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IMPACT OF ELECTRIC VEHICLES AND NATURAL GAS VEHICLES ON THE ENERGY MARKETS

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Document Impact of Electric Vehicles and Natural Gas Vehicles on the Energy Markets

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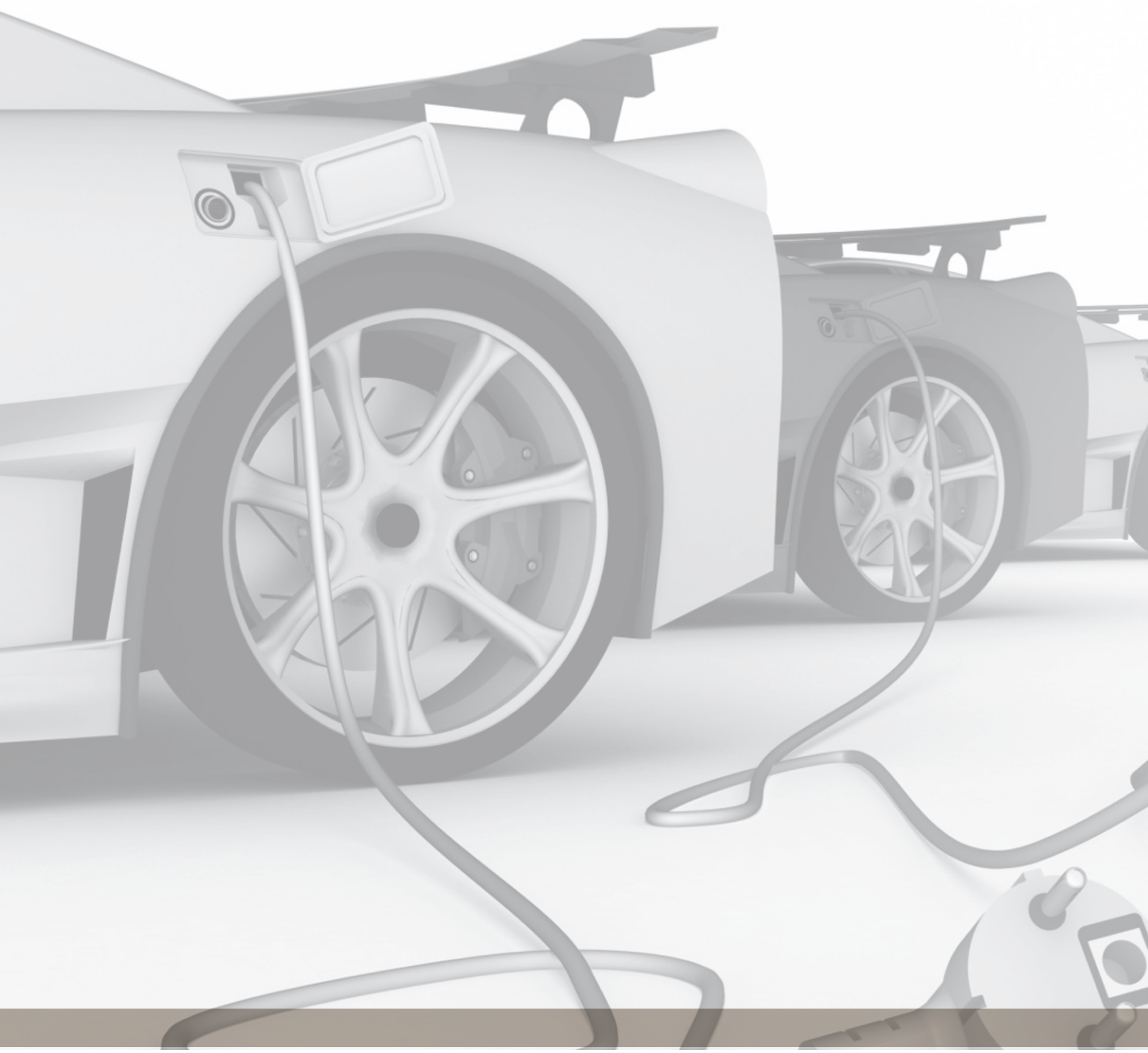
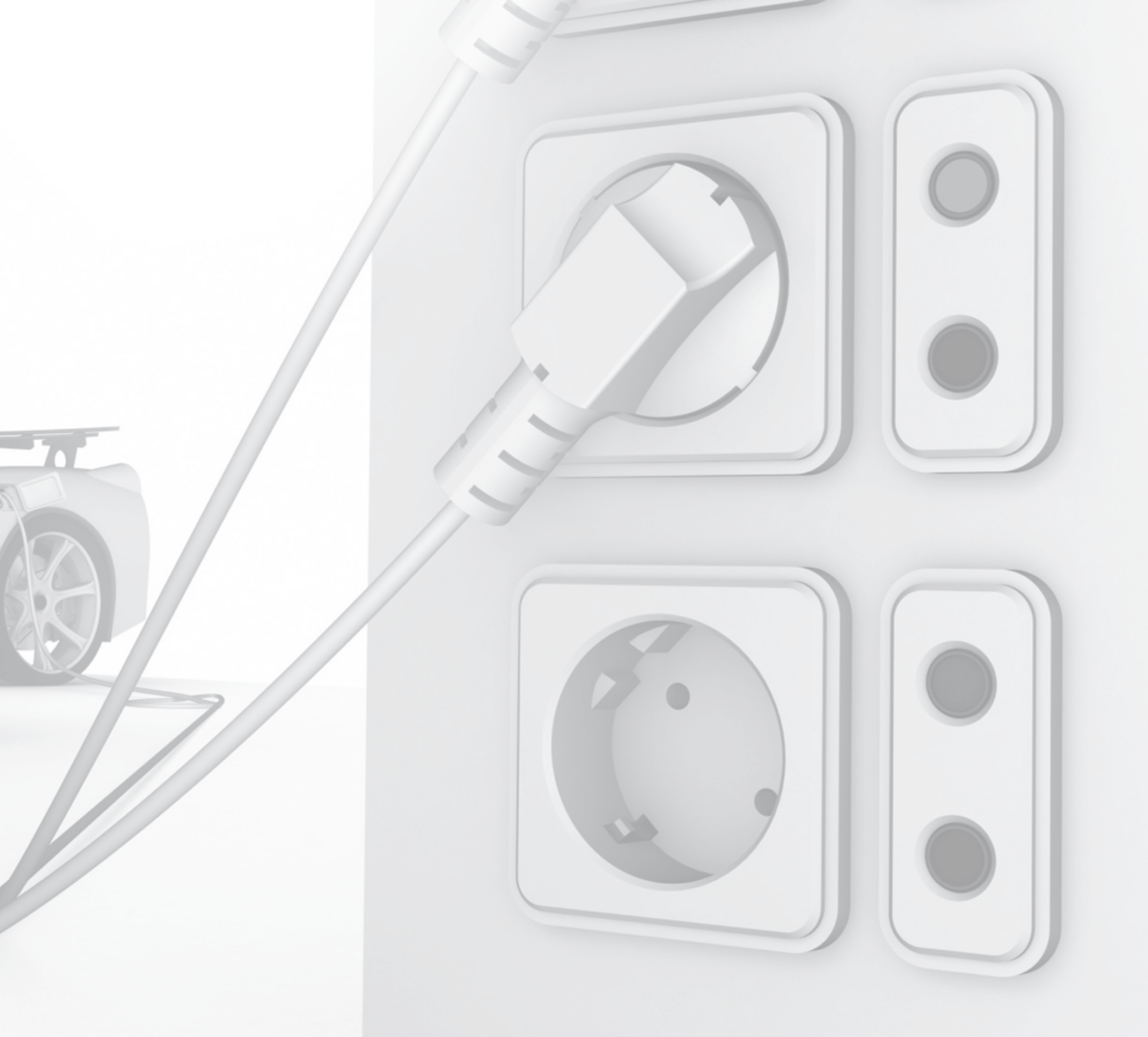




Executive Summary

Executive Summary

The Australian Energy Market Commission (AEMC) has commissioned AECOM to undertake a study to investigate the broad costs and benefits of Electric Vehicles (EVs) and Natural Gas Vehicles (NGVs) on their respective energy markets. The study also identifies the arrangements necessary within these energy markets to facilitate the efficient uptake of these vehicles. This report:

- assesses the potential uptake of EVs and NGVs
- identifies the costs and benefits of EVs and NGVs to the energy markets.

This study considers the impact on the National Electricity Market (NEM) and the South West Interconnected System (SWIS). As such, the study area comprises Queensland, New South Wales, Australian Capital Territory, Victoria, Tasmania, South Australia and Western Australia.

The analysis in this study is intended to be high level to identify the magnitude of impacts. As such, a number of assumptions and simplifications have been made which do not alter the extent of impacts but mean that this analysis should not be used for any other purpose. In particular, the analysis of costs and benefits is relatively simple and not intended to be a full cost-benefit analysis but instead provide an indication of the likely magnitude of costs and benefits.

Electric vehicles

Electric Vehicles are likely to play an important role in the future of motor vehicles in Australia…

There is a global movement to transition away from motor vehicles powered by petrol and diesel, driven primarily by increased awareness and action on reducing greenhouse gas emissions and a desire by most countries to reduce their dependence on imported oil. As low emission vehicles, EVs have the potential to provide environmental benefits, through reduced greenhouse gas emissions and ambient air pollution, while reducing Australia's exposure to crude oil prices and oil import dependency.

Our study identified the following key factors affecting the take up of EVs:

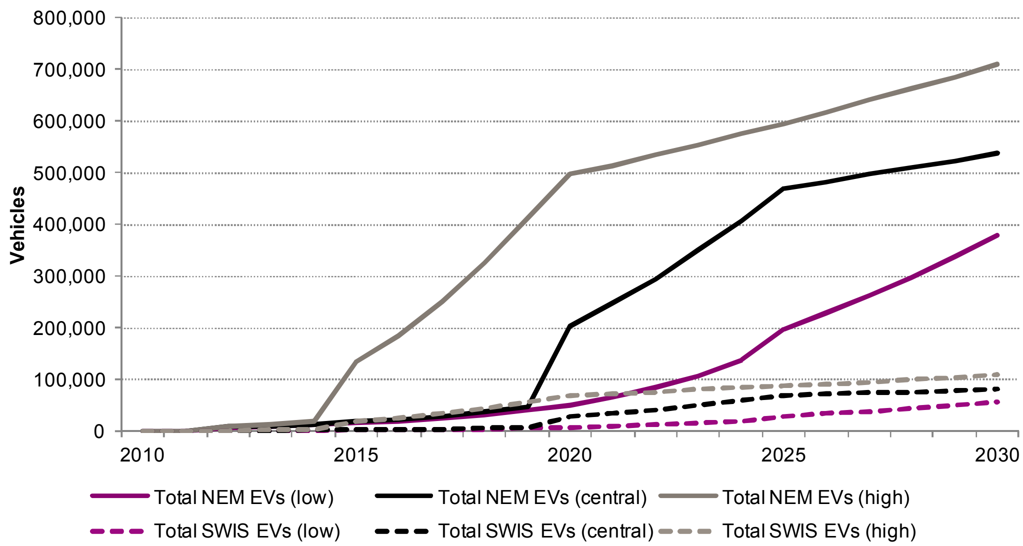
- vehicle price (which is largely driven by battery prices) and rate at which it converges with an internal combustion engine (ICE) vehicle
- global supply constraints in the EV market
- supply of infrastructure with research to date suggesting that, whilst most charging will occur at home, the provision of public infrastructure is necessary to alleviate range concerns
- fuel prices, particularly higher oil prices which impact on the operating cost of ICE vehicles
- vehicle range.

Following an extensive literature review on the factors affecting the decision to purchase a vehicle, AECOM developed a vehicle choice model which takes into account the vehicle purchase cost, fuel cost, vehicle range, emissions, availability of refuelling / charging infrastructure and multi-fuel bonus.

There are inherent uncertainties in making forward estimates, so it is important to understand the likely range of take up and the key influencing factors. Therefore, this study has developed three scenarios around the key factors identified as affecting the take up of EVs.

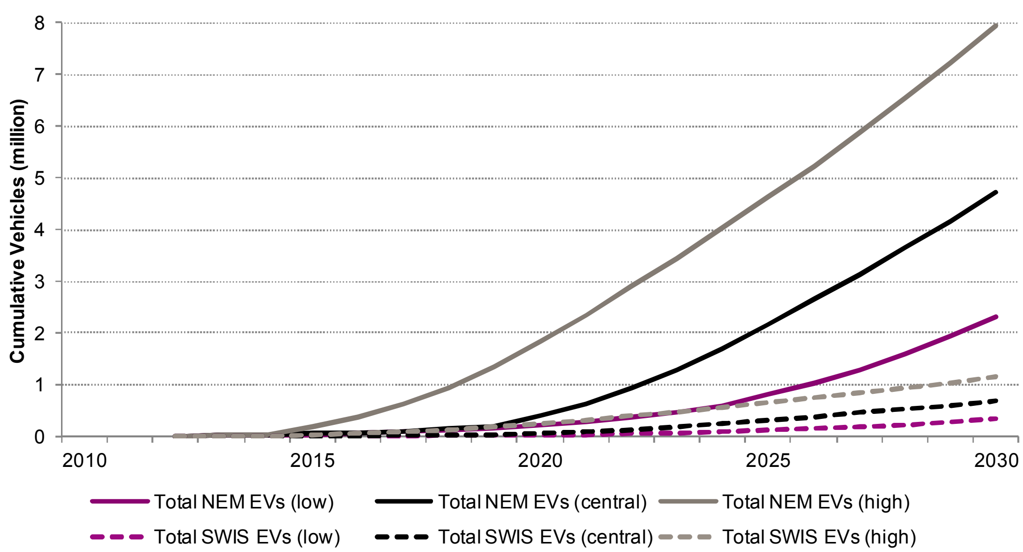
AECOM's analysis suggests that within 10 to 15 years EVs could have a significant presence in the Australian market (see **Figure 1** and **Figure 2**). While vehicle sales are expected to be slow initially, accounting for around 1 to 2 percent until 2015, once vehicle prices fall, global supply constraints ease and infrastructure availability increases, EV sales are expected to be around 20 percent of sales by 2020 rising to around 45 percent of sales by 2030 (see **Table 1**) . Take up could be slower, as illustrated in our low scenario, if EV prices take longer to reach price parity and supply constraints remain in the Australian market. However, it is also possible that take up could be much quicker (as illustrated in our high scenario) if for example, battery prices fall much quicker than currently anticipated, Australia is seen as a key electric vehicle market with supply constraints easing quicker and the emergence of leasing arrangements that reduce the upfront purchase cost.

