEVs, but Energeia sees this as unlikely given the slow rate of development of FCEVs, the limited model availability, and the imposing infrastructure roll-out challenge.

- **Shared Autonomous Electric Vehicles** – SAEVs could impact on future demand for public charging infrastructure by requiring automated refuelling technology and by reducing the number of cars on the road. Energeia's view is that the long-term impact of SAEVs and TaaS is likely to be significant, but there is a lack of data to support a strong view as to future likely developments, and more work in this space is needed.

Energeia found that there is a wide variation in PEV uptake forecasts at both the global level, and in Australia, with a range of scenarios from infrastructure capped (BNEFs view) through to 100% saturation (DNV GLs view, and that of various Australian studies). Current Energeia forecasts completed for AEMO's Electricity Forecasting Insights program of work forecast PEV uptake of 20% of new vehicle sales by 2030.

To meet the demand for PEV uptake, overseas jurisdictions are examining both L2 and DCFC charging solutions, with the recent focus being on an elevated role for DCFC charging. However, estimate of public charging requirements per PEV by 2030 in the studies reviewed by Energeia vary by an order of magnitude. Given the large discrepancy between the two jurisdictions, and the significant impact this has estimates of future charging infrastructure requirements, Energeia recommends that the CEFC and ARENA consider further detailed analyses to better understand the key differences between the various approaches.

7.1.1.3 *Supply of Public Charging Infrastructure*

Energeia's research found that leading overseas jurisdictions following a common approach to scaling their charging infrastructure, from Step 1 (workplace charging), Step 2 (DCFC range extension), Step 3 (access to chargers for PEV drivers without a dedicated charger), as the PEV and charger network markets mature. Scaling up charging networks to match demand as PEV uptake rises is the final step, which addresses increasing congestion as the PEV:EVSE ratio increases.

Energeia analysis on the cost to fill up a PEV found that over the next 10 years, PEVs could expect to pay around $11 to fill up their 100 kWh tank at the local DCFC station in about 5 minutes or less, whilst the same fill-up would take 4 hours (parked at work during the day or at home overnight) and cost $17-19 using a L2 solution. This assumes that DCFC can be expected to cost around USD $60,000-$80,000 in the medium term, once the industry has matured and realises economies of scale.

Based on our review of the key players in Australia and overseas, key lessons learned and critical success factors, Energeia concludes that petrol station operators, major domestic operators, automotive associations, regulated electricity networks and energy retailers are in the strongest positions to deploy Australia future public charging network.

7.1.2 Market Review of Electric Vehicle Sales, Stock and Infrastructure

Under the Energeia Moderate Intervention case, PEV sales (both BEV and PHEV) are forecast to reach 611,800 vehicles per annum by 2030, increasing to 1.89 million annual new vehicle sales by 2040, or 49% and 100% of sales respectively. There is a relatively steady increase in PEV sales to around 28% per annum by 2026 driven by falling PEV prices supported by falling battery prices, increased model availability by OEM, and an increasing differential between electricity and petrol prices.

Under the Moderate Intervention case, PEV sales are set to increase over the next 5 years from 3,100 to 70,700 electric vehicles sales. The rapid rise in uptake is based on a shift in PEV model availability from niche vehicles and non-leading OEMs to electric equivalent models of leading brands and models.

Public DCFC are required to meet charging demand from the majority of PEVs that do not have access to dedicated L2 charging at home or the workplace. These chargers are based on the gas station model with charge times below 5 minutes to serve drivers with non-dedicated public parking (local public chargers), while range extension charges (regional chargers to address range-anxiety) are required to supply the <1% trips required for inter-region driving over 150kms. Under the most Moderate Intervention case, Australia will require over 28,400 DCFC over the period to 2040, costing $1.69 billion, split by access and congestion chargers.

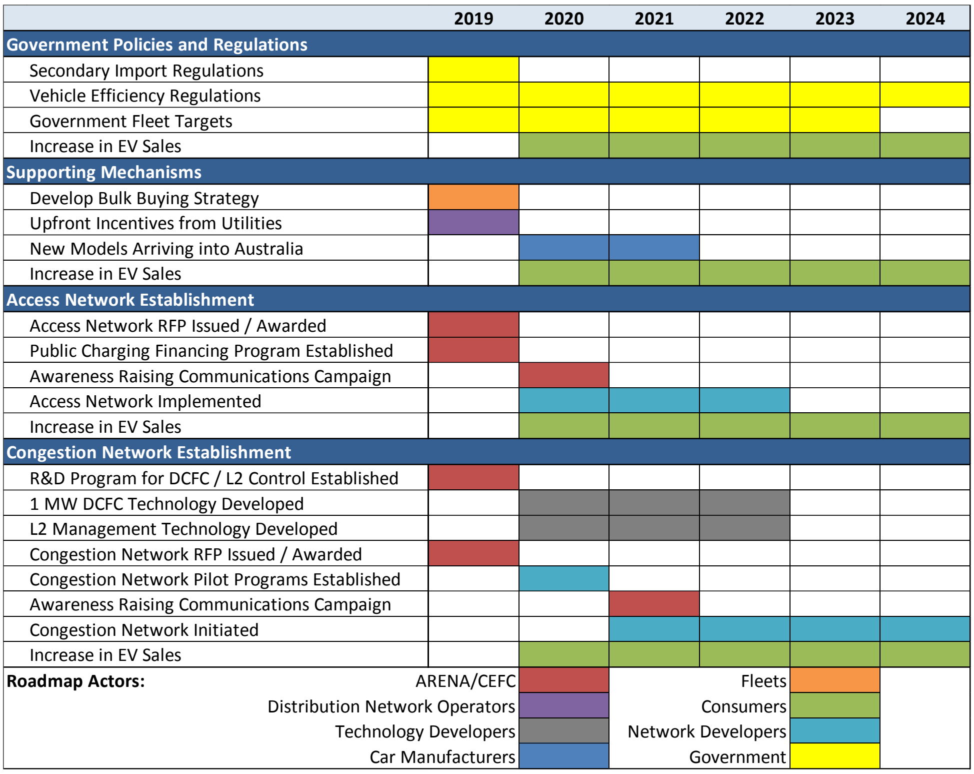
Energeia's modelling shows PEV charge management avoiding any significant increase in maximum demand in the Moderate Intervention scenarios. DCFC is expected to occur in proportion to cars on the road and is therefore not amendable to managed charging. Overall, the impact of PEV charging on system peak demand is 2.8 GW by 2040.

7.2 Public Charging Infrastructure Roadmap

Based on the combined findings from Part A and Part B of this project, Energeia developed a recommended Australian PEV and public infrastructure deployment roadmap, which is summarised in Figure 61.

The roadmap would see Australia's uptake of PEVs reach international best practice levels, once differences in PEV subsidies are taken into account. It would also see Australia's public charging infrastructure catch-up to international best practice by 2022. Finally, it would support development of Australian technology in key areas.

Figure 61 – Australian PEV and Public Infrastructure Deployment Roadmap (Moderate Intervention Scenario)



Source: Energeia

The Energeia recommended roadmap assumes government implements the key policy levers of secondary import regulations, vehicle efficiency regulations and fleet targets starting in 2019.

The roadmap includes actions by major fleet operators including government, utilities and private operators to develop a bulk buying strategy in 2019 and agreeing with OEMs to import additional PEV models. The roadmap also calls for electric utilities to offer aggressive, Rules compliant PEV charging rates by 2019.

The roadmap calls for ARENA and the CEFC to establish a number of programs by 2019 to support the completion of the otherwise uneconomic Step 2 public access network, raise awareness and provide funding for research and development of high power, DCFC recharging technology and charging management technology.

The congestion network would be kicked off by a series of DCFC pilots targeting areas with a high concentration of drivers without access to dedicated parking and high levels of traffic. This would help bootstrap the business model, with operators then able to organically grow their footprint with experience and growing congestion.

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Appendix A: Scenario Modelling Results