Figure 1: Estimated annual sales of EVs in NEM and SWIS



Source: AECOM

Figure 2: Estimated number of EVs in NEM and SWIS



Source: AECOM

Table 1: Estimated take up of EVs in the NEM and SWIS as a proportion of new sales

	Central			Low			High		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
NEM									
PHEV	1.3%	18.7%	36.3%	1.4%	4.6%	31.0%	13.0%	41.0%	38.0%
BEV	0.7%	1.5%	7.6%	0.3%	0.6%	2.6%	1.3%	6.0%	15.4%
Total	2.0%	20.2%	43.9%	1.7%	5.3%	33.6%	14.4%	47.0%	53.4%
SWIS									
PHEV	1.3%	18.7%	37.5%	1.3%	4.4%	32.2%	12.8%	42.0%	38.6%
BEV	0.7%	1.6%	8.5%	0.3%	0.6%	2.9%	1.4%	6.6%	17.0%
Total	2.0%	20.3%	45.9%	1.7%	5.1%	35.1%	14.2%	48.6%	55.7%
Total									
PHEV	1.3%	18.7%	36.5%	1.3%	4.6%	31.2%	13.0%	41.1%	38.0%
BEV	0.7%	1.5%	7.7%	0.3%	0.6%	2.6%	1.3%	6.0%	15.6%
Total	2.0%	20.2%	44.2%	1.7%	5.2%	33.8%	14.3%	47.2%	53.6%

Source: AECOM

There are 4 key findings that warrant further discussion:

- *higher take up of Plug-in Hybrid Electric Vehicles (PHEVs)in early years will reduce the impact on the electricity market*

  In early years, the take-up of PHEVs is projected to be stronger than that of pure Battery Electric Vehicles (BEVs) due to superior range and the ability to use both electricity and petrol as fuel. However, over time there will be a shift towards BEVs as purchase prices converge to parity with ICE, battery improvements result in increased vehicle range, the provision of more charging infrastructure, and higher fuel prices have the potential to make BEVs more competitive. The higher take up of PHEVs in early years may reduce the impact that EVs will have on the electricity market, because PHEVs will typically use less electricity and the dual charging is likely to reduce range anxiety and make PHEV charging more flexible which will in turn reduces the impact on peak load.

- *higher take up of smaller vehicles in early years will minimise the impact on the electricity market*

  The take up of EVs also varies significantly by vehicle size and distance travelled. The price premium of an EV is directly related to the battery price, which in turn is directly related to the size and weight of the vehicle. Currently, a large EV has a much higher premium than a small EV. This results in higher take up of small EVs, typically travelling short distances, in the short term. However, as vehicle prices fall, the vehicle range increases and more charging infrastructure becomes available, owners of larger vehicles and vehicles that travel long distances tend to purchase a higher proportion of EVs. This is due to the fact that operating costs are relatively more important for these vehicle owners. The early preference for small vehicles, travelling shorter distances, will also minimise the impact that EVs will have on the electricity market.

- *higher take up of EVs in New South Wales, Victoria and Queensland*

  At a state and territory level within the NEM, equivalent results are observed in terms of the proportion of new sales; however the magnitude of sales varies between regions. New South Wales (and ACT), Victoria, and Queensland make up the majority of vehicle sales with approximately 90 percent of take up in the NEM. This is reflective of current vehicle sale patterns.

- *spatial clusters in early years*

  Whilst this study focuses on take up at a state level, it is important to recognise there may be spatial patterns especially in early years. Take up is likely to be initially concentrated in urban and major hub areas where people typically drive shorter distances and public and commercial charging infrastructure is more likely to be available. In the short to medium term, take up is also likely to be driven by early adopters, who are typically characterised as having higher incomes, higher levels of education, and being more technologically and environmentally aware. As such, it is likely that early take up could be clustered around areas with these socio-demographic characteristics.

It is important to recognise that there are a number of factors that impact on the take up of EVs and these factors are continuously changing. National forecasts should be updated regularly to assist in the preparation for EVs.

The impact of EVs on the electricity market depends on the ability to incentivise drivers to charge in off-peak periods…

The impact that EVs will have on the electricity markets is largely dependent on the amount of energy used and the timing of charging. In the worst case scenario where EV charging is unmanaged and occurs during existing load peaks, peak load will increase. As a result, distribution and transmission systems will need to be strengthened and more generation built. Conversely, if charging happens in off-peak periods, then it is not expected to increase peak load, even in high take up scenarios.

Table 2 sets out energy usage and the increase in peak load (if charging is unmanaged) under the three take up scenarios. Key highlights include:

- energy consumption remains relatively low as a proportion of total energy demand even in the high take up scenario for both the NEM and SWIS at 3.7 and 4.3 percent respectively. The proportion of total energy demand is slightly higher in the SWIS than the NEM but remains low
- the energy consumption depends on a number of factors including the split between PHEVs and BEVs as well as the size of the vehicle and distance travelled and as such, changes over time in line with take up patterns
- the energy consumption from EVs as proportions of total energy consumption in New South Wales and Australian Capital Territory, Victoria and South Australia are slightly higher than the total for the NEM, whereas Queensland and Tasmania have lower proportions than the total for the NEM
- an often discussed concept is the ability of renewable energy generation to supply some or all of the energy demanded by EVs to recharge. Analysis in this study suggests renewable generation is more than capable of supplying the energy requirements of EVs in aggregate, although not necessarily at each moment
- if charging is unmanaged and everyone comes home and charges at peak periods, under the central take up scenario, peak demand is expected to increase by around 730MW by 2020 and 8.6GW by 2030 in the NEM. Peak demand in the SWIS is expected to increase by around 100MW by 2020 and 1.3GW by 2030 in the SWIS. This analysis assumes around 50 percent of charging occurs in peak periods and every EV owner has a level 1 charger (15A). However if 100 percent of charging occurs in peak periods with a Level 1 charger, which is very unlikely, then there could be double the increase in the additional peak load. Likewise, if 25 percent of charging occurs in peak periods, which is still realistic, this results in approximately half the additional peak load and cost imposed by EVs
- the increases in peak load forecast under the EV take up scenarios are relatively small in the short term when compared with the increase in peak demand required for business as usual. However the increases could be substantial over the medium to long term. The Australian Energy Market Operator (AEMO) forecast an additional 13,000MW will be required by 2020 and an additional 27,500 MW by 2030 in their core scenario with 50 percent probability of exceedance (PoE). In the central take up scenario, unmanaged charging of EVs may require an additional

7.3 percent of additional peak demand in the NEM by 2020 compared to what is required for business as usual and an additional 36.5 percent by 2030. Additional investment in peak demand in the SWIS is smaller, rising to just over 27 percent by 2030 in the central take up scenario with unmanaged charging. In the high take up scenario, additional peak load, compared to what is required for business as usual, could be 25.5 percent in 2020 and 43.8 percent by 2030 in the NEM and 18.3 percent by 2020 and 33.8 percent by 2030 in the SWIS. These estimates are based on the 50 percent PoE estimates of peak demand in the 2011 Statement of Opportunities. If the 10 percent PoE is used these proportions are smaller

- in the central take up scenario, unmanaged charging of EVs starts to have a significant impact on peak demand around 2020. This should allow sufficient time for the electricity market to plan and manage the additional increase in peak load that may be required. However, it is possible that take up could be much quicker (as illustrated in our high take up scenario) – if for example, battery prices fall much quicker than currently anticipated – in which case the impact of EVs on peak demand, if unmanaged, could be felt as early as 2015 which is just inside the five year planning cycle.

Table 2: Impact of EVs on the energy market in selected years with unmanaged charging

EVs	2015		2020		2030	
	NEM	SWIS	NEM	SWIS	NEM	SWIS
Central take up scenario						
Energy consumption (MWh)	88,300	10,400	648,800	80,900	8,536,700	1,173,800
% of total MWh in NEM	0.0%	0.0%	0.2%	0.2%	2.2%	2.6%
Increase in peak load if unmanaged charging (MW)	95	10	730	100	8,595	1,260
% increase in additional peak load	1.8%	1.0%	7.3%	4.8%	36.5%	27.2%
Low take up scenario						
Energy consumption (MWh)	66,400	7,800	323,700	38,900	4,039,300	545,800
% of total MWh in NEM	0.0%	0.0%	0.1%	0.1%	1.1%	1.2%
Increase in peak load if unmanaged charging (MW)	80	10	385	50	4,210	605
% increase in additional peak load	1.9%	1.1%	5.0%	3.1%	24.3%	17.2%
High take up scenario						
Energy consumption (MWh)	273,100	32,600	3,035,400	389,000	14,261,400	1,948,700
% of total MWh in NEM	0.1%	0.1%	1.1%	1.0%	3.7%	4.3%
Increase in peak load if unmanaged charging (MW)	325	40	3,435	470	14,220	2,065
% increase in additional peak load	5.1%	2.8%	25.5%	18.3%	43.8%	33.8%

Source: AECOM

However, unlike many other high energy consumer goods, such as air conditioning, use of electric vehicle charging has more flexibility. If electric vehicle drivers can be encouraged to charge their vehicles in off-peak periods, either through incentivising customers to charge at off-peak times through time of use charging or smart metering, or enforcing off-peak charging through ripple control or regulation, the impacts fall significantly.

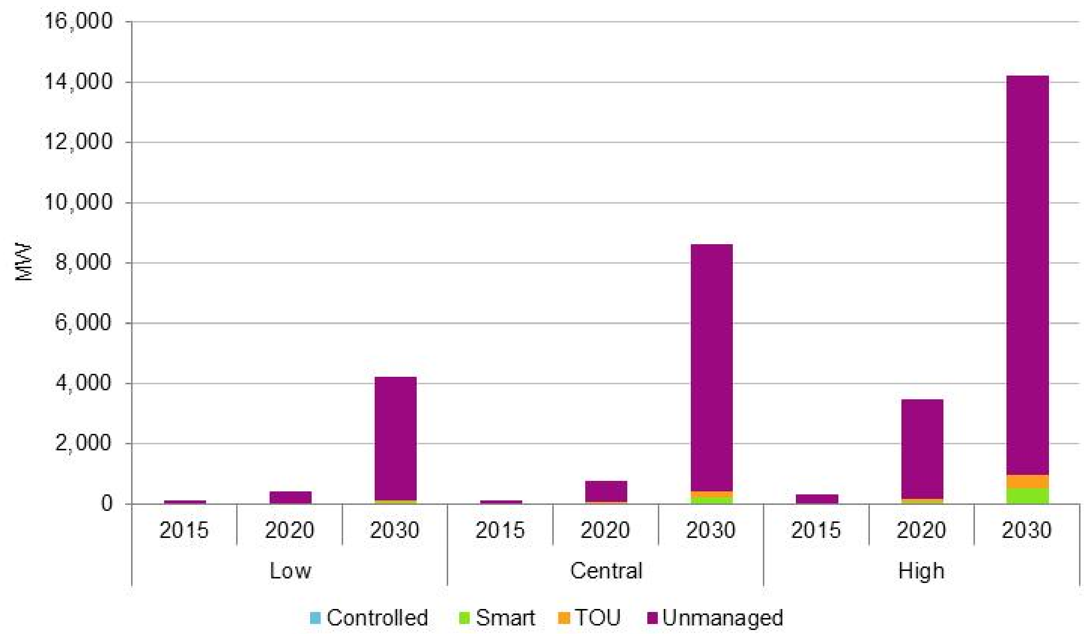
This study examined three charge management scenarios, designed to encourage off-peak charging, in addition to the base case of unmanaged charging:

- unmanaged charging – charging occurs when people arrive home from work and coincides with the peak period

- controlled charging – charging is forced to occur in off-peak periods, for example, by using controlled load such as time switches or ripple control
- time of use (ToU) charging – EV drivers have time of use tariffs that will incentivise a proportion of these to charge during off-peak periods
- smart charging – EV drivers have smart chargers that respond to signals such as real time pricing and provide better incentives than ToU pricing for off-peak charging.

Figure 3 highlights the potential benefits from encouraging off-peak charging in the NEM. If charging is unmanaged and around 50 percent of EV users come home and charge at peak periods, under the central take up scenario, peak demand is expected to increase by around 730MW by 2020 and 8.6 GW by 2030. However, if charging occurs in off-peak periods, by incentivising customers to charge at off-peak times through ToU charging or smart metering, or enforcing off-peak charging through ripple control or regulation, the costs fall significantly. ToU charging is expected to result in an increase in peak demand of 50MW in 2020 and around 410 MW by 2030. Smart metering could reduce this even further to an increase in peak demand of around 25 MW in 2020 and 205 MW by 2030. Controlled charging, which would ensure all charging occurs off-peak, would result in no additional increase in peak demand. The largest increases in peak load occur in states with the largest take up of EVs. The state with the largest increase in peak load is New South Wales, followed closely by Victoria. The increase in peak demand is lower in more rural states (such as Queensland) and states with smaller populations.