Table A1 – EV Uptake

Jurisdiction	Scenario	Type	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
QLD	No Intervention	Annual EVs	343	310	632	1,772	2,406	5,367	6,060	6,826	8,103	9,142	10,360	11,849	23,868	40,183	55,757	69,526	84,386	99,070	113,836	129,367	146,517	164,342	179,748	203,192	230,327
		Annual Sales Market %	0%	0%	0%	1%	1%	2%	3%	3%	3%	4%	4%	5%	10%	16%	22%	27%	32%	37%	42%	47%	52%	57%	63%	68%	73%
		Cumulative EVs	1,053	1,363	1,979	3,752	6,158	11,524	17,585	24,360	32,408	41,334	51,340	62,846	86,386	125,937	179,921	247,041	326,060	419,070	526,081	647,344	784,720	938,702	1,106,601	1,285,925	1,476,069
	Moderate Intervention	Annual EVs	343	310	663	1,864	2,545	5,921	15,102	26,541	38,893	55,784	72,944	90,131	103,721	118,764	134,746	152,018	171,292	195,021	221,073	249,383	282,370	316,644	355,873	393,244	426,592
		Annual Sales Market %	0%	0%	0%	1%	1%	2%	6%	11%	15%	22%	28%	34%	39%	44%	49%	55%	60%	66%	71%	76%	81%	86%	90%	96%	100%
		Cumulative EVs	1,053	1,363	2,011	3,875	6,420	12,341	27,443	53,935	92,772	148,340	220,930	310,718	414,109	532,209	665,091	814,564	979,935	1,159,854	1,354,385	1,564,876	1,791,462	2,035,162	2,300,904	2,590,428	2,898,257
	Accelerated Intervention	Annual EVs	343	310	694	5,251	9,591	24,339	45,995	66,503	86,724	101,970	117,780	134,168	151,823	170,039	191,179	212,959	241,736	276,120	313,255	351,649	392,166	434,091	474,994	497,621	515,588
		Annual Sales Market %	0%	0%	0%	2%	4%	9%	17%	25%	32%	37%	42%	47%	53%	59%	64%	69%	74%	79%	83%	88%	93%	98%	100%	100%	100%
		Cumulative EVs	1,053	1,363	2,043	7,293	16,884	41,224	87,218	153,672	240,340	342,095	459,520	593,346	744,838	914,183	1,100,112	1,303,480	1,520,877	1,751,002	1,997,754	2,262,679	2,552,875	2,869,186	3,210,012	3,555,809	3,901,359
NSW	No Intervention	Annual EVs	627	537	1,128	3,162	4,419	9,846	11,085	12,434	14,479	16,292	18,407	20,966	39,192	66,307	92,368	116,447	142,527	168,284	193,704	220,326	250,852	282,580	295,765	333,896	379,021
		Annual Sales Market %	0%	0%	0%	1%	1%	2%	3%	3%	4%	4%	4%	5%	9%	15%	21%	26%	31%	36%	41%	46%	51%	57%	62%	68%	73%
		Cumulative EVs	1,837	2,374	3,479	6,642	11,061	20,907	31,992	44,346	58,733	74,654	92,451	112,790	151,411	216,590	305,795	417,823	550,504	707,703	888,973	1,094,820	1,329,380	1,593,553	1,868,351	2,163,056	2,475,770
	Moderate Intervention	Annual EVs	627	537	1,147	3,223	4,532	10,522	26,611	43,138	61,257	88,399	116,007	143,942	166,055	191,574	218,851	249,298	283,151	324,592	368,163	414,826	469,104	526,239	571,591	628,989	673,494
		Annual Sales Market %	0%	0%	0%	1%	1%	3%	6%	10%	14%	20%	27%	33%	37%	42%	48%	54%	59%	65%	70%	76%	81%	85%	92%	97%	100%
		Cumulative EVs	1,837	2,374	3,499	6,722	11,254	21,776	48,387	91,445	152,609	240,637	356,035	499,349	664,832	855,260	1,070,888	1,315,655	1,588,283	1,886,264	2,211,288	2,564,858	2,945,562	3,355,794	3,783,444	4,246,377	4,728,297
	Accelerated Intervention	Annual EVs	627	537	1,167	8,895	16,473	41,026	66,903	97,165	127,454	156,608	184,167	211,204	241,291	272,362	308,273	345,444	393,008	446,091	505,216	565,861	630,657	697,674	724,115	759,445	788,816
		Annual Sales Market %	0%	0%	0%	2%	4%	10%	16%	22%	29%	35%	40%	46%	52%	58%	63%	69%	74%	79%	84%	88%	93%	98%	100%	100%	100%
		Cumulative EVs	1,837	2,374	3,520	12,414	28,887	69,913	136,816	233,902	361,263	517,500	701,058	911,635	1,152,353	1,423,548	1,722,927	2,051,898	2,403,881	2,783,068	3,191,119	3,629,527	4,103,575	4,617,083	5,129,994	5,648,148	6,164,602
TAS	No Intervention	Annual EVs	29	25	60	167	227	507	572	644	724	860	975	1,118	2,287	3,844	5,321	6,637	8,058	9,466	10,884	12,358	14,031	15,758	13,495	15,337	17,521
		Annual Sales Market %	0%	0%	0%	1%	1%	2%	3%	3%	3%	4%	4%	5%	10%	16%	22%	27%	32%	37%	42%	47%	52%	57%	63%	68%	73%
		Cumulative EVs	86	111	170	337	564	1,070	1,642	2,282	3,001	3,844	4,791	5,880	8,140	11,925	17,079	23,489	31,041	39,935	50,174	61,808	74,979	89,762	102,138	115,189	128,865
	Moderate Intervention	Annual EVs	29	25	63	177	242	562	1,429	2,547	3,752	5,359	6,992	8,624	9,922	11,359	12,885	14,530	16,367	18,628	21,131	23,853	27,017	30,323	29,441	32,383	34,751
		Annual Sales Market %	0%	0%	0%	1%	1%	2%	6%	11%	15%	22%	28%	34%	39%	44%	49%	55%	60%	66%	71%	76%	81%	86%	92%	97%	100%
		Cumulative EVs	86	111	174	351	593	1,155	2,584	5,127	8,875	14,217	21,180	29,775	39,670	50,966	63,673	77,962	93,767	110,965	129,549	149,650	171,309	194,640	215,456	237,917	261,308
	Accelerated Intervention	Annual EVs	29	25	67	597	916	2,315	4,412	6,324	8,297	9,757	11,269	12,839	14,552	16,331	18,430	20,455	23,206	26,511	30,047	33,739	37,635	41,671	40,084	42,030	43,562
		Annual Sales Market %	0%	0%	0%	2%	4%	9%	17%	24%	32%	37%	42%	47%	53%	58%	64%	69%	74%	79%	83%	88%	93%	98%	100%	100%	100%
		Cumulative EVs	86	111	177	774	1,690	4,005	8,417	14,737	23,029	32,769	44,010	56,820	71,344	87,608	105,442	124,980	145,871	167,971	191,694	217,136	245,014	275,415	302,661	330,139	357,370
SA	No Intervention	Annual EVs	110	100	204	570	654	1,756	1,975	2,216	2,481	2,791	3,283	3,736	7,127	12,360	17,437	21,461	26,203	30,842	35,648	40,619	45,685	51,450	50,384	56,928	64,882
		Annual Sales Market %	0%	0%	0%	1%	1%	2%	3%	3%	3%	4%	4%	5%	9%	16%	22%	26%	31%	36%	41%	46%	51%	57%	62%	67%	72%
		Cumulative EVs	335	435	633	1,203	1,858	3,613	5,588	7,788	10,251	12,971	16,146	19,771	26,793	38,949	55,816	76,622	101,070	129,937	163,369	201,507	244,401	292,568	339,216	389,018	441,540
	Moderate Intervention	Annual EVs	110	100	207	580	665	1,868	4,694	6,981	10,326	16,109	21,510	26,885	31,218	35,548	40,386	45,369	51,399	58,711	66,082	74,429	84,525	95,297	99,795	109,756	117,409
		Annual Sales Market %	0%	0%	0%	1%	1%	2%	6%	9%	13%	21%	27%	34%	39%	43%	48%	54%	59%	65%	70%	76%	80%	85%	92%	97%	100%
		Cumulative EVs	335	435	636	1,216	1,881	3,749	8,442	15,408	25,716	41,754	63,156	89,931	121,044	156,384	196,191	240,895	290,426	344,444	403,544	467,646	536,062	609,849	682,759	761,297	843,158
	Accelerated Intervention	Annual EVs	110	100	211	1,573	2,411	6,713	10,714	16,707	22,689	28,812	34,040	38,817	43,824	48,851	54,724	60,477	68,540	77,193	87,380	98,089	109,571	122,118	123,426	129,628	134,942
		Annual Sales Market %	0%	0%	0%	2%	3%	9%	14%	21%	28%	35%	41%	46%	52%	57%	62%	67%	72%	76%	81%	85%	89%	94%	98%	98%	99%
		Cumulative EVs	335	435	640	2,213	4,624	11,337	22,051	38,742	61,413	90,154	124,085	162,792	206,511	255,151	308,302	366,367	428,194	494,674	565,346	640,746	721,506	809,584	894,193	979,997	1,066,088
WA	No Intervention	Annual EVs	152	153	412	1,153	1,570	3,491	3,938	4,428	4,972	5,960	6,737	7,685	15,050	25,549	35,585	44,371	53,842	63,181	72,548	82,245	93,283	104,570	124,251	139,843	158,170
		Annual Sales Market %	0%	0%	0%	1%	1%	2%	3%	3%	3%	4%	4%	5%	9%	16%	22%	27%	32%	37%	42%	47%	52%	57%	62%	68%	73%
		Cumulative EVs	505	658	1,064	2,217	3,787	7,278	11,216	15,616	20,558	26,405	32,980	40,513	55,396	80,533	114,965	157,767	208,117	267,360	335,480	412,753	500,076	597,909	714,475	839,268	971,889
	Moderate Intervention	Annual EVs	152	153	437	1,227	1,684	3,911	9,943	17,013	24,822	35,928	47,197	58,508	67,216	76,982	87,338	98,555	111,065	126,475	143,145	161,274	182,534	204,711	232,106	260,493	288,774
		Annual Sales Market %	0%	0%	0%	1%	1%	2%	6%	10%	15%	21%	28%	34%	39%	44%	49%	55%	60%	66%	71%	76%	81%	86%	85%	92%	98%
		Cumulative EVs	505	658	1,090	2,317	4,000	7,912	17,855	34,840	59,631	95,447	142,482	200,838	267,887	344,432	430,544	527,415	634,569	751,100	877,233	1,013,685	1,160,290	1,317,804	1,491,402	1,684,679	1,896,471
	Accelerated Intervention	Annual EVs	152	153	461	3,492	6,393	16,127	30,261	43,061	56,330	66,412	76,840	87,648	99,496	111,779	125,808	140,140	159,002	181,547	205,508	230,557	256,957	284,254	317,339	343,465	357,227
		Annual Sales Market %	0%	0%	0%	2%	4%	9%	17%	24%	31%	36%	42%	47%	53%	58%	64%	69%	74%	79%	83%	88%	93%	99%	96%	99%	100%
		Cumulative EVs	505	658	1,115	4,607	11,000	27,127	57,388	100,422	156,720	223,019	299,697	387,193	486,520	597,839	720,154	853,901	996,777	1,148,063	1,310,510	1,484,738	1,675,283	1,882,698	2,112,389	2,356,358	2,601,806
VIC	No Intervention	Annual EVs	520	460	607	1,708	1,979	5,303	6,009	6,791	7,657	9,154	10,403	11,909	23,101	39,778	55,997	70,074	85,575	100,909	116,456	132,579	149,826	168,972	147,011	168,196	192,331
		Annual Sales Market %	0%	0%	0%	1%	1%	2%	3%	3%	3%	4%	4%	5%	9%	16%	22%	27%	32%	37%	42%	46%	51%	57%	63%	68%	72%
		Cumulative EVs	1,557	2,018	2,586	4,293	6,272	11,575	17,585	24,306	31,880	40,711	50,602	61,991	84,620	123,791	178,081	246,176	326,448	421,348	531,013	655,936	796,608	955,178	1,090,280	1,235,375	1,387,928
	Moderate Intervention	Annual EVs	520	460	609	1,711	1,974	5,519	14,002	21,080	32,580	50,704	67,420	83,969	97,499	112,073	127,625	144,490	163,823	187,170	210,964	238,441	270,641	305,178	286,476	317,499	343,031
		Annual Sales Market %	0%	0%	0%	1%	1%	2%	6%	9%	14%	21%	28%	34%	39%	44%	49%	54%	60%	65%	71%	76%	80%	85%	92%	97%	100%
		Cumulative EVs	1,557	2,018	2,588	4,299	6,274	11,792	25,795	46,805	79,302	129,683	196,592	280,041	377,068	488,532	614,446	756,962	915,266	1,088,433	1,278,318	1,484,178	1,704,115	1,941,873	2,144,379	2,364,378	2,595,337
	Accelerated Intervention	Annual EVs	520	460	612	4,566	7,052	19,669	34,362	52,298	70,349	87,002	102,275	116,993	133,340	150,357	169,857	189,119	215,102	244,393	277,235	301,631	337,107	375,964	344,406	363,909	380,631
		Annual Sales Market %	0%	0%	0%	2%	3%	9%	15%	22%	29%	36%	41%	47%	52%	58%	64%	69%	74%	79%	83%	85%	89%	94%	98%	98%	99%
		Cumulative EVs	1,557	2,018	2,591	7,157	14,209	33,878	68,240	120,468	190,734	277,414	379,178	495,651	628,519	778,264	943,555	1,125,622	1,321,055	1,531,086	1,756,023	1,987,305	2,237,410	2,511,098	2,738,511	2,969,080	3,199,354

Source: Energeia

Table A2 – EVSE Deployment

Jurisdictions	DCFC	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
AU	Access DCFCs - Cumulative Hoses	0	0	481	963	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444	1,444
	Access DCFC - Cumulative Hose Capex ($M)	0	0	73	145	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214
	Congestion DCFCs - Cumulative Hoses	0	0	27	80	210	316	421	525	600	625	582	700	822	950	1,146	1,360	1,592	1,844	2,115	2,407	2,703	3,026	3,366
	Congestion DCFCs - Cumulative Hose Capex ($M)	0	0	2	6	17	29	47	64	86	105	123	147	172	203	237	278	323	375	432	496	564	640	720
QLD	Access DCFCs - Cumulative Hoses	0	0	74	148	222	222	222	222	222	222	222	222	222	222	222	222	222	222	222	222	222	222	222
	Access DCFC - Cumulative Hose Capex ($M)	0	0	11	22	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	Congestion DCFCs - Cumulative Hoses	0	0	6	17	44	69	93	116	132	138	128	153	180	207	249	295	345	398	456	518	586	659	738
	Congestion DCFCs - Cumulative Hose Capex ($M)	0	0	0	1	4	6	10	14	19	23	27	32	38	44	52	61	70	82	94	108	123	139	157
NSW	Access DCFCs - Cumulative Hoses	0	0	191	381	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572
	Access DCFC - Cumulative Hose Capex ($M)	0	0	29	57	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85
	Congestion DCFCs - Cumulative Hoses	0	0	10	30	78	117	153	189	213	221	205	247	290	335	404	480	563	653	750	854	963	1,081	1,204
	Congestion DCFCs - Cumulative Hose Capex ($M)	0	0	1	2	6	11	17	23	31	38	44	53	61	72	84	99	115	133	153	176	200	227	256
TAS	Access DCFCs - Cumulative Hoses	0	0	6	25	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
	Access DCFC - Cumulative Hose Capex ($M)	0	0	0	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Congestion DCFCs - Cumulative Hoses	0	0	1	2	4	7	9	11	13	13	12	15	17	20	24	28	33	38	44	50	55	61	67
	Congestion DCFCs - Cumulative Hose Capex ($M)	0	0	0	0	0	1	1	1	2	2	3	3	4	4	5	6	7	8	9	10	12	13	15
SA	Access DCFCs - Cumulative Hoses	0	0	21	85	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
	Access DCFC - Cumulative Hose Capex ($M)	0	0	2	11	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Congestion DCFCs - Cumulative Hoses	0	0	2	5	14	20	26	33	38	40	37	45	53	61	74	88	103	119	136	155	174	194	215
	Congestion DCFCs - Cumulative Hose Capex ($M)	0	0	0	0	1	2	3	4	5	7	8	9	11	13	15	18	21	24	28	32	36	41	46
WA	Access DCFCs - Cumulative Hoses	0	0	63	125	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188
	Access DCFC - Cumulative Hose Capex ($M)	0	0	10	19	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
	Congestion DCFCs - Cumulative Hoses	0	0	3	11	29	44	60	75	85	89	83	99	116	134	162	191	223	258	295	335	380	429	483
	Congestion DCFCs - Cumulative Hose Capex ($M)	0	0	0	1	2	4	7	9	12	15	17	21	24	29	34	39	46	53	61	70	79	90	102
VIC	Access DCFCs - Cumulative Hoses	0	0	98	196	293	293	293	293	293	293	293	293	293	293	293	293	293	293	293	293	293	293	293
	Access DCFC - Cumulative Hose Capex ($M)	0	0	15	29	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
	Congestion DCFCs - Cumulative Hoses	0	0	5	16	42	60	80	102	118	124	116	141	166	193	233	277	325	378	434	494	546	602	661
	Congestion DCFCs - Cumulative Hose Capex ($M)	0	0	0	1	3	5	9	12	17	20	24	29	34	40	47	56	65	75	87	100	114	129	144

Table A3 – EVSE Demand Impacts

EV Demand (GW)	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
No Intervention	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.08	0.12	0.18	0.25	0.33	0.43	0.54	0.66	0.80	0.96	1.13	1.30	1.49
Moderate Intervention	0.00	0.00	0.00	0.01	0.01	0.02	0.05	0.08	0.14	0.20	0.29	0.39	0.50	0.63	0.78	0.94	1.12	1.31	1.53	1.75	2.00	2.26	2.54	2.83
Accelerated Intervention	0.00	0.00	0.01	0.01	0.04	0.07	0.13	0.20	0.30	0.40	0.52	0.66	0.82	1.00	1.19	1.40	1.63	1.87	2.13	2.41	2.72	3.04	3.36	3.68

Table A4 – OEM Market Shares

OEM	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Mazda	0%	0%	0%	0%	20%	25%	27%	29%	26%	23%	21%	20%	19%	18%
Toyota	0%	0%	0%	6%	8%	10%	11%	11%	10%	9%	8%	8%	8%	7%
Hyundai	0%	9%	9%	10%	5%	6%	7%	7%	9%	11%	12%	14%	15%	16%
Holden	0%	0%	0%	7%	5%	6%	7%	7%	8%	9%	9%	9%	8%	8%
Subaru	0%	0%	0%	0%	3%	2%	1%	1%	3%	5%	6%	8%	7%	7%
Honda	0%	0%	0%	9%	11%	7%	5%	4%	4%	5%	5%	5%	5%	5%
Mitsubishi	0%	0%	0%	0%	10%	13%	14%	15%	13%	12%	11%	10%	10%	9%
Volkswagen	0%	0%	0%	3%	4%	5%	5%	5%	6%	7%	7%	7%	8%	9%
Nissan	0%	4%	4%	3%	4%	5%	5%	6%	5%	4%	4%	4%	4%	3%
Kia	0%	0%	0%	7%	3%	4%	5%	5%	6%	7%	8%	9%	10%	11%
Tesla	80%	69%	69%	42%	21%	13%	9%	7%	7%	6%	5%	5%	5%	5%
Other	20%	18%	18%	12%	5%	4%	3%	2%	2%	2%	2%	2%	2%	1%