Figure 3: Estimated additional peak demand in NEM (MW)

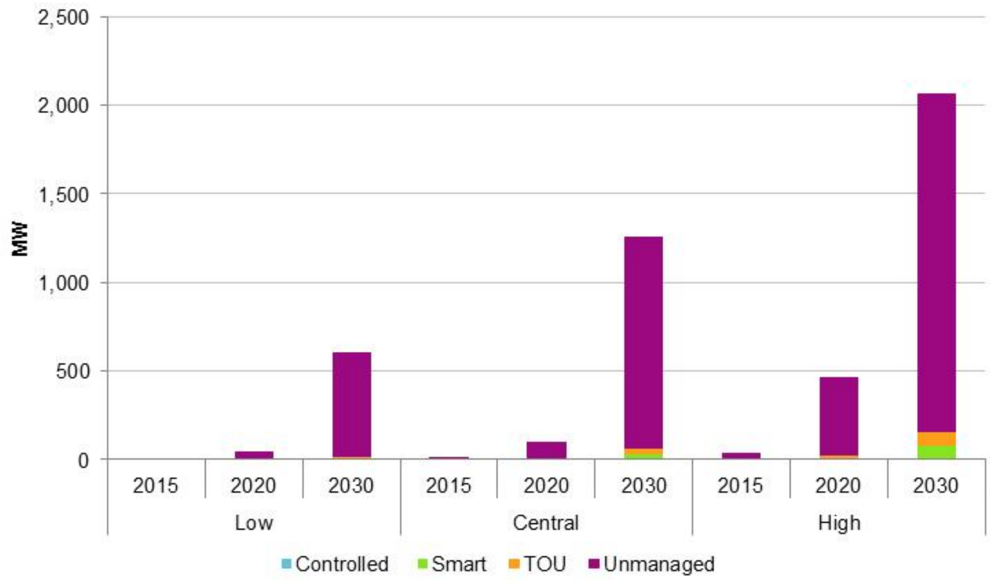


Source: AECOM

Note: The above chart shows estimated additional peak demand, with increments attributable to each charging type. For example, under the central take up scenario, by 2030, with unmanaged charging 8,600 additional MW are required; for ToU charging this is 410MW and for smart charging an additional 205MW.

Figure 4 highlights the potential benefits from encouraging off-peak charging in the SWIS. If charging is unmanaged and around 50 percent of EV users come home and charge at peak periods, under the central take up scenario, peak demand is expected to increase by around 100 MW by 2020 and 1,260 MW by 2030. However, if charging occurs in off-peak periods the costs fall significantly. ToU charging is expected to result in an increase in peak demand of 7 MW in 2020 and around 65 MW by 2030. Smart metering could reduce this even further to an increase in peak demand of around 3MW in 2020 and 30 MW by 2030. Controlled charging, which would ensure all charging occurs off-peak, would result in no additional increase in peak demand.

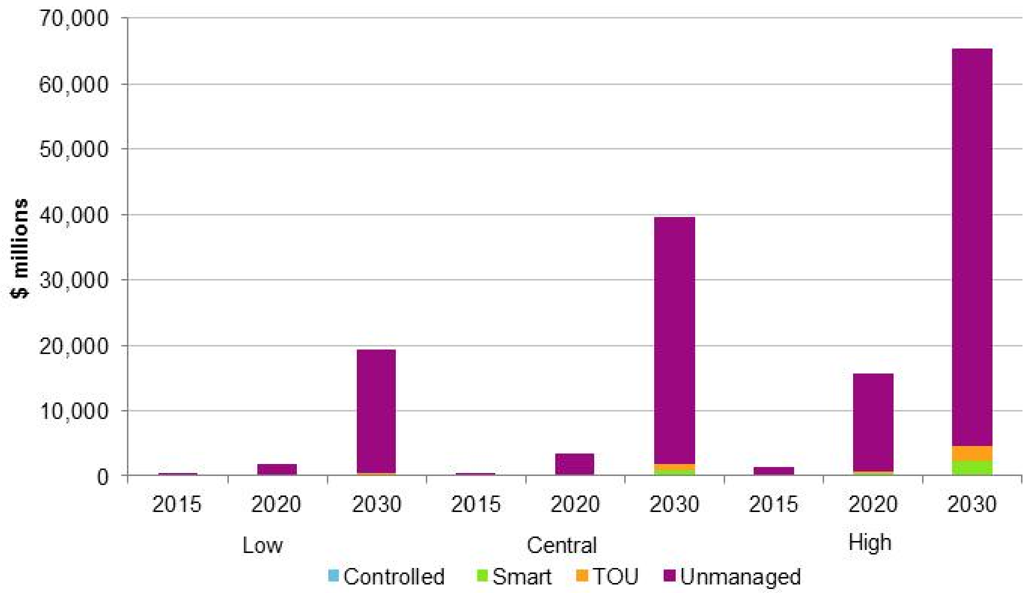
Figure 4: Estimated additional peak demand in SWIS (MW)



Source: AECOM

Figure 5 shows that, if charging is unmanaged and around 50 percent of EV users come home and charge at peak periods, under the central take up scenario the cost of increased capacity in the NEM could be around $3.3 billion by 2020 and $39.5 billion by 2030. This equates to around $10,000 per EV, although the actual amount will vary by location and use profile. However, if charging occurs in off-peak periods, the costs fall significantly. ToU charging is expected to result in additional costs of around $220million by 2020 and $1.9 billion by 2030. Smart metering could reduce this even further to around $110 million by 2020 and $940 million by 2030. Controlled charging, which would ensure all charging occurs off-peak, would result in no additional increase in peak demand. These estimates have not been discounted to reflect timing of investments. This analysis assumes around 50 percent of charging occurs in peak periods and every EV owner has a level 1 charger (15A). If 25 per cent of charging occurs in peak periods and every owner has a level 1 charger (15A) this results in approximately half the additional peak load and cost imposed by unmanaged EVs. However if 100 percent of charging occurs in peak periods and every EV owner has a level 1 charger (32A) this results in an approximately double the increase in the additional cost of peak load. The largest component of this cost will be driven by investment in distribution, which will account for between 60 and 75 percent depending on the state. Generation accounts for around 15 to 25 percent and transmission accounts for around 10 to 20 percent. The impacts and costs also vary significantly by state depending on the take up of vehicles in each state. The impact is expected to be greater in New South Wales, Queensland and Victoria, the states with the largest take up of EVs. Interestingly, the cost of increasing capacity in Queensland could be higher than in Victoria, even though Victoria has a higher estimated increase in peak load, because cost of upgrading capacity in Queensland seems to be higher.

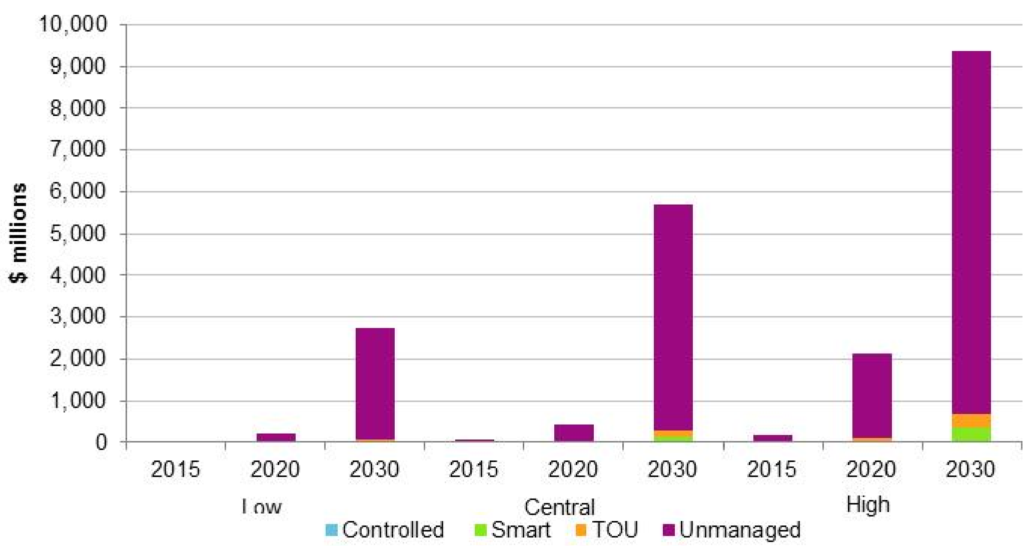
Figure 5: Estimated cost (for both generation and network upgrades) of additional peak demand in NEM ($ millions undiscounted)



Source: AECOM

Figure 6 shows that, if charging is unmanaged and around 50 percent of EV users come home and charges at peak periods, under the central take up scenario the cost of increased capacity in the SWIS could be around $440 million by 2020 and $5.7 billion by 2030. This equates to around $9,000 per EV, although the actual amount will vary by location and use profile. However, if charging occurs in off-peak periods the costs fall significantly. ToU charging is expected to result in additional costs of around $30 million by 2020 and $290 million by 2030. Smart metering could reduce this even further to around $15 million by 2020 and $145 million by 2030. Controlled charging, which would ensure all charging occurs off-peak, would result in no additional increase in peak demand. These estimates have not been discounted to reflect timing of investments.

Figure 6: Estimated cost (for both generation and network upgrades) of additional peak demand in SWIS ($ millions undiscounted)



Source: AECOM

It is unlikely that the take up of EVs will have a significant impact on the reliability of the electricity market, at either the generation or network level, for the following reasons:

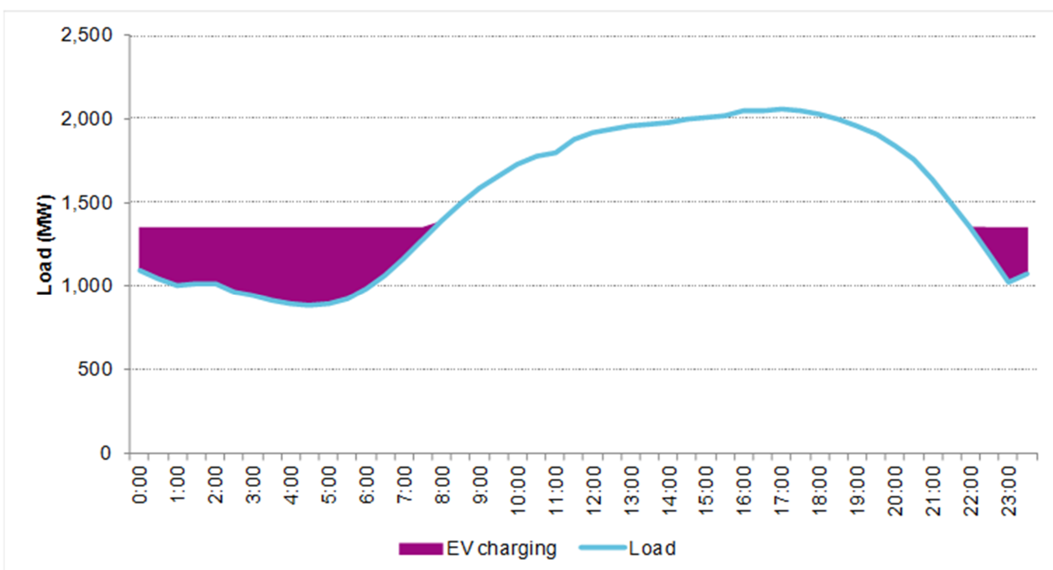
- take up is likely to be gradual with enough lead time for the market to respond
- there will be appropriate intervention to prevent unmanaged charging
- we assume the electricity markets and regulation continue to work effectively and provide the right incentives for the generation and network businesses to respond to the take up of EVs.

Consequently, our analysis assumes quality of service (including reliability, congestion and availability of generation) remain unchanged and the cost of maintaining this service is fully reflected in the cost of increased capacity.

Figure 7 highlights that, even in the high take up scenario, networks will be able to accommodate charging during off-peak periods without increasing their peak capacity. Based on Net System Load Profiles (NSLP), South Australia had the least available off-peak charging capacity during its day with the highest peak load in 2010. South Australia, therefore, provides the toughest test of the ability to accommodate EV charging in the off-peak. AECOM tested this in other states in the NEM and found the same result.

It is recognised that, whilst it is possible to accommodate EV charging in off-peak periods without increasing peak load, this could cause other impacts in the electricity market. In particular, concern has been raised that there may be issues regarding the adequacy of system capacity, particularly at the generation level. Given off-peak generation is predominantly base load coal and gas, there is unlikely to be major capacity issues as a direct result of EVs charging in off-peak periods. In AECOM's opinion, the current electricity market design provides the right incentives and is capable of responding to the issue of system capacity, particularly given the long lead times before there is significant take up of EVs.

Figure 7: Accommodating EV charging without increasing peak load, South Australia



Source: Net System Load Profiles from AEMO (2011a), EV charging AECOM

Further, if EVs can be managed to ensure the majority of charging occurs in non-peak periods, they present significant opportunities for improving the efficiency of the electricity market.

- Improved load factor: the cost of meeting peak demand is generation and network capacity that is used infrequently. Most networks operate at less than 50 percent load factor for a large proportion of the day. Going forward, this load factor is expected to deteriorate with peak demand forecast to grow faster than average energy use in the NEM. By flattening the load curve, the fixed costs of the network can be spread across a larger base, resulting in improved load factor. Our analysis estimates that EVs can improve the load factor of the network, resulting in retail price reductions of up to 2 percent per annum by 2020 and up to 7 percent per annum by 2030 under the high take up scenario with controlled charging, compared to what might happen otherwise, depending on take up and varying within each state
- Flexibility benefits: provided there is some form of dynamic pricing with the charging of EVs, there are further benefits from EVs including managing transmission and distribution networks, managing wholesale price risk and more efficient use of intermittent generation.

Vehicle-to-Grid presents opportunities for further benefits but there are still some issues that need addressing…

EVs also provide an opportunity to act as energy storage devices and feedback electricity to the grid (known as Vehicle-to-Grid (V2G)) or to the house (known as Vehicle-to-Home (V2H)). This opportunity could be used to reduce strain on the grid during periods of peak demand, provide ancillary services or power a house. The benefits of V2G could be large; however, the success of V2G depends on a number of factors including:

- Impact on battery life: as yet the full consequences for battery life are unknown and many manufacturers are concerned about battery warranty
- Driver concern: drivers may be wary about coming back to a vehicle that is discharged. This concern will ease over time as more information is available about charging behaviour, more charging infrastructure becomes available and technology becomes smarter so that it can ensure a minimum battery charge
- Tariff arrangements: Usher et al (2011) shows the viability of V2G is dependent on EV drivers receiving a higher tariff than they pay for electricity. Also, additional home infrastructure may be needed, as for other feed-in arrangements
- Take up of EVs: the success of V2G is dependent on a critical mass of EVs. As shown above, significant levels of take up are not expected in the short term, with high take up starting to occur in 10 to 15 years.

Overall, the impact of EVs on the electricity market depends on the ability to incentivise drivers to charge in off-peak periods.