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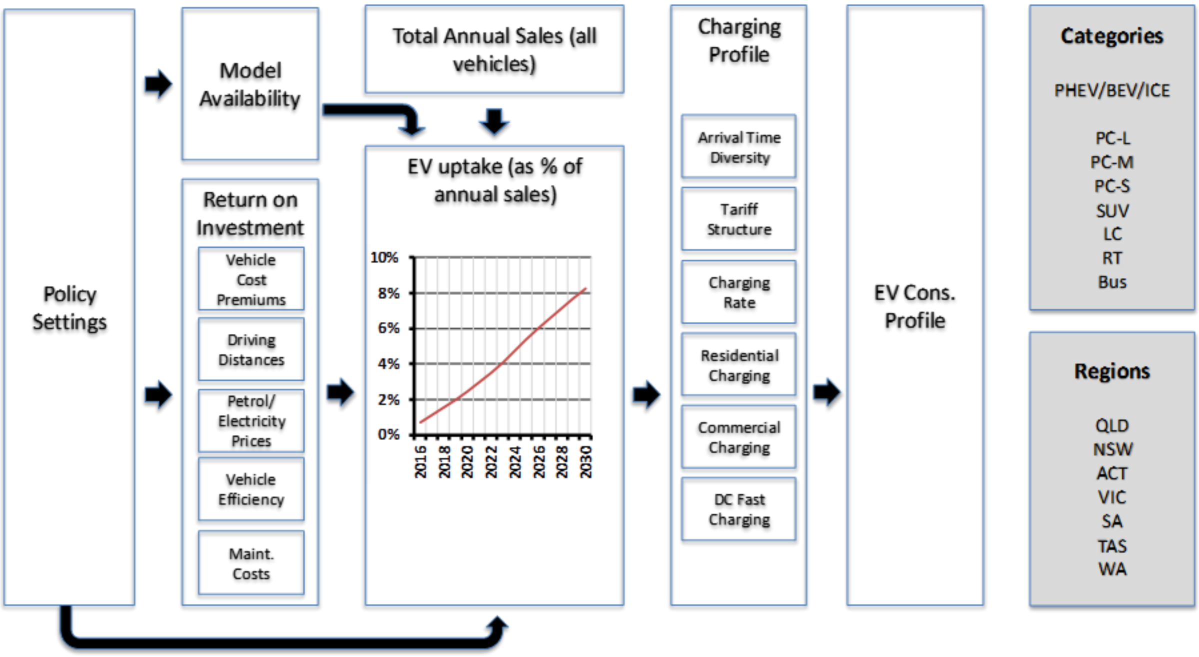
Appendix B: PEV Uptake Model

B.1 Overview

Energeia's PEV forecasting model is comprised of two parts, PEV uptake and PEV charging as shown in Figure B1.

Figure B1 – Energeia PEV Forecasting Model



Source: Energeia

The PEV uptake module forecasts PEV uptake for each category of vehicle using vehicle model availability and the vehicle owner's return on investment as inputs. The forecast is allocated on a pro-rata basis to each state based on that state's 2016 share of vehicles on the road based on ABS data[28]. The PEV charging module then applies a charging regime to each vehicle adopted based on its:

- charging type,
- arrival and departure time for home and workplace charging or transportation profile for DCFC,
- the number of kilometres travelled and
- grid load to optimise workplace and home charging.

The model considers 8 categories of vehicle types including:

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

[28] ABS 9208.0 - Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2016

- Light Commercial (LC)
- Rigid Truck (RT)
- Bus (B)

Each of these categories have specific characteristics which drive both uptake and charging, including:

- purchase premium,
- energy consumption per km, and
- battery size.

Fuel costs and average daily driving are based on state level factors.

B.2 EV Uptake

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

1. PEV premium payback more than two years:

$$EV\ Uptake_t = Total\ New\ Vehicle\ Sales_t * (a_t \times ROI_t + b_t \times Model\ Availability_t)$$

2. PEV premium payback less than two years (tipping point):

$$EV\ Uptake_t = Total\ New\ Vehicle\ Sales_t * \ MIN(Upper\ EV\ Limit, Model\ Availability_t)$$

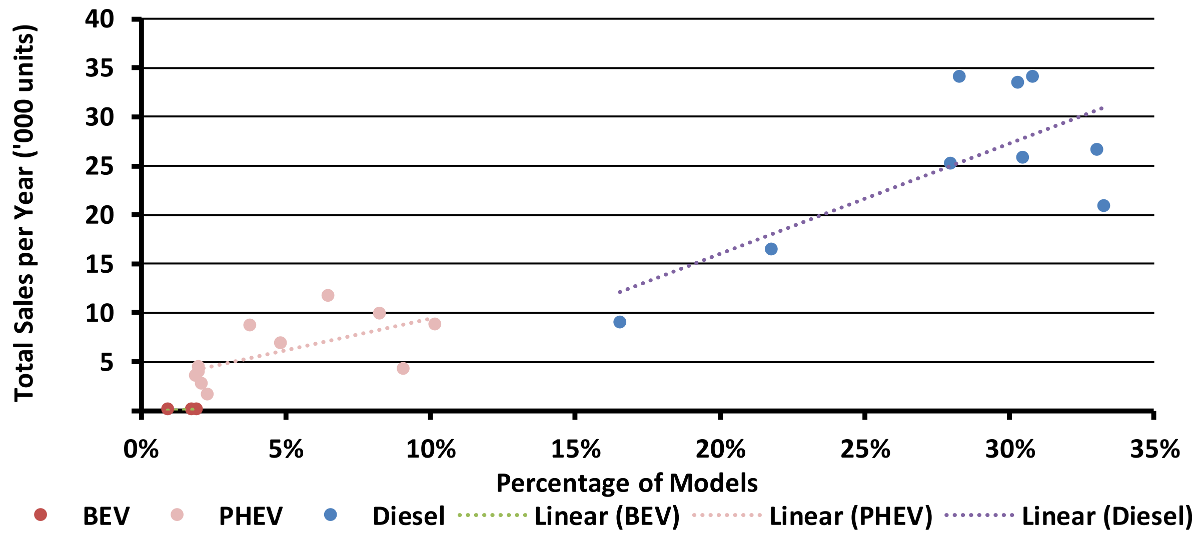
Where:

- $Total\ New\ Vehicle\ Sales_t$ = Total new vehicle sales within a given vehicle class in year t
- $Model\ Availability_t$ = Percentage of models within a given vehicle class available in PEV form in year t. This inclusion of this factor reflects that, for the mass market, a primary driver of vehicle purchase is the availability of that model in PEV form. This factor effectively places an upper bound on PEV adoption, which is determined by a scenario based parameter.
- $Upper\ EV\ Limit$ = Upper model availability limit for all vehicles within a given vehicles class
- ROI_t = The first-year return on investment for the vehicle owner investing in an PEV in year t in terms of reduced operational costs (fuel) and premium paid compared to the equivalent ICE vehicle
- a_t = Model coefficient derived from historical data of diesel and hybrid electric vehicle uptake for observed ROIs
- b_t = Model coefficient derived from historical data of diesel and hybrid electric vehicle uptake for observed model availability

PEV uptake depends on the functional form assumed for model availability and change in ROI over time. It should be noted that Energeia's ROI calculation does not take into account step changes in depreciation or salvage value due to increasing PEV penetration. These factors are explained in further detail below.

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 diesel vehicle and hybrid electric vehicle adoption patterns in Australia which showed uptake was best explained by a combination of these parameters. The historical relationship between vehicle uptake and model availability in the Australia market for alternative technologies is shown in Figure B2.

Figure B2 – Relationship between PEV Uptake and Model Availability

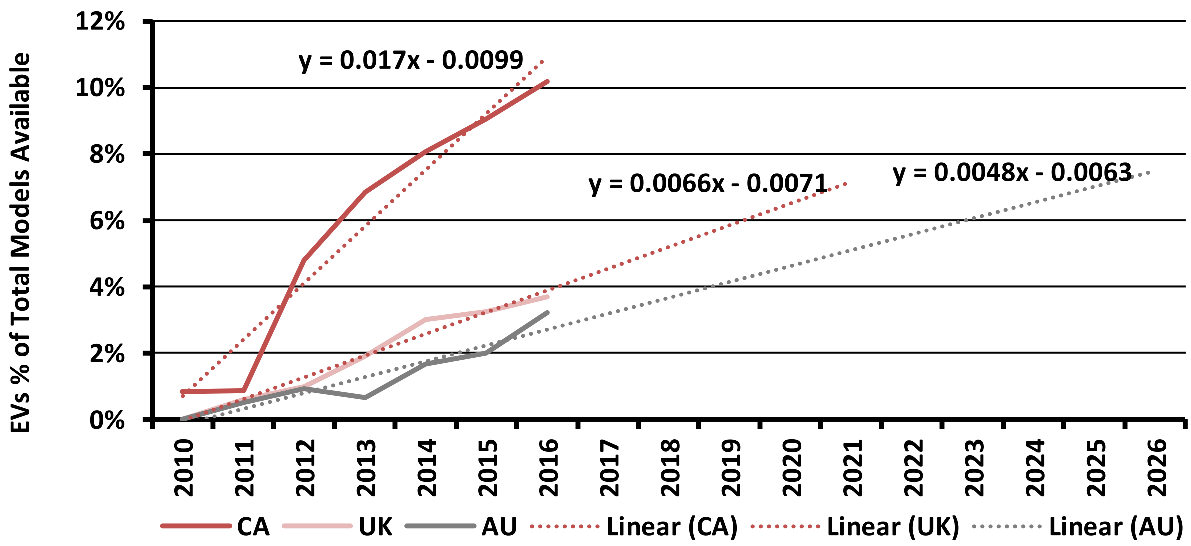


Source: VFACTS, Energeia

E.2.1 Incentives Impact on Model Availability

Energeia has developed its assumed rate of PEV model availability based on an empirical analysis of model availability relative to the level of jurisdictional incentives. Figure B3 displays the results of our analysis of the UK, California and Australian markets. It shows that California, the market with the highest PEV incentive at around $10,000 USD including Federal incentives, sees the fastest rate of new PEV model introductions. The UK market, which offers around $5,000 USD in incentives, is higher than virtually incentive-free Australia.

Figure B3 – PEV Model Availability by Year by Key Market



Source: Energeia

This analysis was used to develop an PEV model introduction function based on the level of assumed incentive. Scenarios with incentives comparable to California see OEM introducing new PEV models at the California rate, while scenarios with incentives closer to zero see new PEV models introduced at the historical Australian rate, as shown in Figure E3.