Natural gas vehicles

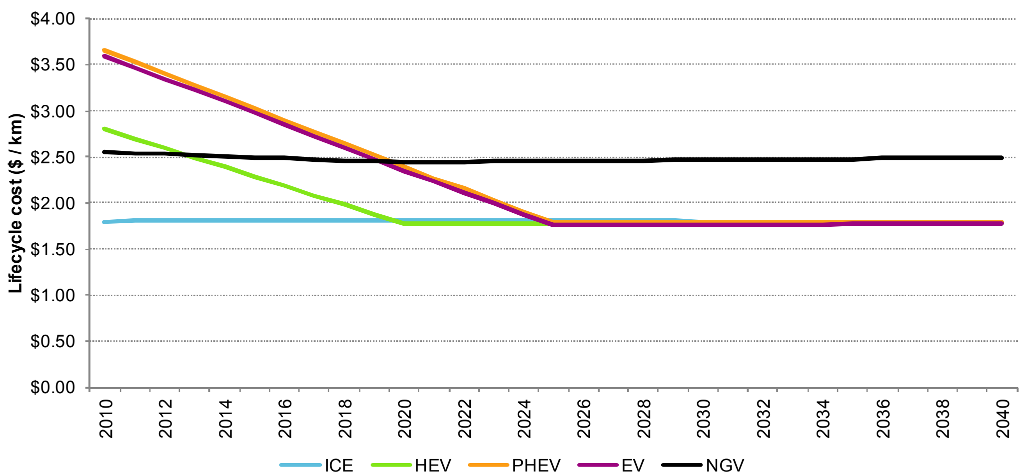
The take up of NGVs is uncertain but, even if it was large, if not anticipated to create any major impacts on the gas markets…

Like EVs, NGVs offer a lower emissions alternative to the traditional vehicles powered by petrol and diesel. NGVs currently have some advantages over EVs. In particular, they are more cost effective for drivers who travel large distances and offer a superior range. Our research suggests that this advantage may diminish over time as the upfront cost of EVs falls, EV vehicle range improves, and gas prices increase relatively more than electricity prices. In addition, NGVs require substantial investment in refuelling. In contrast, there is an existing electricity network which will allow recharging of EVs at home relatively easily. However, both natural gas vehicles and electric vehicles are emerging technologies and there is uncertainty about how both markets will evolve.

Analysis of the lifecycle cost of passenger NGVs shows that only vehicles that travel large distances are likely to be competitive against other passenger ICE vehicles and EVs over the medium to long term. **Figure 8** and **Figure 9** illustrate the range of lifecycle costs ($ / km) for different engine types of a medium sized car with low and high vehicle kilometres travelled respectively. The figures show that for vehicles travelling short distances, NGVs are uncompetitive with ICE for all years, and only competitive with EVs in the short to medium term. After 2020, when the upfront cost of EVs has fallen, NGVs have the highest lifecycle cost. For a vehicle that travels longer distances, NGVs are again only competitive against all technologies in the short to medium term and are only marginally better than ICE vehicles in the short term. Similar results are observed for small and large vehicles.

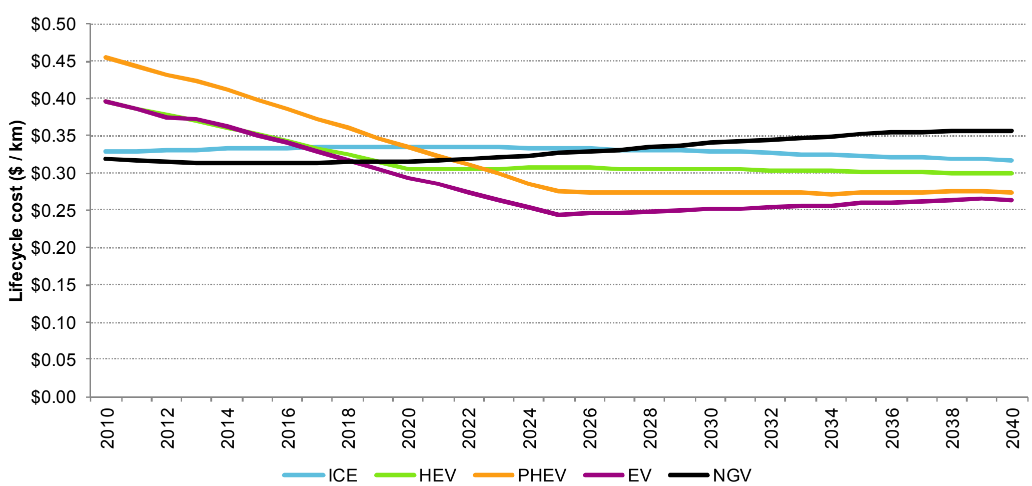
Therefore demand for passenger NGVs is likely to be minimal in all segments of the passenger market except for those that travel large distances, which is consistent with the observed take up of LPG, predominantly in the taxi market. From around 2020, as EV supply constraints are removed, and continued purchase price reductions and efficiency improvements occur, the relative competitiveness of passenger NGVs is likely to be eroded. However, as noted above this is an emerging market and there is uncertainty about how the market will evolve.

Figure 8: Lifecycle cost – medium car, low vehicle kilometres travelled



Source: AECOM

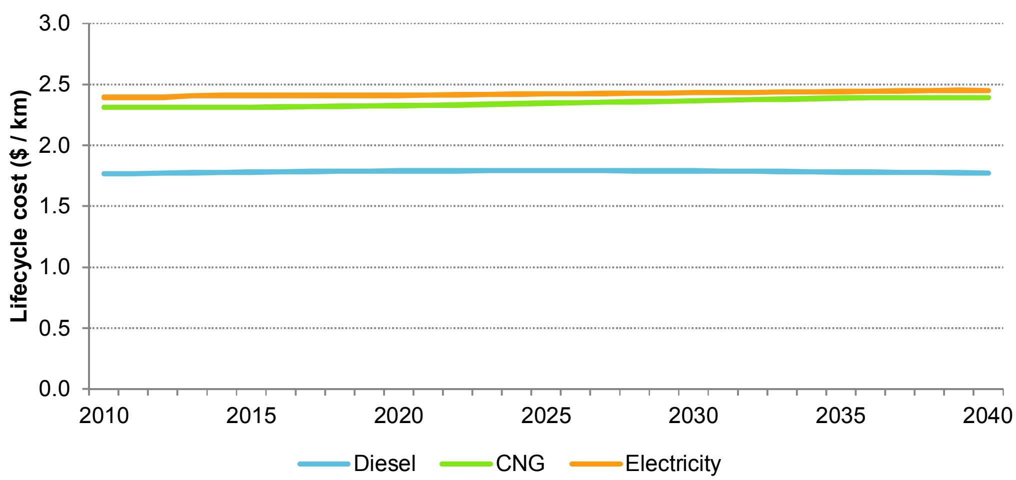
Figure 9: Lifecycle cost – medium car, high VKT



Source: AECOM

Take up of NGVs is more likely in buses and trucks, which typically travel longer distances so benefit more from the reduced operating costs. They can also refuel at a central base or specific locations, making it a viable option to install the refuelling infrastructure. Analysis of the life cycle costs from CNG buses suggests they do not offer significant financial benefits compared with diesel buses (see **Figure 10**). However, most buses are operated by government who will face increasing pressure to reduce their greenhouse gas emissions. Given transport typically accounts for a large proportion of greenhouse gas emissions, it is possible that there will be increased take up of natural gas buses, despite not being financially viable, to assist in meeting greenhouse gas reduction targets.

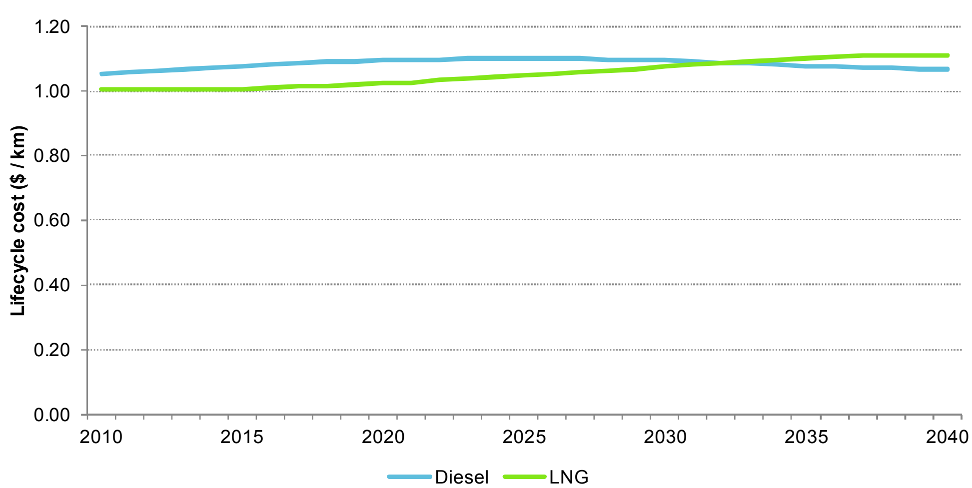
Figure 10: Lifecycle cost of buses



Source: AECOM

Figure 11 shows that the financial viability of liquefied natural gas (LNG) trucks is marginal compared to diesel trucks. Analysis of the lifecycle costs from (LNG) trucks showed that this viability is dependent on the distance travelled. A number of businesses are operating LNG trucks, primarily for long haul freight.

Figure 11: Lifecycle cost of trucks

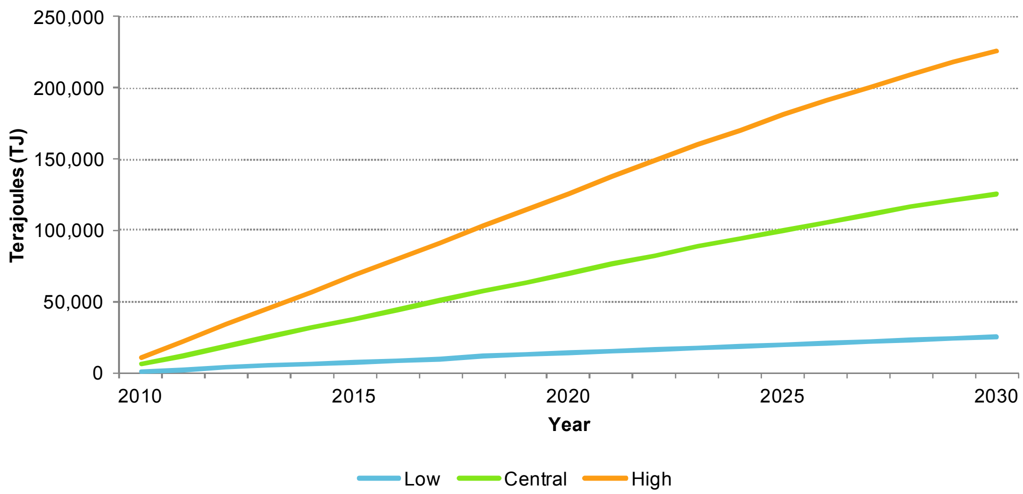


Source: AECOM

As discussed above, on purely financial grounds, take ups of CNG buses and LNG trucks are expected to be low. However there are other factors such as greenhouse gas emissions reductions that mean take up may be higher than otherwise expected. Therefore, for the purposes of considering the impact of NGVs on the gas market, three take up scenarios have been considered as discussed below.

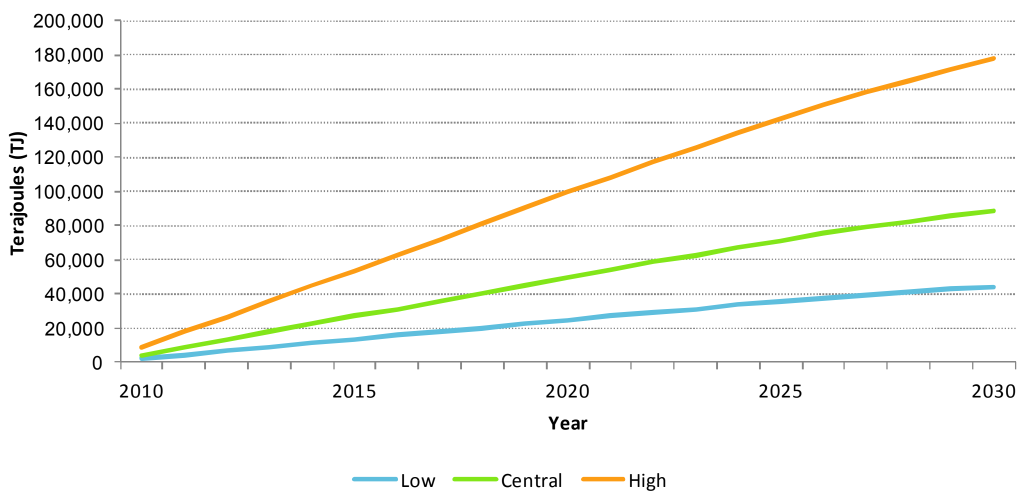
Figure 12 shows gas consumption assuming 10 percent take up, 50 percent take up and 90 percent take up of CNG buses nationally. **Figure 13** shows gas consumption assuming 10 percent take up, 20 percent take up and 40 percent take up for LNG trucks nationally. Under the central scenario, the total gas required would be around 65 PJ (65,000 TJ) of gas by 2015, rising to around 120 PJ of gas by 2020 and around 215 PJ of gas by 2030 in the central case. In the high case volumes could be 120 PJ of gas by 2015, rising to around 225 PJ of gas by 2020 and around 400 PJ of gas by 2030.

Figure 12: CNG bus gas consumption



Source: AECOM

Figure 13: LNG truck gas consumption



Source: AECOM

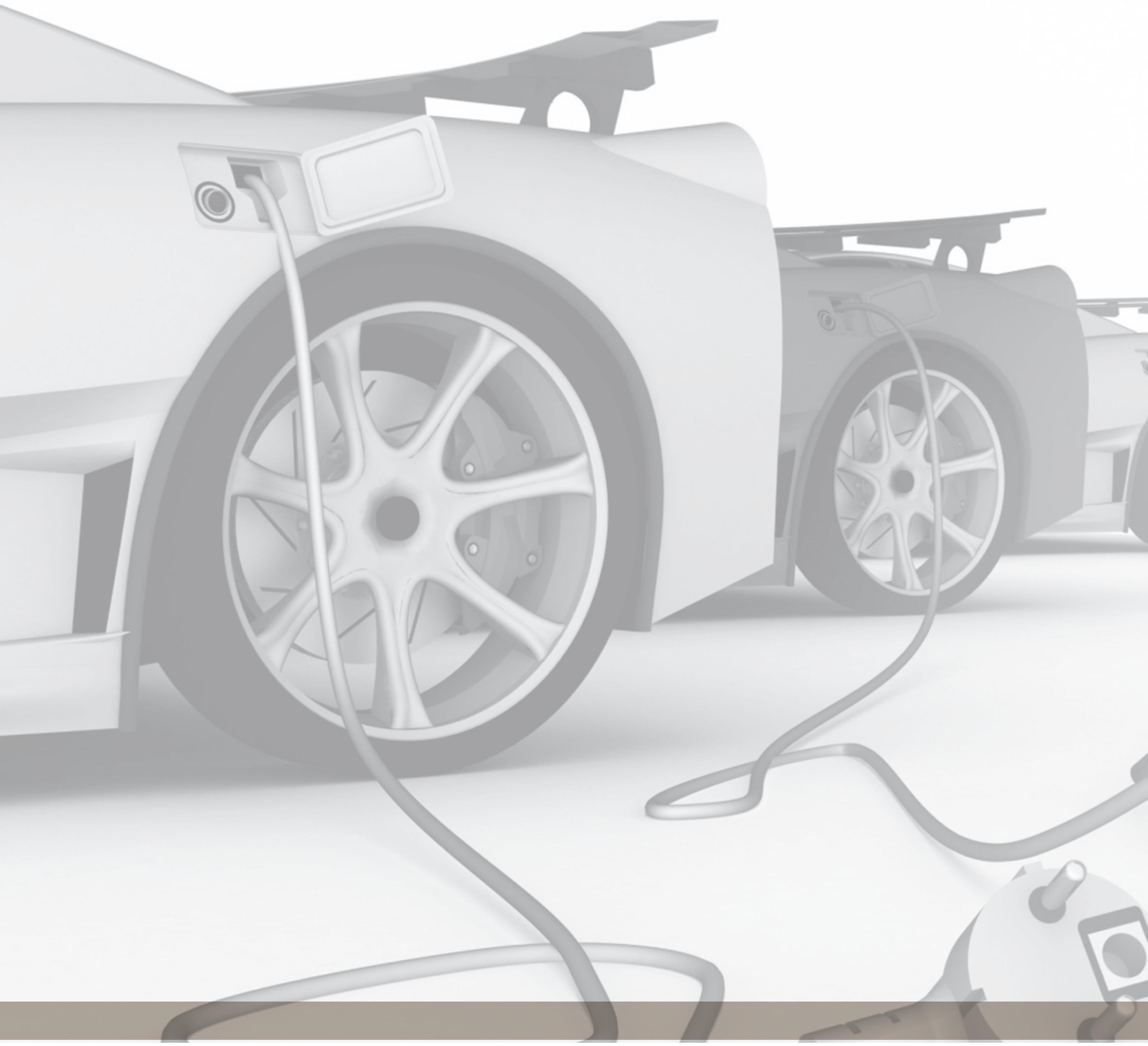
The take up of NGVs is not expected to cause significant issues with eastern or western Australian gas markets because gas networks can generally balance on a daily basis rather than instantaneously, so the timing of charging is not a major issue, and any additional load is likely to be relatively predictable on a daily basis.

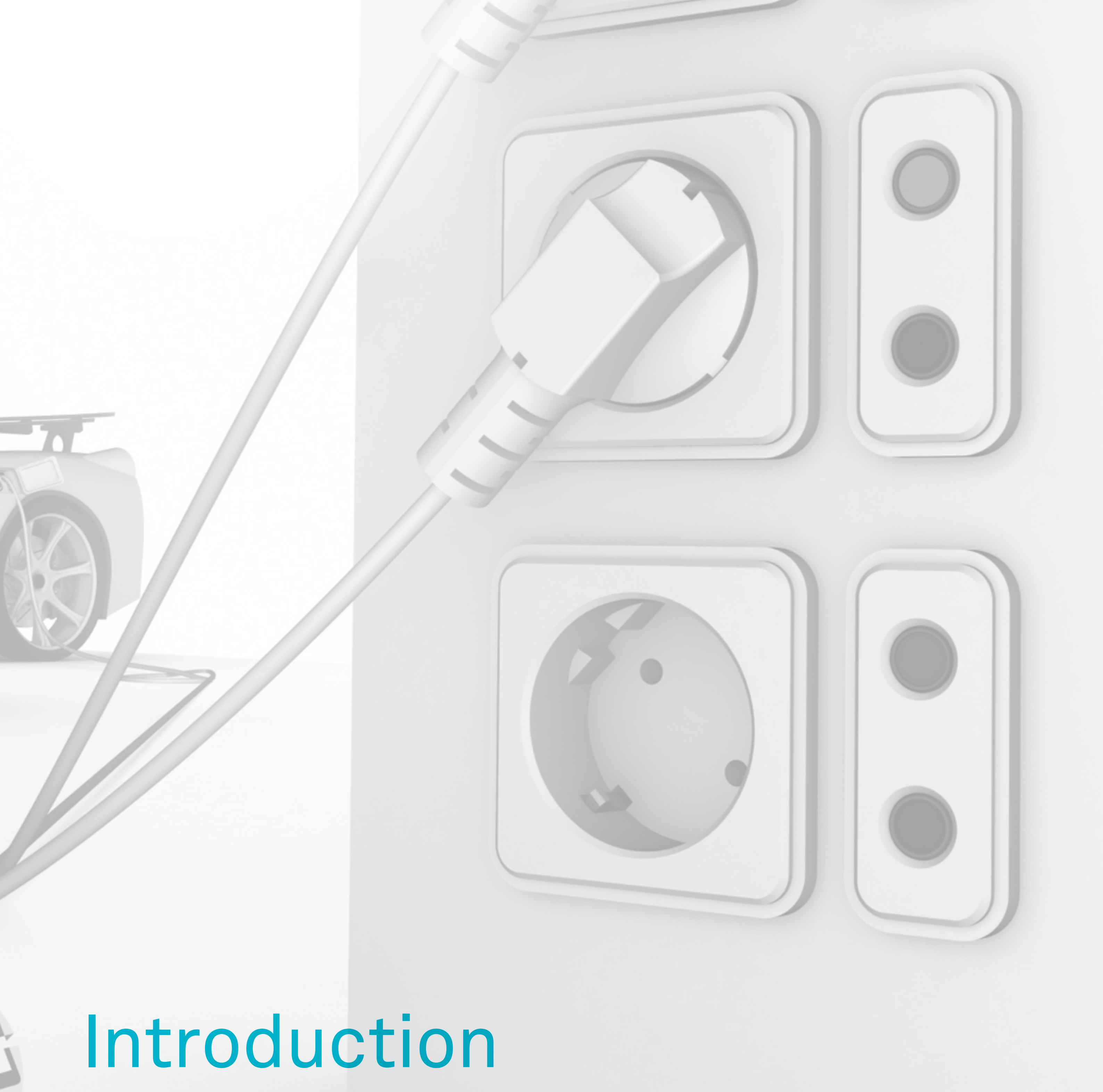
Commercial CNG or LNG vehicles will need specialised refuelling stations, which are likely to be connected either at transmission or sub-transmission level if large quantities of gas are required. Network impacts from commercial refuelling are likely to be small, and presumably customer funded, for the following reasons:

- LNG facilities are likely to require high capacity connections to transmission or sub-transmission pipelines, in order to supply sufficient quantities
- there are already clear price signals for withdrawals through high capacity connections. These signals recognise the need for gas balancing and the scope for line-pack within high capacity gas networks
- facilities will need to provide storage for CNG or LNG prior to distribution to refuelling stations, so should be able to manage their withdrawals to reduce network impacts and costs.

Similarly, refuelling of passenger vehicles fleets will require facilities with special agreements.

Refuelling of passenger vehicles at home can be accommodated within standard supply agreements, provided that the gas distribution network is operating at high pressure. Some older areas are operating are lower pressure to reduce leaks, but over time will be upgraded to enable high pressures.





Introduction

1.0

Introduction

1.1 Introduction

The Australian Energy Market Commission (AEMC) has commissioned AECOM to undertake a study to investigate the costs and benefits of Electric Vehicles (EVs) and Natural Gas Vehicles (NGVs) on the energy markets and to identify the arrangements necessary within the energy markets to facilitate the efficient take up of these vehicles. The AEMC has developed a five step analytical framework to assist with this project, as set out in **Table 3**.

Table 3: Analytical framework for considering the impact of EVs and NGVs on the energy markets

Stage of Approach	Objective
Step 1	Identify and describe the technology (either EV or NGV).
Step 2	Assess the potential take up of EVs and NGVs.
Step 3	Identify the costs and benefits of EVs and NGVs to the energy markets.
Step 4	Identify the appropriate electricity market or natural gas market regulatory arrangements necessary to facilitate the economically efficient take up of EVs and NGVs.
Step 5	Identify the changes required to achieve the appropriate electricity market or natural gas market regulatory arrangements and propose recommendations.

This report addresses steps 2 and 3 with the objective of:

- assessing the potential take up of EVs and NGVs
- identifying the costs and benefits of EVs and NGVs to the energy market.

The analysis in this study is intended to be high level to identify the magnitude of impacts. As such, a number of assumptions and simplifications have been made which do not alter the extent of impacts but mean that this analysis should not be used for any other purpose. In particular, the analysis in **Sections 5.0, 6.0,** and **7.0**, which considers the costs and benefits, is relatively simple and not intended to be a full cost-benefit analysis but instead provide an indication of the likely magnitude of costs and benefits. As such, not all costs and benefits have been quantified. For example, the analysis considers how the costs vary with different incentives to encourage off peak charging (e.g. smart metering) but does not consider the costs of these incentives (e.g smart meters). As such, the analysis in this report may suggest that smart metering reduces the costs of EVs on the electricity market. However, prior to implementing smart metering a full cost-benefit analysis should be undertaken.

Steps 4 and 5 of the AEMC study, which look at identifying appropriate regulatory arrangements, are the subject of a separate report.

1.2 Submissions

This report draws on submissions made to the AEMC in both their Approach Paper (released in September 2011) and their Issues Paper (released in January 2012). A full list of submissions made is listed with the references in **Section 11.0**. AECOM have endeavoured to consider all submissions and where appropriate have updated the study to reflect better information. Appendix B summarises AECOM’s response to the key comments raised in the submissions.

1.3 Study Area

This study considers the impact on the National Electricity Market (NEM) and the South West Interconnected System (SWIS). As such, the study area comprises Queensland, New South Wales, Australian Capital Territory, Victoria, Tasmania, South Australia and Western Australia.

1.4 Technology

Multiple vehicle configurations are possible using electric, gas and combustion components. This study focuses on five main types of technology namely: internal combustion engine (ICE); hybrid electric vehicles (HEV); plug-in hybrid electric vehicles (PHEV); battery electric vehicles (BEV); and natural gas vehicles (NGV). These are described in **Table 4**. The focus of this study is on EVs that may be charged externally by the electricity grid, namely PHEVs and BEVs – denoted EVs, and on NGVs.

Table 4: Engine configurations

Configuration	Description
Internal Combustion Engine vehicle (ICE)	Standard Internal Combustion Engine vehicle.
Hybrid electric vehicles (HEV)	HEVs combine both an internal combustion engine with an electric engine, with electrical energy stored in batteries. Vehicle propulsion is a mix of the ICE and electric powertrains typically dependent on vehicle speed (urban/non-urban use). Hybrids are more fuel efficient than regular ICE vehicles as they take advantage of the complementary power generating characteristics of the two technologies.
Plug-in hybrid electric vehicles (PHEV)	PHEVs are similar to regular hybrids in that they combine the use of combustion and electric motors, however PHEVs are capable of being recharged by plugging in to the electricity grid. Charging can be achieved through a conventional household wall socket and at charging stations similar to existing petrol stations. The batteries in a PHEV are typically larger than those in a hybrid leading to a greater all-electric range that is sufficient for average metropolitan use. The trade off for larger batteries and greater range is increased battery cost, size and weight. The ICE is used to extend driving range beyond battery capacity for longer distances and to recharge the battery itself.
Battery Electric Vehicles (BEV)	Pure battery electric vehicles (BEVs) are powered only by electricity stored in batteries. BEVs face similar limitations as hybrids and PHEVs due to the need for batteries. In BEVs, battery shortcomings are highlighted as there is no ICE to boost range and acceleration, for example. To increase range, more or larger batteries are required with costs and weight also increasing. Improvements in battery technology will gradually address these issues.
Natural Gas Vehicle (NGV)	This study defines a Natural Gas Vehicle as either a vehicle that uses compressed natural gas (CNG) or liquefied natural gas (LNG). NGVs tend to be used more in commercial vehicles than passenger vehicles.
Compressed Natural Gas (CNG)	Vehicles that use CNG refuel their vehicles through the gas distribution network so can recharge in their base location (with an appropriate charging unit) or at a commercial refuelling station. As such, CNG vehicles typically include fleets of buses and other vehicles that operate on a return to base cycle within a limited range.
Liquefied Natural Gas (LNG)	LNG means gas that is in liquid form and requires low temperatures. LNG vehicles are typically heavy duty vehicles where LNG is a substitute for diesel.

Source: AECOM

1.5 Report Structure

The remainder of the report is structured as follows:

Chapter 2.0 provides background information on the Australian vehicle market.

Chapter 3.0 sets out our assumptions and estimates for the take up of EVs.

Chapter 4.0 sets out our assumptions on charging behaviour.

Chapter 5.0 looks at the potential costs EVs may impose on the electricity market.

Chapter 6.0 looks at the potential benefits EVs may have for the electricity market.

Chapter 7.0 looks specifically at vehicle-to-grid.

Chapter 8.0 sets out our assumptions and estimates for the take up of NGVs.

Chapter 9.0 looks at the impact of NGVS on the gas market.