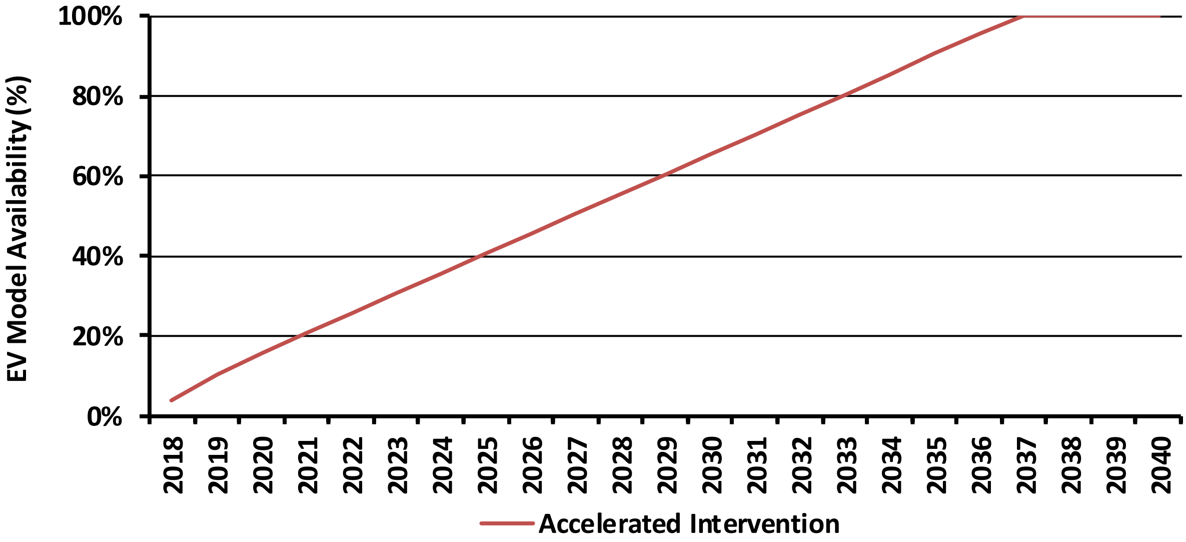
B.2.2 Assumed Model Availability

Assumed model availability varies by vehicle class and by scenario. Each scenario's model availability curve shown in Figure B4, B5 and B6 is based on:

- the current percentage of models available,
- the level of PEV incentives, additional models available due to bulk buying, and allowance of third party imports, each of which increases the slope of the increase up to the trigger,
- the ramp rate once the trigger has been reached, which is constrained by the supply side, and finally,
- the maximum percentage of PEV models relative to ICEs.

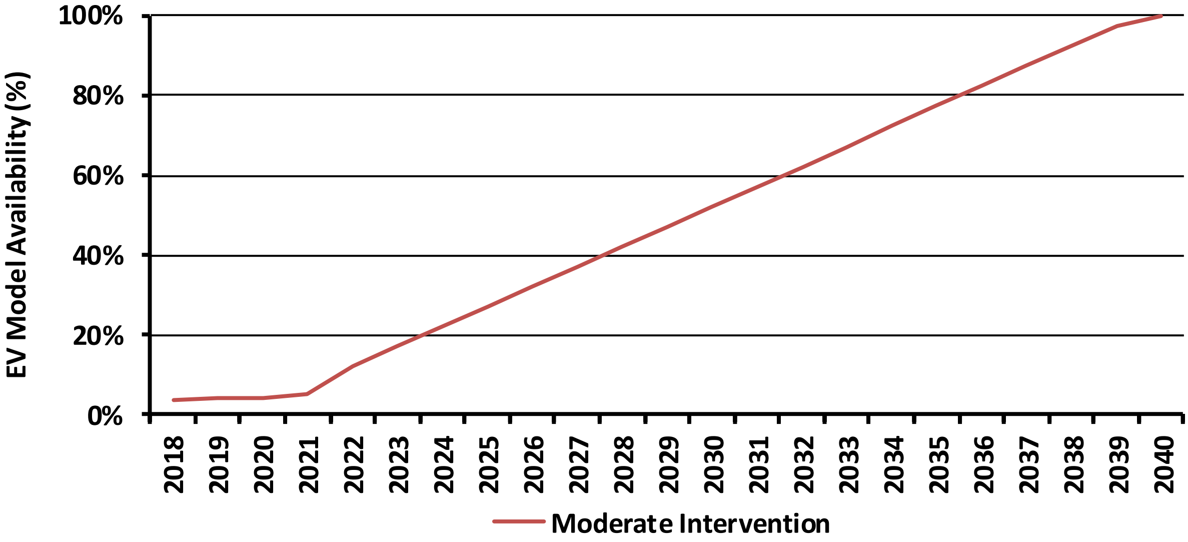
The 9% threshold trigger for PEVs hitting a maximum ramp rate is based on research and analysis of international PEV model availability ramp rates given varying incentives over time and by region.

Figure B4 – Model Availability Accelerated Intervention Scenario



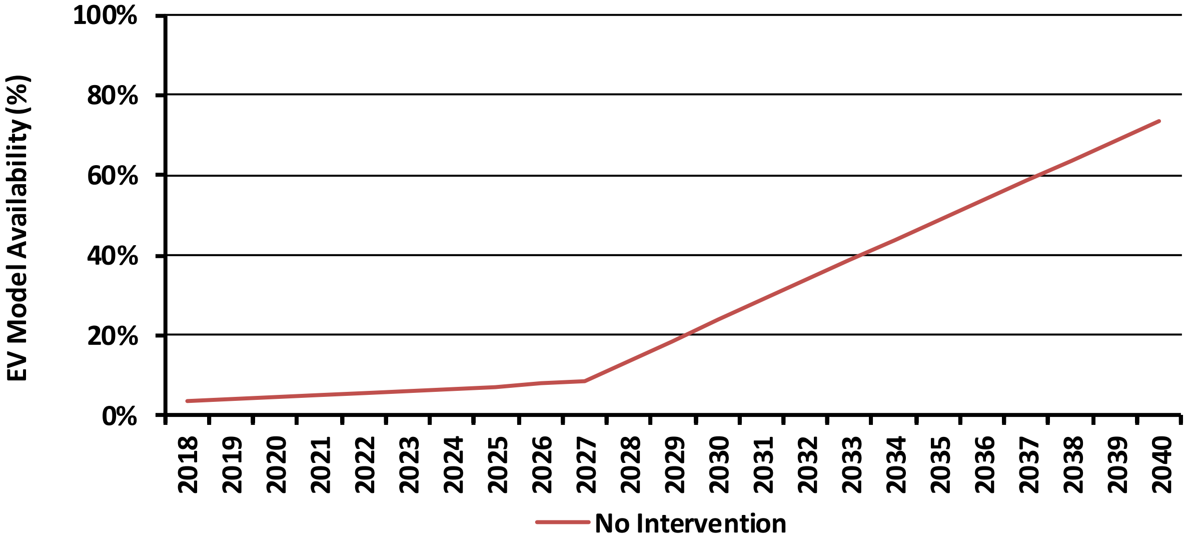
Source: Energeia Modelling

Figure B5 – Model Availability Moderate Intervention Scenario



Source: Energeia Modelling

Figure B6 – Model Availability No Intervention Scenario



Source: Energeia Modelling

B.3 Operation and Maintenance Costs

B.3.1 Electricity Tariffs

The model assumes the PEVs are charged at a residential or commercial premise on a controlled load tariff or at a commercial fast charging premise with DCFCs at the appropriate, uncontrolled retail rate. The controlled load tariffs described in Table B1 are used in the model and are not scenario dependent.

Table B1 – Electricity Controlled Load Retail Tariffs

State	2017 Retail Price ($/kWh)
QLD	$0.1368
NSW	$0.1241
VIC	$0.1669
SA	$0.2063
TAS	$0.1160
WA	$0.1132

Source: Energeia

B.3.2 Electricity Price

Both the retail and network components of PEV charging tariffs are grown over time in the PEV uptake model and vary by state and by scenario. The model uses the retail electricity price projections developed by Jacobs for AEMO[29] in real terms.

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

[29] Jacobs, Retail electricity price history and projections – Public, June 2017

B.3.3 Petrol Price

Energeia's petrol price forecasts have been developed using historical relationships between the price of petrol and the oil price, which are then projected using the scenario assumption for oil prices. Our assumed inputs by state, year and scenario are shown in Table B2.

Table B2 – Fuel Price by State

Year	Low						Neutral						High					
	WA	QLD	SA	TAS	ACT/ NSW	VIC	WA	QLD	SA	TAS	ACT/ NSW	VIC	WA	QLD	SA	TAS	ACT/ NSW	VIC
2017	$1.15	$1.15	$1.14	$1.21	$1.15	$1.14	$1.15	$1.15	$1.14	$1.21	$1.15	$1.14	$1.15	$1.15	$1.14	$1.21	$1.15	$1.14
2018	$1.14	$1.13	$1.12	$1.19	$1.13	$1.12	$1.17	$1.17	$1.16	$1.22	$1.17	$1.16	$1.21	$1.20	$1.19	$1.26	$1.20	$1.19
2019	$1.12	$1.11	$1.10	$1.17	$1.11	$1.10	$1.19	$1.18	$1.17	$1.24	$1.18	$1.17	$1.26	$1.25	$1.24	$1.31	$1.25	$1.24
2020	$1.10	$1.09	$1.08	$1.15	$1.09	$1.08	$1.20	$1.20	$1.19	$1.26	$1.20	$1.19	$1.31	$1.30	$1.29	$1.37	$1.31	$1.29
2021	$1.08	$1.07	$1.06	$1.13	$1.08	$1.06	$1.22	$1.21	$1.20	$1.28	$1.22	$1.20	$1.36	$1.35	$1.34	$1.42	$1.36	$1.34
2022	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2023	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2024	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2025	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2026	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2027	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2028	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2029	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2030	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2031	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2032	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2033	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2034	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2035	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2036	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2037	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2038	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2039	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39
2040	$1.06	$1.05	$1.05	$1.11	$1.06	$1.05	$1.24	$1.23	$1.22	$1.29	$1.23	$1.22	$1.41	$1.41	$1.39	$1.48	$1.41	$1.39

Source: Energeia Modelling

B.3.4 Travel Distance

The travel distance dictates energy requirements and therefore has a direct impact on both ICE vehicles and PEV 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 B3.