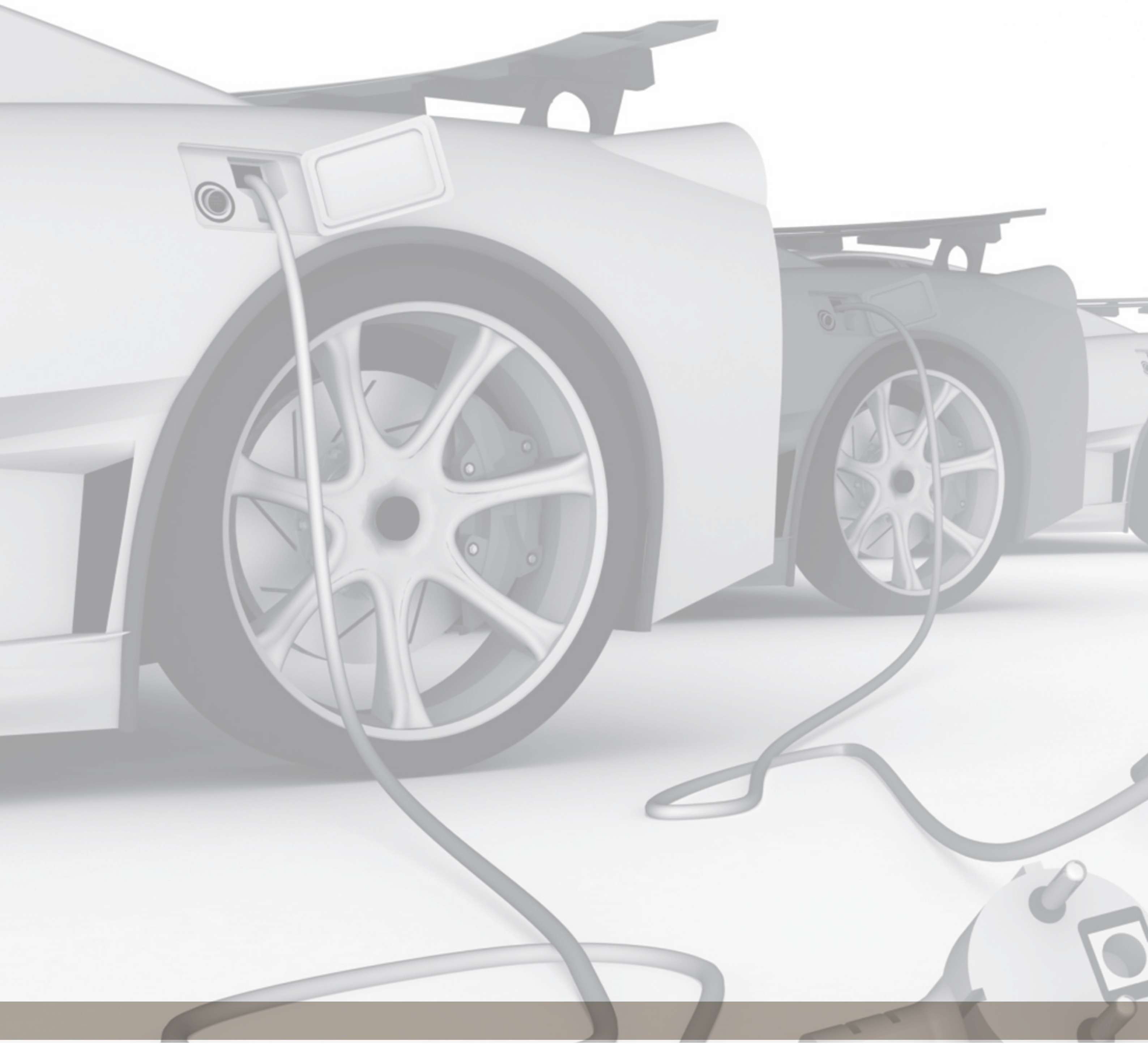
Chapter 11.0 provides references used in this study.

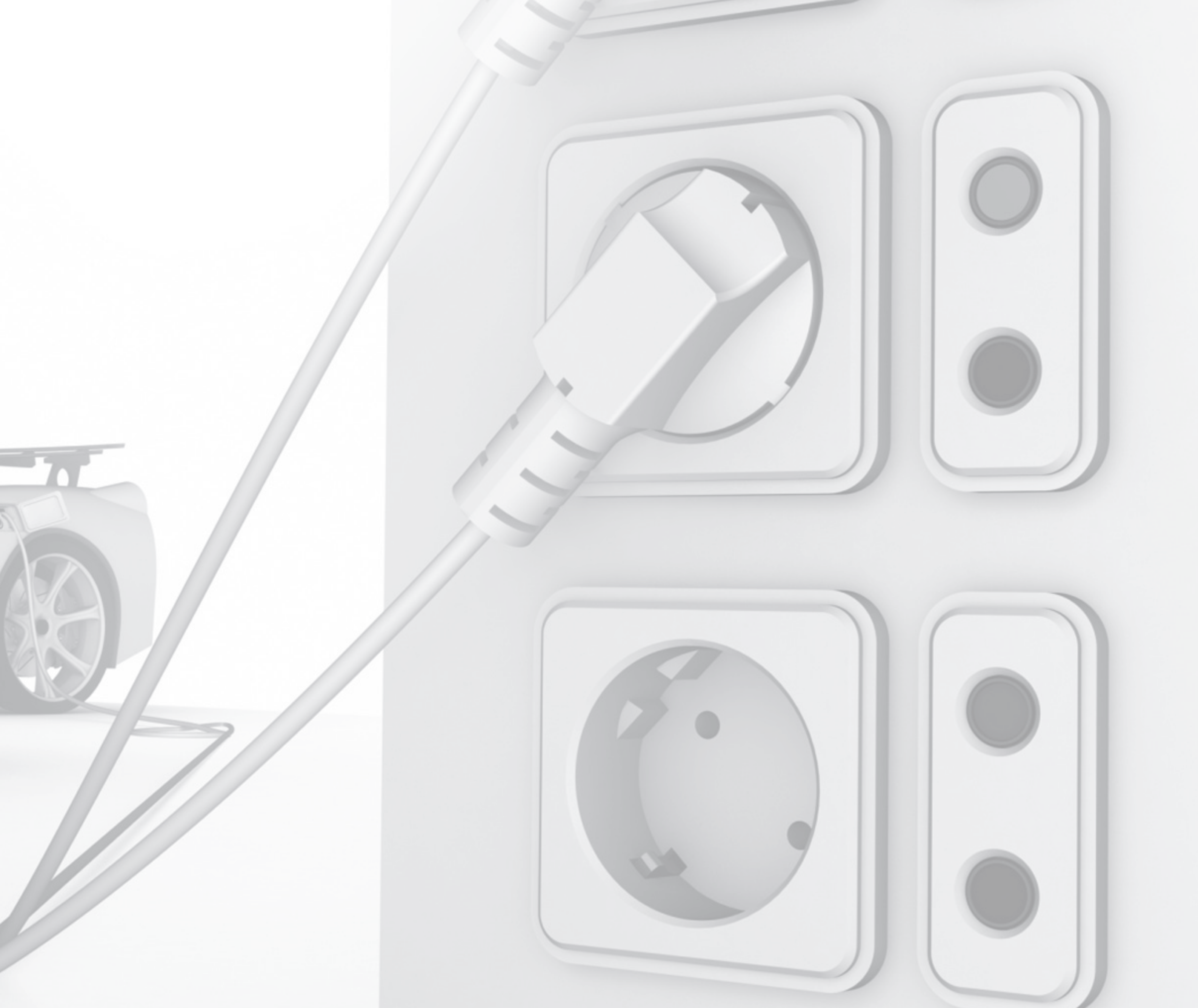
As requested by AEMC, EVs and NGVs are discussed separately – **chapters 3.0** to **7.0** discuss EVs and c**hapters 8.0** and **9.0** discuss NGVs.

1.6 Acronyms

ABS	Australian bureau of statistics	kW	Kilowatt
AC	Alternating current	kWh	Kilowatt-hour
A	Ampere	LCV	Light commercial vehicle
AEO	Annual Energy Outlook	LNG	Liquefied natural gas
AEMC	Australian Energy Market Commission	LGC	Large-scale generation certificates
AEMO	Australian Energy Market Operator	LPG	Liquid propane gas
AER	Australian Energy Regulator	LRET	Large-scale Renewable Energy Target
ATO	Australian Tax Office	LV	Low voltage
BEV	Battery electric vehicle	MJ	Megajoule
CO_2-e	Carbon dioxide equivalent	MW	Megawatt
CPRS	Carbon pollution reduction scheme	MWh	Megawatt hour
CSIRO	Commonwealth Scientific and Industrial Research Organisation	NEM	National Energy Market
CNG	Compressed natural gas	NGV	Natural Gas Vehicle
DoD	Depth of discharge	NSLP	Net System Load Profile
DC	Direct current	ORER	Office of the Renewable Energy Regulator
DNSP	Distribution Network Service Provider	PoE	Probability of exceedance
EVSE	Electric Vehicle Supply Equipment	PJ	Petajoule
EV	Electric Vehicle	PHEV	Plug-in hybrid electric vehicle
EIA	Energy Information Administration	REC	Renewable Energy Certificate
ENA	Energy Networks Association	SCER	Standing Council on Energy and Resources
FCAS	Frequency Control Ancillary Services	SoO	Statement of Opportunities
GMLG	Gas Market Leaders Group	SWIS	South West Interconnected System

GJ	Gigajoule	TJ	Terajoule
GW	Gigawatt	ToU	Time of use
GWh	Gigawatt hour	TNSP	Transmission Network Service Provider
GST	Goods and Services Tax	U.S.	United States
Hz	Hertz	VKT	Vehicle kilometres travelled
HEV	Hybrid electric vehicle	V2G	Vehicle-to-grid
IANGV	International Association of Natural Gas Vehicles	V2H	Vehicle-to-home
ICE	Internal combustion engine	V	Volt
IEA	International Energy Agency		





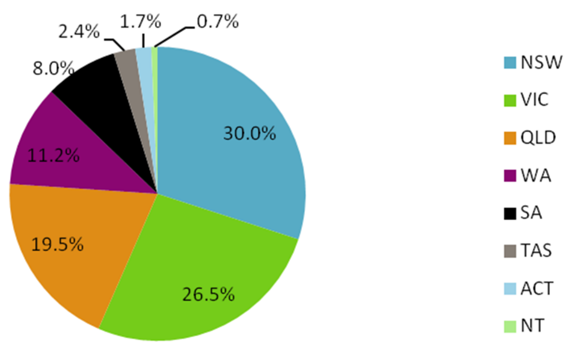
Background to the Australian Vehicle Market

2.0

Background to the Australian Vehicle Market

The total number of vehicles on Australia's roads in 2011 is estimated to be over 16 million (ABS 2011). **Figure 14** show that New South Wales has the highest number of vehicles on the road in 2011, with over 4.7 million. Together, New South Wales, Victoria and Queensland have over three quarters of the total number of vehicles. In 2010, more than one million new vehicles were sold in Australia, with around 820,000 being passenger vehicle sales.

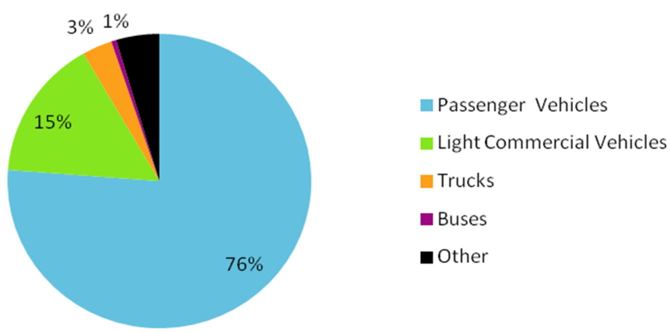
Figure 14: Passenger vehicles in Australia in 2011



Source: ABS (2011)

Figure 15 show that 76 percent of vehicles are passenger vehicles, 15 percent light commercial vehicles and around 3 percent are trucks.

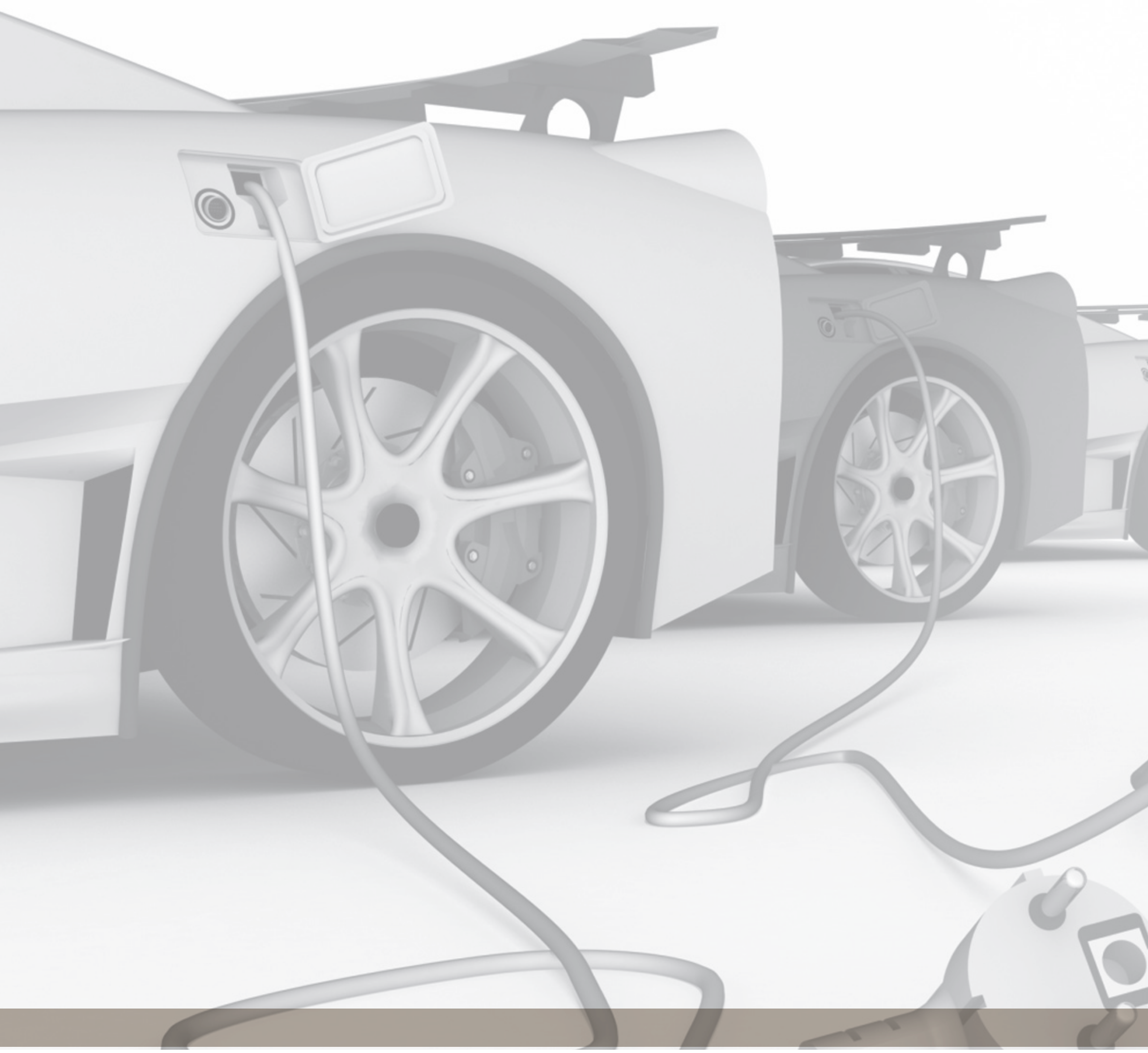
Figure 15: Vehicle types in Australia in 2011

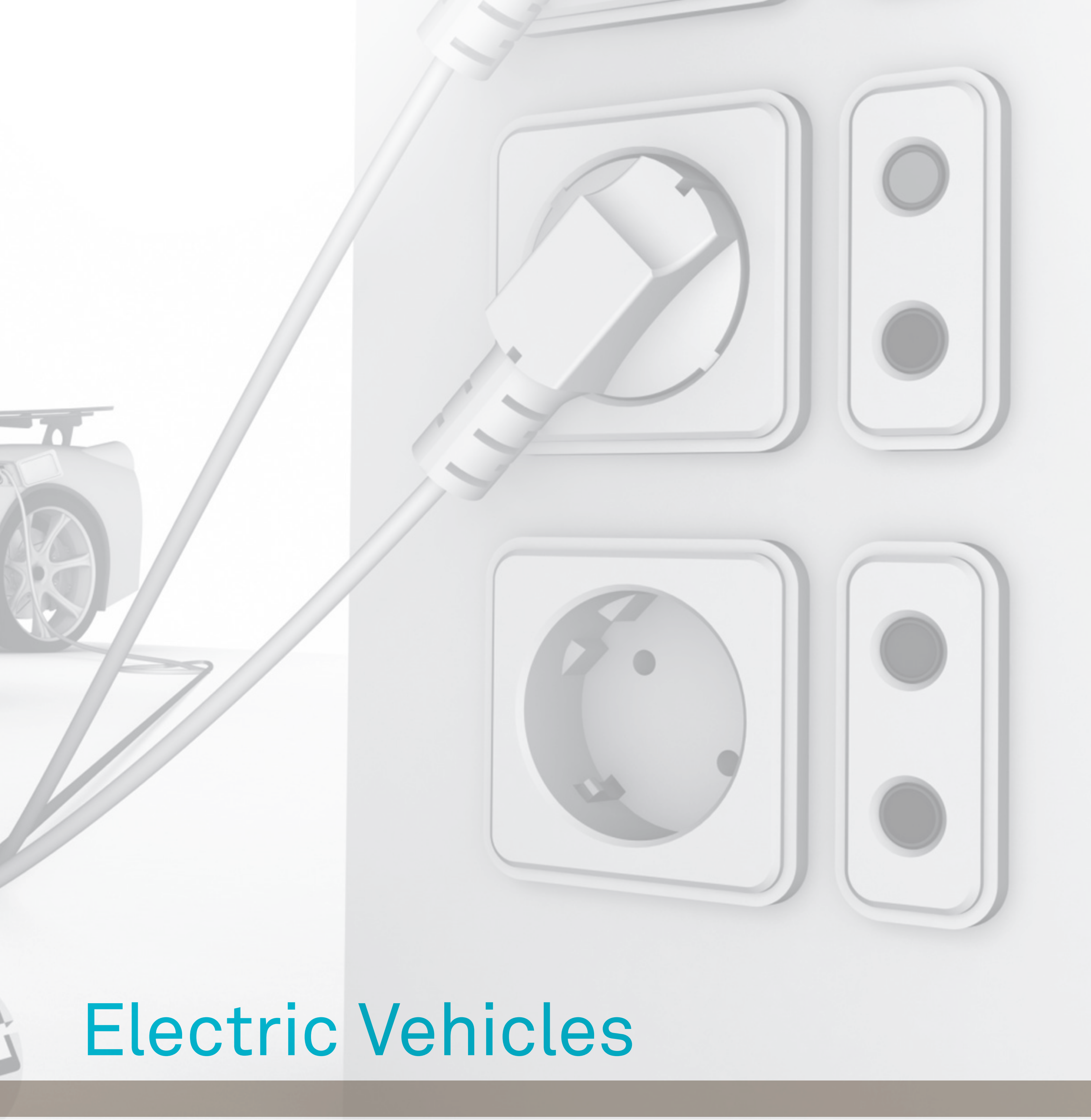


Source: ABS (2011)

Australian passenger vehicles are typically driven for around 12 to 14 kilometres per day, depending on which state they are from. Buses travel an average of around 30 kilometres per day, articulated trucks around 70 kilometres per day and rigid trucks around 20 kilometres per day (ABS 2010b). [1]

[1] An articulated truck consists of a prime mover and trailer together. A rigid truck has the prime mover and trailer connected without a pivot point.





Electric Vehicles

3.0

Electric Vehicles

3.1 Introduction

Assessing the potential take up in demand for EVs is necessary to determine the impact that EVs will have on the electricity markets. The take up of these EVs is dependent on a number of factors including their prices relative to ICEs, relative running costs including fuel and maintenance and the availability of charging and distribution infrastructure. This chapter provides an outline of AECOM's methodology for estimating take up, presents key assumptions and discusses the results.

3.2 Overview of methodology

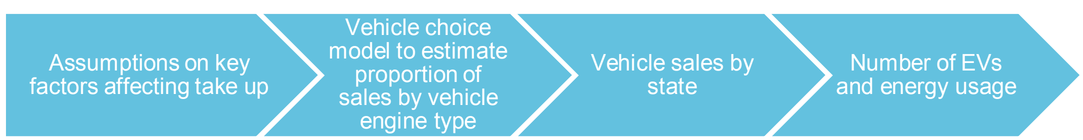
AECOM has previously developed a bespoke passenger and light commercial vehicle (LCV) choice model that estimates the potential take up of EVs through its '*Economic Viability of Electric Vehicles*' studies in New South Wales and Victoria. The studies are publicly available:

- Victorian Study: AECOM (2011) available at: http://www.transport.vic.gov.au/__data/assets/pdf_file/0010/33499/Economic-Viability-of-Electric-Vehicles-in-Victoria-rev-C-final-issued.pdf
- NSW Study: AECOM (2009) available at: http://www.environment.nsw.gov.au/resources/climatechange/ElectricVehiclesReport.pdf

This current study draws substantially on the approach and assumptions of the previous studies, as only high level estimates of vehicle sales for each state and territory were required in order to establish the magnitude of energy consumption and vehicle sales for further analysis.

AECOM's model estimates the take up of passenger vehicles, LCVs and taxis based on a set of assumptions related to vehicle prices, operating costs, charging infrastructure, available supply and so on. These assumptions are input into a vehicle choice model that estimates the proportion of new vehicle sales by engine type (ICE, HEV, PHEV, BEV). Estimates are established for each state.

Figure 16: Overview of approach to estimating take up of electric vehicles



Many studies of this type do not estimate take up of different engine types, but rather make assumptions based on experience elsewhere. In our previous studies, AECOM directly estimated take up of EVs for two reasons. Firstly, as this is a new market, there is not a lot of information on past experience from which to draw meaningful assumptions about the future of EVs in Australia.

Secondly, by directly estimating take-up it is possible to consider the impact of various potential sensitivities around prices (such as electricity price, fuel price, vehicle price) and how these affect take up.

Consumers consider a number of factors when deciding which vehicle to purchase. Whilst the financial cost plays a significant role, the decision of what vehicle to purchase is influenced by consumer preferences. The approach used in this study tries to capture these preferences. After an extensive literature review on the factors affecting the decision to purchase a vehicle, AECOM developed a vehicle choice model which takes into account the vehicle purchase cost, fuel cost, vehicle range, emissions, availability of refuelling / charging infrastructure and multi-fuel bonus.2 For full details of the parameters used in AECOM's vehicle choice model, please see our previous studies (AECOM, 2011; 2009). AECOM's vehicle choice model calculates the proportions of vehicle sales by engine type, which are applied to forecasts of new vehicle sales to obtain number of vehicles and energy usage.3 AECOM's vehicle choice model is based on the best information currently available and is designed to model the mainstream market segment which will account for the biggest impact on the electricity market. However, as highlighted in Verdant Vision's (2012) submission, early adopters may have different preferences to the mainstream.

3.3 Assumptions

This study makes assumptions about key factors that affect the take up of EVs. As highlighted in many of the submissions (including Energex, 2012, p2, the Australian Electric Vehicle Association, 2012, and Tasmanian Department of Infrastructure Energy and Resources,2012, p5) there are inherent uncertainties in making forward estimates, so it is important to understand the likely range of take up and the key influencing factors. Therefore, this study has developed scenarios around the key factors identified as affecting the take up of EVs. Three scenarios were modelled:

1) *Central scenario*: represents a likely take up scenario given currently available information and central assumptions on key factors.
2) *High scenario*: represents an upper bound on take up if all of the key factors are favourable to supporting the take up of EVs.
3) *Low scenario*: represents a lower bound on take up if all of the key factors are unfavourable to supporting the take up of EVs.

The following sections provide a high level summary of key assumptions. Given that the primary objective of this study is to identify the impacts of EVs on the electricity market, available New South Wales and Victorian data were used as a proxy for the other states and territories in the modelling. Specifically, this relates to market shares of engine size for passenger vehicles, annual vehicle kilometres travelled and the share of passenger vehicle segments by vehicle kilometres travelled (VKT) and engine size. Further detail on assumptions is provided in AECOM (2011).

3.3.1 Key assumptions

3.3.1.1 General assumptions

The estimates of EVs focus on passenger vehicles and light commercial vehicles, which together account for 92 percent of all vehicles in Australia. Whilst some electric buses and trucks do exist, they are relatively more expensive due to the weight to battery ratio and, purely on a financial basis, are unlikely to see significant take up in the next 10 to 15 years until battery prices significantly reduce. However, most buses are operated by government, which will face increasing pressure to reduce their greenhouse gas emissions so there could be increased take up of electric buses, despite not being financially viable, to assist in meeting greenhouse gas reduction targets. Even if there is a significant take up of electric trucks and buses in the short to medium term, this is not expected to have a significant impact on the electricity market. The charging of electric buses and trucks will be relatively predictable and can occur in off peak periods. Also, charging will occur through specialised commercial charging infrastructure with any significant costs to the national electricity market being borne by the commercial operator at the time of connection. As such, the rest of this analysis of EVs focuses on passenger and light commercial vehicles, which are expected to have the largest take up and the biggest impact on the electricity market.

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[2] A synthetic multinomial logit choice model was developed to forecast future market shares for ICE, HEV, PHEV and BEV. A multinomial logit model is called synthetic when elasticities are imposed on, rather than derived from, the choice model and where constants are calibrated to better reflect current market shares of existing vehicle classes.

[3] This means that factors such as how many vehicles a household has access to are not considered explicitly but are considered through the vehicle choice parameters such as vehicle range and charging infrastructure (which will be more important for households with one vehicle).

This study does not consider other EVs such as electric golf buggies and electric bikes where additional take up is expected to be smaller in magnitude than in motor vehicles and the impact on the electricity market is likely to be smaller because the distances travelled will typically be less and charging behaviour is likely to be more predictable and easier to incentivise to off-peak charging. This study has also not considered take up of hydrogen vehicles. Based on our research of current literature, hydrogen vehicles are not considered to be commercially viable within the study timeframe. Consequently, we have excluded them from the vehicle choice model.

Fleet sales are not considered separately and this study assumes the decision about which vehicle to purchase remains a consumer choice and the majority of people driving fleet vehicles will take their vehicle home at the end of the day. Private fleets are more likely to place a higher weight on the financial viability of EVs which may result in delayed take up of EVs until the upfront cost reduces. However, a large proportion of fleet vehicles are likely to be government owned, which will place a higher weight on the environmental benefits of EVs. Most fleet vehicles typically drive further than household vehicles so will benefit more from the fuel cost savings of EVs. Some of the proposed business models, which lease the EV to reduce the upfront vehicle purchase price, may result in higher take up for fleet vehicles in early years as they are likely to benefit more from the fuel cost savings. As our vehicle choice model estimates take up of EVs for different vehicle sizes and distances travelled, fleet vehicles will be captured under these categories.

As highlighted in the submission from the Centre for Energy and Environmental Markets (Centre for Energy and Environmental Markets, 2012, p2) it is important to recognise that the energy market arrangements can play a key role in facilitating or hindering deployment of EVs. This analysis assumes markets support the efficient take up of EVs.

3.3.1.2 Vehicle sales

As discussed in **Section 2.0**, there are around 820,000 passenger vehicles sold in Australia each year, with around 90 percent of these sold within the NEM region and around 10 percent in WA. Whilst vehicle sales vary year by year, there has been a long term trend for annual growth of around 1 to 2.5 percent depending on the state. **Table 5** sets out our assumptions on future growth in vehicle sales. The central case is based on trend annual growth; the low scenario assumes a trend for fewer vehicles per household so the average long term trend decreases by 0.5 percent in each state relative to the central case scenario; and the high scenario assumes a trend for more vehicles per household so the average long term trend increases by 0.5 percent in each state relative to the central case scenario.

Overall sales of passenger vehicles were segmented by vehicle size and average annual kilometres travelled (a total of nine segments) to produce estimated sales for each segment. This is because take up is expected to vary by vehicle size and distance travelled due to disproportionally higher costs of larger vehicles in early years and the fact that people travelling longer distances will benefit more from the fuel efficiency savings.