Table B3 – Travel Distance

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

Source: ABS Survey of Motor Vehicle Use

B.3.5 Fuel Consumption

Fuel efficiency in the model is a key factor in determining energy requirements and fuel costs. The underlying fuel efficiency of ICE vehicles and PEVs stay constant in the model as combustion and electric engines are well understood and established technologies.

The assumptions for fuel consumption are summarised in Table B4. These estimates have been developed based on OEM reported efficiency data.

Table B4 – Fuel Consumption

Vehicle Type	2017 Efficiency	
	EV kWh/km	ICE L/km
Passenger Car Small	0.137	0.052
Passenger Car Medium	0.178	0.063
Passenger Car Large	0.181	0.102
Sport Utility Vehicle Medium	0.181	0.064
Sport Utility Vehicle Large	0.181	0.104
Light Commercial	0.155	0.065
Rigid Truck	0.400	0.488
Bus	0.364	0.445

Source: Energeia Research

B.4 Capital Costs

The vehicle purchase price is broken down into three components in the model as shown in Table B5.

Table B5 – Capital Cost

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

Source: Energeia Modelling

The balance of system of a vehicle encompasses all the components of the vehicle other than the PEV batteries. Each of the components in Table B5 is described in the following sections.

B.4.1 PEV Premium

The model assumes a PEV premium costs described in Table B6 in 2017. These estimates have been developed based on OEM reported efficiency data. Premiums reduce over time by scenario.

Table B6 – PEV Premium

Vehicle Class	Vehicle Type	EV Premium
Passenger Car Small	BEV	$ 30,110
Passenger Car Medium	BEV	$ 15,500
Passenger Car Large	BEV	$ 22,805
Sport Utility Vehicle Medium	PHEV	$ 2,398
Sport Utility Vehicle Large	PHEV	$ 5,689
Light Commercial	BEV	$ 11,010
Rigid Truck	BEV	$ 42, 229
Bus	BEV	$ 583, 463

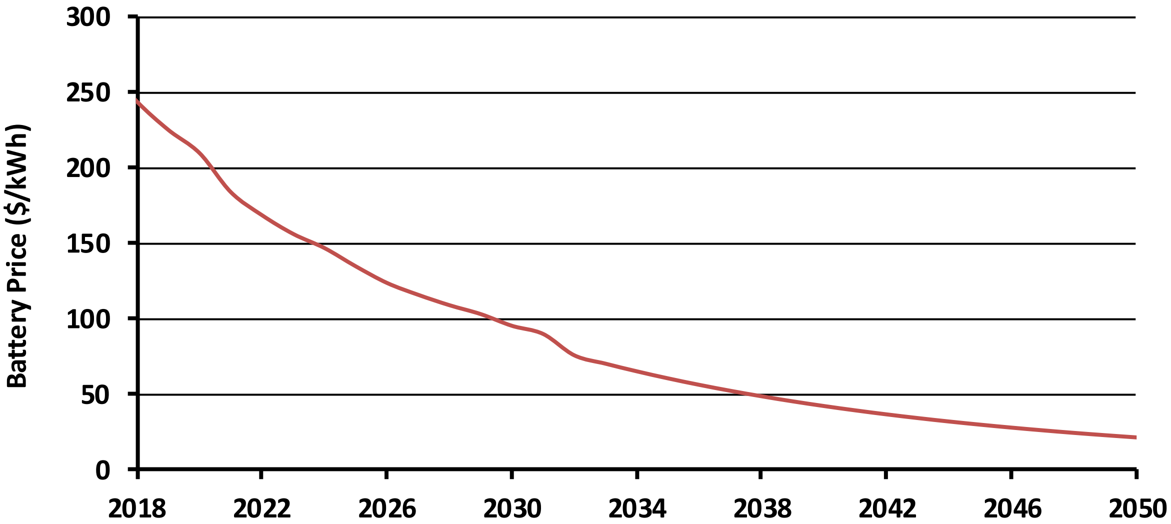
Source: Energeia Research

B.4.2 Battery Cost

Energeia's short and medium-term battery price outlook is a function of expected improvements in lithium-based battery manufacturing and economies of scale, while the long-term battery price outlook is based on next generation storage technologies that will achieve higher energy densities with significantly less raw material.

The model assumes a decline in lithium battery prices over the modelling period leading to the battery cost projection shown in Figure B7. This forecast is based on a consensus average among leading international lithium battery price forecasters. The battery price does not vary with scenario.

Figure B7 – PEV Storage Price Outlook



Source: Energeia Research

B.5 PEV Charging

The PEV 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 L2 (9.6kW) home charging, L2 commercial charging (charges at work or depot location), or DCFC which is defined as the PEV equivalent of a gas station (1MW station with 5 min charge time)
- DCFC chargers enable drivers without a garage to own a PEV, encourage PEV charging during daytime hours of excess supply from solar PV, and extend PEV range to enable PEV use for any trip type
- 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 commercial 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 commercial charging) which dictates when charging must cease in the absence of any other tariff restrictions
- For home and workplace charging, the optimal PEV weekday and weekend demand profile for a given state to minimise whole-of-system cost
- For DFCF charging, the weekday and weekend DCFC demand profile is based on the weekday and weekend transportation demand profile, no demand management of DCFC load is assumed
- No vehicle-to-grid exporting of kWh from the vehicle to the grid is assumed

B.5.1 Type of Charging

A vehicle can be assigned to either a L2 home charger, a L2 commercial charger or DCFC.

Passenger vehicles with dedicated overnight parking are assigned to a L2 home charger. Passenger vehicles without access to dedicated overnight parking are allocated to a DCFC charger. Commercial vehicles are assumed to be charged using an L2 charger at their respective depots overnight.

Detailed charge type assumptions are shown in Table B7.

Table B7 – Charger Type

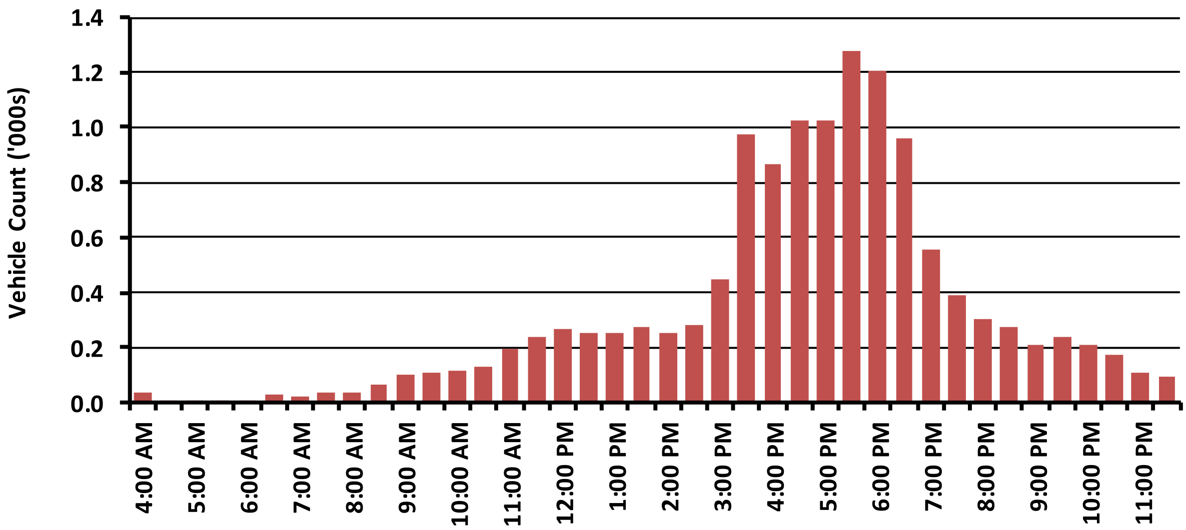
Vehicle Type	Charger Type	NSW	QLD	SA	VIC	WA	TAS
Residential	Home Charging	78%	78%	78%	78%	78%	78%
	DCFC Public Charging	22%	22%	22%	22%	22%	22%
Commercial	Depot Charging	100%	100%	100%	100%	100%	100%

Source: Energeia

B.5.3 Destination Charging Start Times

The charging start time constraint for each managed charging PEV is determined by the vehicle arrival time. The model uses the arrival time distribution shown in Figure B8.

Figure B8 – Vehicle Arrival Distribution by Vehicle Type



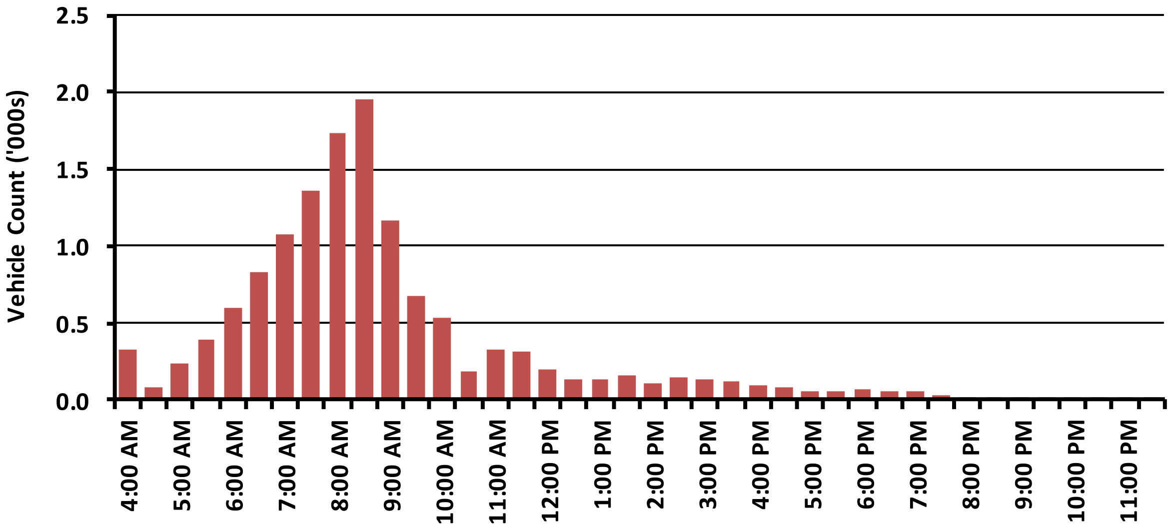
Source: Queensland Household Travel Survey (2014)

E.5.4 Destination Charging Completion Times

The charging completion time depends upon the start time, the assumed departure time, and the amount of charge required, which is in turn dependent on the daily driving distance. Generally speaking, the charging management function attempts to recharge the vehicle as quickly as possible while maximising the impact on minimum demand and minimising the impact on maximum demand.

The model uses the departure time distribution shown in Figure B9.

Figure B9 – Vehicle Departure Distribution by Vehicle Type



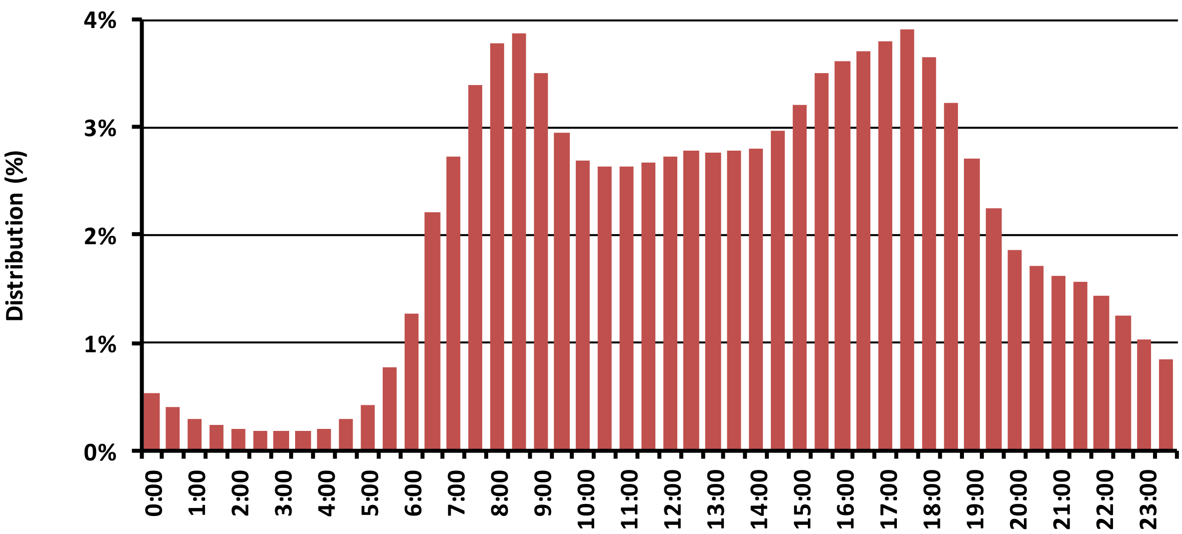
Source: Queensland Household Travel Survey (2014)

B.5.5 DCFC Charging Times

EV fast charging starts as soon as the vehicle arrives at the charging station and is completed within 5 minutes using 1MW chargers by 2036.

The charging start time is based on the Victorian Managing Traffic Congestion report and uses the traffic volume by time of day to determine the distribution of DCFC use, this is shown in Figure B11.

Figure B11 – Arrival Time Distribution



Source: VAGO (2013), Managing Traffic Congestion. Access from: https://www.audit.vic.gov.au/report/managing-traffic-congestion

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B.6 Vehicle Stock Model

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

$$ICE_t = \sum^{i,j} \left[ICE_{i,j(t-1)} + (Vehicle\ Sales_{i,j(t)} - EV\ Uptake_{i,j(t)}) - \text{if}\left(t \leq AvgLifetime, \frac{ICE_{i,j(0)}}{AvgLifetime}, 0\right) \right]$$

$$EV_t = \sum^{i,j} \left[EV_{i,j(t-1)} + EV\ Uptake_{i,j(t)} - \text{if}\left(t \leq AvgLifetime, \frac{EV_{i,j(0)}}{AvgLifetime}, 0\right) \right]$$

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
- Average Lifetime = Average vehicle lifetime

B.6.1 Opening Stock

The opening stock of vehicles by vehicle class is sourced from VFACTS data for the calendar year 2016[30] for PEV and ICE vehicles by state. The opening stock feeds into the vehicle stock model at t=0 in the above equations.

B.6.2 Market Growth

Each year, each vehicle class in their respective market is assumed to grow at a constant rate per capita based on ABS forecasts of low, neutral and high population growth.

B.6.2 Average Lifetime

Average vehicle lifetime of all ICE vehicles is assumed to be 22 years based on ABS data[31], while the average vehicle lifetime of all PEVs are assumed to be 10 years.

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[30] Federal Chamber of Automotive Industries (2016), VFACTS

[31] ABS 9208.0 - Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2016

B.7 Limitations

Energeia's PEV forecasts are independent of the base electricity price forecasts. That is, there is no feedback loop between the forecasted PEV uptake and the corresponding response from networks, retailers or the wholesale market.

Further, there are a range of future possibilities as to how PEV loads will be priced and how the PEV market will integrate with the electricity market and it is foreseeable that tariff products could evolve to encourage increased charging of PEVs during solar generation times. This analysis assumes initial PEV tariffs for home and workplace charging reflect controlled load tariffs, which will be orchestrated to ensure they minimise peak demand impacts.

The household transport model upon which the PEV forecast model relies are derived from the Queensland Household Travel Survey and the Victorian Auditor-General's Managing Traffic Congestion Report. 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 for passenger vehicles with access to private parking, while travel patterns for commercial PEVs and vehicles without access to private parking are consistent with drivers in Victoria.

The PEV uptake model is driven in part by the financial return on investment to vehicles owners based on the PEV vehicle premium and reduced operational costs. The model does not consider costs associated with any required upgrade to the household switch board and/or service, which could add considerable cost. However, this is not expected to be a material number of households based on anecdotal evidence from pilots, etc.

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Appendix C: Public Charging Infrastructure Scaling Model

Energeia's PEV public charging infrastructure model is based on our research and analysis of international best practice approaches to delivering an optimal public charging infrastructure, summarized in Table C1. Step 1 is not included in our model as it is no longer needed given the range of second generation PEVs.

Table C1 – PEV Charging Network Scaling

Step	Network Name	Driving Segment	Charging Solution	Locations	Targeted Trips	Populations Affected
1	L2 – Workplace	Dedicated Residential - Daily Commuter	L2	Workplace	Long-Distance Commutes	20% of Commuters
2	DCFC – Access	All	DCFC	Main Roads, Destinations	Road Trips, Regional Tourism	Less than 1% of trips
3	L2/DCFC – Shared Parking	Drivers without Dedicated Overnight Parking	L2 or DCFC	Public Parking	Daily Commutes	20% of All Res Drivers

Source: Energeia Analysis

- **Step 1 –** Targeted first generation PEVs, which did not have the driving range to meet common commuting distances. Stage 1 networks targeted public charging near workplaces to enable commuters to purchase and use first generation PEVs. Second generation PEVs have sufficient range for commuting, and Step 1 is therefore no longer required for this segment (and chargers can be used to address Step 3).
- **Step 2 –** Focused on establishing a network of DCFC to enable PEVs to 'access' the road network, particularly inter-region and long-haul destinations. The number of DCFCs depending on PEV range. Early range extending access networks targeted at least 1 DCFC every 40-50 miles, consistent with the maximum range of first generation PEVs. New access networks are able to be spaced further apart as PEV ranges have increased.
- **Step 3 –** Public charging networks have focused on the roughly 20% of drivers without access to dedicated parking and therefore their own Level 2 charger. To date, for reasons discussed in previous sections, public charging infrastructure deployment targeting this segment has focused on public L2 chargers near work and home. However, the most recent studies also include petrol station style DCFC solutions for this segment.

Energeia's charging infrastructure scaling model assumes that all required charging infrastructure is delivered as required.

C.1 DC Fast Charger – Shared Parking Network

Energeia's DC fast charger network for drivers without dedicated overnight parking (Shared Parking Network) sizing methodology is comprised of three parts:

- the total number of petrol pump hoses today,
- cumulative PEVs on the road, and
- access to private charging.

The number of petrol pump hoses is calculated based on desktop research, cumulative PEV uptake data is taken from the outputs of Energeia's PEV uptake model, while the number of vehicles with access to private charging is taken from UK travel data as per part A.

The model assumes that all vehicles without access to private charging will use public DCFC, and that the ratio of vehicles on the road to petrol pump hoses remain the same over time. The number of DC fast chargers needed is calculated as the ratio of cumulative PEVs without access to private charging to total ICEs today, multiplied the number of petrol pumps today, multiplied by the ratio of PEV charge time to ICE refuel time.

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$$Congestion\ DCFC_t = [Total\ Vehicle\ on\ the\ Road_t * (1 - Access\ to\ Private\ Parking_t)] * \left[\left(\frac{Total\ ICEs_{2017}}{Total\ Petrol\ Pumps_{2017}}\right) * \left(\frac{EV\ Charge\ Time}{Petrol\ Refuel\ Time}\right)\right]$$

The model ramps up from the start of the Shared Parking Network infrastructure rollout to meet 100% of needs over a configurable of years.

There is also an assumed ramping from inefficient usage of this network by drivers, to using it at the same efficiency as current petrol stations. It is currently set to be 25% of efficient levels the year it commences, moving to 100% of efficient levels after ten years. This assumption is configurable as well.

C.2 DC Fast Charger – Range Extension Network

Energeia's range extension (Range Extension Network) or road access network scaling methodology is comprised of two parts:

- types of roads covered,
- total kilometres of road,
- road coverage required (%),
- maximum distance between sites, and
- number of hoses per site.

The model forecasts the required number of DCFC hoses that allow PEVs to cover the targeted coverage of roads given a configurable PEV driving range.

Road coverage required is ramped from 0% to 100% over a configurable period starting in a configurable year, this is then multiplied by the total length of roads in Australia and divided by a configurable PEV driving range to calculate the total number of access chargers required over time.

This calculation remains the same across scenarios.

$$Access\ DCFC_t = \frac{Road\ Coverage_t * Total\ kms\ of\ Road_t}{EV\ Driving\ Range_t}$$

For this report, the modelling assumed 90% of all highway and arterial roads were included, 2 hoses per site, and a maximum distance of 300 km per site.

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Appendix D: OEM Market Share Model

Energeia developed an OEM market share model to predict OEM market shares of PEV sales over time. The model assumes that OEM's will be as successful in the medium to longer-term in developing PEV equivalents to their ICE vehicles. It therefore assumes that PEV leadership to date has been driven more by lack of entry by ICE incumbents, than any real first mover advantage – which is probably the most important key assumption.

D.1 Market Share Scaling

Energeia's OEM market share forecasting methodology is comprised of three parts:

- Annual PEV sales
- OEM global model availability forecasts/targets,
- Assumed Australian share of global models and introduction delay, and
- Current OEM market shares.

The model estimates OEM market shares of PEV sales each year based on an estimate of each OEM's number of PEVs in Australia relative to their total available models in Australia each year, and each OEM's overall Australian market share.

$$OEM\ Market\ Share_{PEV} = \frac{\left[OEM\ Market\ Share\ _{ICE} * \frac{Model\ Availability_{PEV}}{Model\ Availability_{ICE}}\right]}{\sum_{i=o}^{n} \frac{OEM\ Market\ Share_{ICE}}{Model\ Availability_{ICE}}}$$

Where:

- OEM Market Share$_{PEV}$ = future PEV market share in any year n, by OEM
- OEM Market Share$_{ICE}$ = current ICE market share in year 1, by OEM
- Model Availability$_{PEV}$ = future number of models, by OEM, in year n
- Model Availability$_{ICE}$ = current number of models, by OEM, in year 1

Energeia conducted desktop research to identify OEM PEV model availability targets and current market shares for ICE vehicles, PEV uptake data is taken from the outputs of Energeia's PEV uptake model.

The findings from Energeia's research of OEM's global PEV model targets are reported in Table D1.

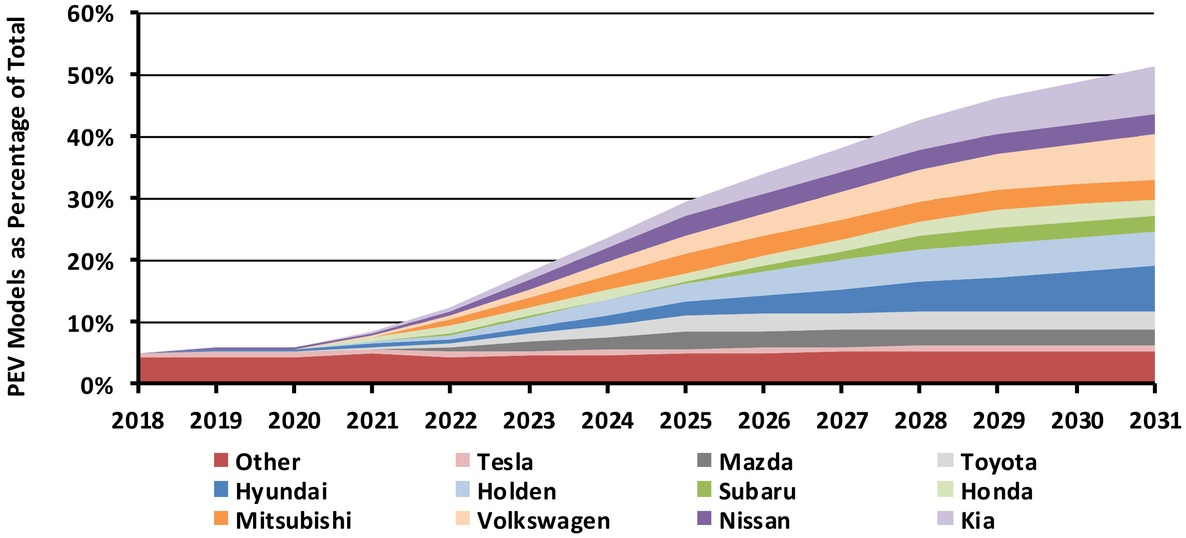
Table D1 – Global OEM PEV Availability Announcements

Target Year	OEM	Parent	HQ	Target No. of Models	Target % Models
2018	Honda	Honda	Japan	2	-
2019	Volvo	Geely	China	-	100
2020	Toyota	Toyota	Japan	10	-
	Mazda	Mazda		10	100
	Jaguar Land Rover	Tata	India	-	-
2021	Ford	Ford	USA	13	-
2022	Mercedes-Benz	Daimler AG	Germany	10	-
	Nissan	Nissan	Japan	12	-
	Mitsubishi	Mitsubishi	Japan	12	-
	Renault	Renault	France	12	-
2023	General Motors	GM	USA	20	-
	PSA	PSA	France	-	80
2025	Audi		Germany	-	33
	Volkswagen			30	-
	BMW	BMW		25	-
	Hyundai	Hyundai	South Korea	38	-
	Kia			16	-

Source: Energeia Research

As OEM targets are for a point in time, Energeia assumed a linear ramp from today.

Figure D2 – PEV Models Relative to Total Models



Appendix E: Glossary

Table E1 – Summary of Abbreviations used throughout the Report

Item	Definition	Explanation
ACT	Australian Capital Territory	Territory of Australia; part of the NEM
BEV	Battery Electric Vehicle	A PEV that runs on an electric drive train powered exclusively by a battery
EVSE	Electric Vehicle Supply Equipment	Charging stations and hoses
ICE	Internal Combustion Engine	Conventional diesel or petrol powered drive train for vehicles
kW	Kilowatt	Unit of power
kWh	Kilowatt Hour	Unit of energy
LC	Light Commercial vehicle	VFACTS data definition
MW	Megawatt	Unit of power
MWh	Megawatt Hour	Unit of energy
NEM	National Electricity Market	The NEM includes Queensland, New South Wales, ACT, Victoria, South Australia and Tasmania
NSW	New South Wales	State of Australia; part of the NEM
NT	Northern Territory	Territory of Australia; not part of the NEM
OEM	Original Equipment Manufacturer	In this report, a vehicle manufacturer
PC- S	Passenger Car – Small	VFACTS data definition
PC-L	Passenger Car – Large	VFACTS data definition
PC-M	Passenger Car – Medium	VFACTS data definition
PEV	Plug-in Electric Vehicle	Any EV (either PHEV or BEV) that plugs into a charger
PHEV	Plug-in Hybrid Electric Vehicle	A PEV that runs on an electric drive train powered by both a battery and an ICE
PV	Photovoltaic	The creation of voltage and electric current in a material upon exposure to light
QLD	Queensland	State of Australia; part of the NEM
SA	South Australia	State of Australia; part of the NEM
SUV-L	Sports Utility Vehicle – Large	VFACTS data definition
SUV-M	Sports Utility Vehicle – Medium	VFACTS data definition
TAS	Tasmania	State of Australia; part of the NEM
V2G	Vehicle-to-Grid	Using a PEV battery to discharge to the grid to provide power
VIC	Victoria	State of Australia; part of the NEM
WA	Western Australia	State of Australia; not part of the NEM

Table E2– Terms used in the Report

Term	Explanation
Public Charging	Chargers located in areas accessible to the public (roadside locations like service stations, or off-road locations like parking garages).
Private Charging	Off-road, dedicated charging on private property (such as at a residential home, or at a workplace.
Dedicated Parking	A dedicated parking spot, such as a residential garage or car port, or an allocated parking spot at a workplace
Non-dedicated Parking	Either on-road curbside parking, or off-road shared parking, such as parking lots or garages.
Rollout Programs	Investments to encourage development of PEV charging infrastructure.
Matching Grants	Policy measure whereby government/organisation will meet an investment made by a firm in PEVs or charging infrastructure, such that the investment is scaled-up.
Concessionary Loans	Loans with terms that are more generous than the going market rate, for investing in PEVs or charging infrastructure.

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