Table 5: Vehicle sales

	VIC	NSW	ACT	QLD	TAS	SA	WA
2010 passenger sales	232,800	258,300	14,100	157,400	14,800	52,600	90,400
Annual growth							
Low	1.0%	0.5%	0.5%	2.0%	1.0%	1.5%	2.0%
Central	1.5%	1.0%	1.0%	2.5%	1.5%	2.0%	2.5%
High	2.0%	1.5%	1.5%	3.0%	2.0%	2.5%	3.0%

Source: AECOM based on ABS' historic Motor Vehicle Census data

3.3.1.3 Vehicle price

In AECOM's previous studies, new vehicle prices were estimated from a survey of global EV products. An equivalent ICE vehicle was used for the price of ICE vehicles to ensure a consistent comparison.

A review of the price assumptions from AECOM (2011) was conducted for the present study to check if there had been significant changes in vehicle prices. Whilst there seem to be changes in the world supply outlook for non-ICEs, the overall findings suggested that vehicle prices had not changed greatly from the previous assumptions. Therefore this study has retained the vehicle purchase price assumptions presented in AECOM (2011). The vehicle price of an EV currently ranges from around $40,000 to $100,000 depending on the vehicle size. Price premiums vary with the engine type and vehicle size, with the premium for PHEVs and BEVs ranging from $21,000 to $50,000 representing the increase in battery requirements for larger cars.

The previous studies also revealed that, for the cars available in Australia (HEVs), there is a premium of around $10,000 over US prices. This likely reflects the supply constraints for non-ICE vehicles in Australia. It has been assumed that there will be similar supply constraints for PHEVs and BEVs. Some of the business models being proposed include leasing arrangements that reduce the upfront purchase costs of an EV. This is covered in our high take up scenario where EVs reach price parity with ICE vehicles more quickly. **Table 6** summarises prices assumed for different engine types and sizes.

Table 6: Vehicle prices in 2010 by size and configuration

Car size	ICE*	HEV	PHEV	BEV
Price premium relative to ICE				
Passenger Small	N/A	$17,000	$21,000	$21,000
Passenger Medium	N/A	$17,000	$30,000	$30,000
Passenger Large	N/A	$18,000	$50,000	$50,000
Light Commercial Vehicle	N/A	$20,000	$64,000	$64,000
Taxi	N/A	$18,000	$50,000	$50,000
New vehicle price				
Passenger Small	$20,000	$37,000	$41,000	$41,000
Passenger Medium	$27,000	$44,000	$57,000	$57,000
Passenger Large	$48,000	$66,000	$98,000	$98,000
Light Commercial Vehicle	$40,000	$60,000	$104,000	$104,000
Taxi	$48,000	$66,000	$98,000	$98,000
Price parity with ICE				
Year	N/A	2020	2025	2025

Source: AECOM and Dr. Andrew Simpson. * An equivalent ICE vehicle was used for the price of ICE vehicles to ensure a consistent comparison.

3.3.1.4 Vehicle price reductions

The future cost reduction of battery packs will play a significant role in bringing down the price of EVs alongside general improvements in drive train technology. However, there is no consensus about the future trajectory of the battery cost curve; with estimates of battery price in 2020 ranging from $250/kWh to $1105/kWh.[4] Verdant's submission suggests prices at the lower end of this range.

There has been a lot of funding in recent years into battery research to reduce costs, reduce weight and improve life. A recent study by the US Department of Energy (2010) on the impact of US investment in batteries estimated that battery prices will fall by 70 percent by 2015, a further 50 percent by 2020, and a further 30 percent by 2030 significantly reducing the purchase price of EVs.

[4] See AECOM (2010), Section 2.6.1 for details.

This highlights how quickly battery performance and prices could change, particularly with increased investment, and the importance of monitoring the battery industry.

Assumptions on when price parity with ICE vehicles is achieved have been retained from the Victorian study (AECOM, 2011) which was informed by a literature review and consultation with industry. The central scenario assumes HEVs will achieve price parity in 2020, PHEVs and BEVs achieve price parity in 2025. The low and high scenarios assume price parity for all electric vehicle variants in 2030 and 2020 respectively.

3.3.1.5 Supply constraints

Whilst a large number of electric vehicle models are expected to be launched in the near future, there is some uncertainty as to how many will be produced and whether this will be sufficient to meet consumer demand.

World supply estimations for BEVs and PHEVs are constantly being revised as new production plans are announced by manufacturers. In AECOM's 2009 and 2011 studies, global production volume was expected to approach one million units by 2015 based on announcements made in the automotive media. A similar projection has been made by a June 2011 publication by the International Energy Agency (IEA), where 0.9 million units of BEVs and PHEVs are expected to be in production by 2015 and about 1.4 million units per year by 2020 (IEA, 2011).

There is a currently a large degree of uncertainty around world supply constraints for EVs, and given this uncertainty the present study has adopted the same supply constraints assumption as the two previous AECOM studies for HEVs and BEVs, but with sensitivity around the timing of the supply constraint in the different take up scenarios. The assumptions for PHEVs are assumed to be equal to those for BEVs.

Whilst Australia has traditionally not been seen as a key market, it is possible that electric vehicle manufacturers will focus their available supply and marketing efforts on countries with suitable infrastructure, consumer preference and driving habits rather than simply distribute EVs to different markets in the same proportions as conventional vehicles. In addition, companies like Better Place have made agreements with vehicle manufacturers to ensure the availability of vehicles in locations where infrastructure investments will be made. As such, our high take up scenario has supply constraints ended by 2015. The submission by Alternative Technology Association supports the assumption that there will be supply constraints until at least 2015 (Alternative Technology Association, 2012, p2).

Table 7 shows the vehicle supply parameters applied in this study.

Table 7: Vehicle supply parameters

Parameter	HEV	PHEV	BEV
Australian proportion of global market	1%	1%	1%
Year of first availability	2009	2012	2012
End of supply constraint			
- Low	2025	2025	2025
- Central	2015	2020	2020
- High	2015	2015	2015
Initial world supply	1,000,000	500,000	500,000
Annual growth in supply:			
- To 2015	35%	40%	40%
- From 2016 onwards	35%	30%	30%

Source: AECOM and Dr. Andrew Simpson based on industry consultation

3.3.1.6 Fuel and electricity prices

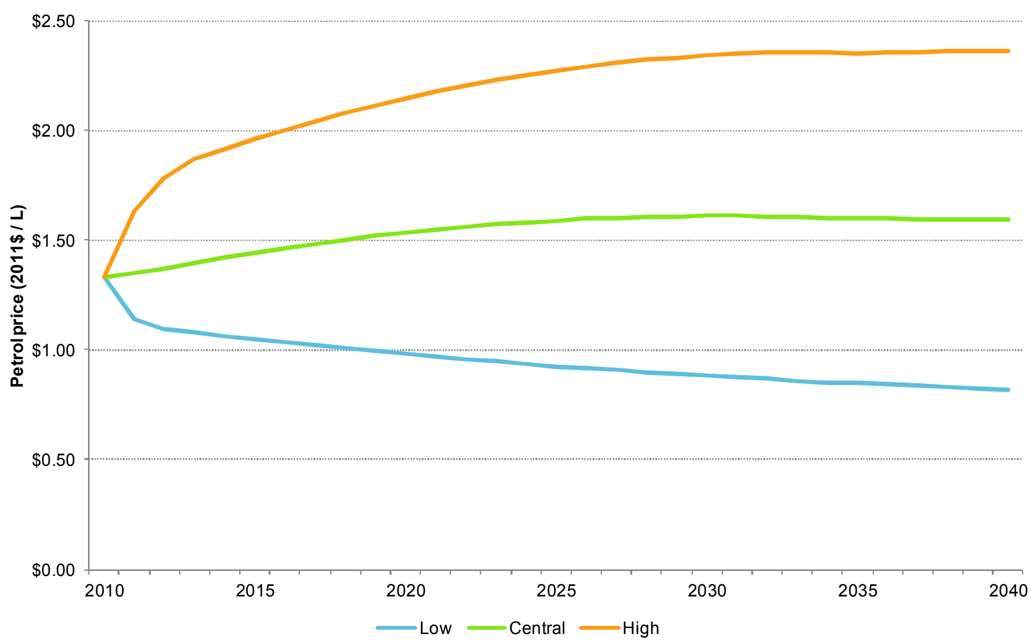
One of the major advantages of EVs over ICE vehicles is the potential cost savings from using electricity instead of petrol or diesel. This section summarises our assumptions on future prices of fuel and electricity.

Crude oil based prices

In order to estimate Australian retail petrol prices, this study adopts the methodology presented in Gargett (2011) that converts global crude oil prices into Australian retail pump prices. Crude oil price projections have been taken from the US Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2011 reference case, high price and low price scenarios (AEO, 2011).

These fuel prices will be used in the low, central and high scenarios. The carbon price does not apply to passenger vehicles and light transport vehicles, and therefore carbon pricing on fuel has not been included in this analysis.

Figure 17: Petrol prices



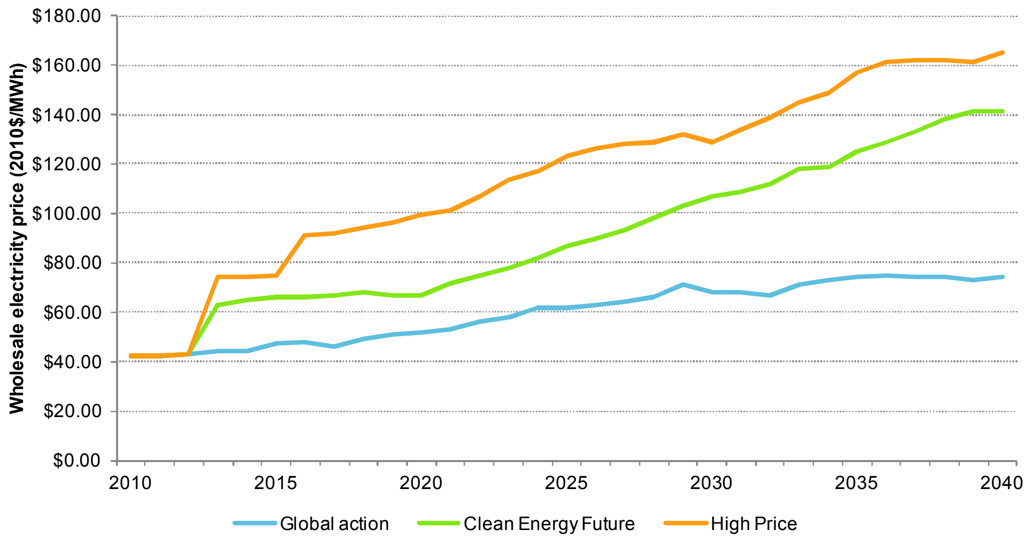
Source: AECOM

Electricity

Electricity prices paid by consumers are modelled as the sum of wholesale electricity prices, network costs and retail margins, and any carbon pricing component (selected through the carbon emission policy options).

Assumptions on future electricity prices are drawn from the *Strong growth low pollution: modelling a carbon price* report released by the Australian Treasury in July 2011, which takes into consideration the most up-to-date carbon pricing scenarios for their modelling. For the central take up scenario the 'Clean Energy Future' electricity projection has been adopted; for the low and high take up scenarios the 'High Price' and 'Global Action' electricity projections were adopted respectively.[5] **Figure 18** shows the electricity prices used in this analysis.

Figure 18: Wholesale electricity prices

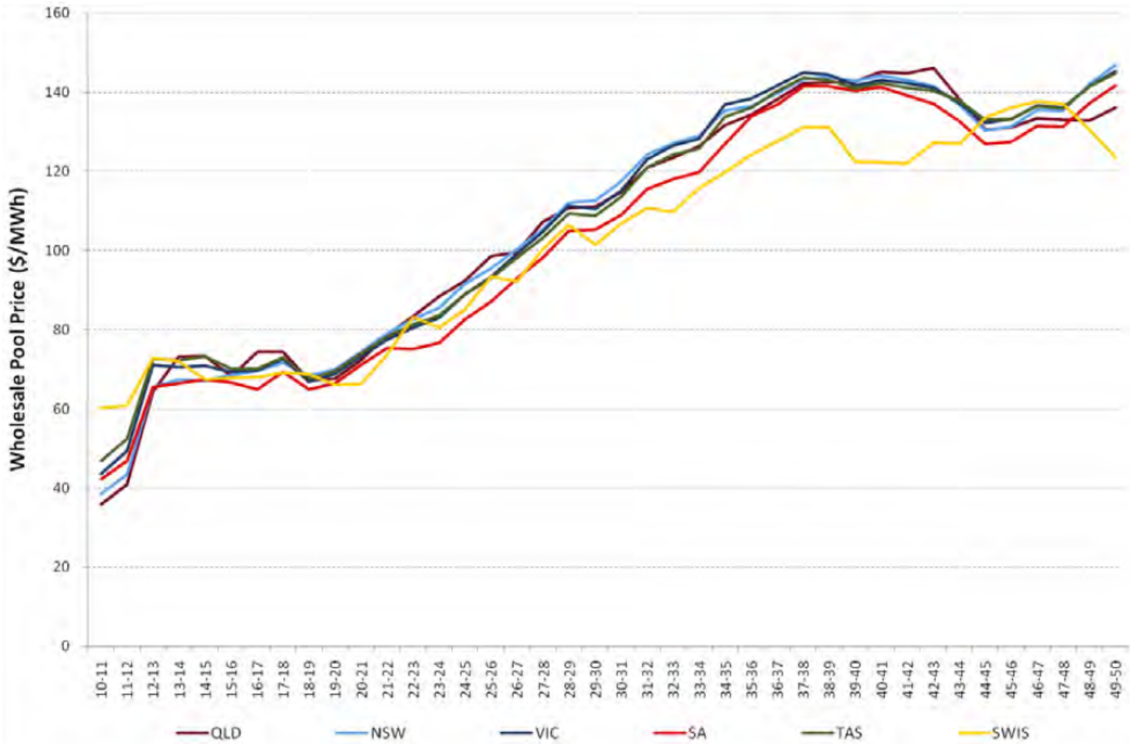


Source: Treasury (2011)

This study uses one electricity price for all states and territories. In practice, the wholesale price of electricity may vary slightly between states reflecting the cost of interconnections between states, in addition to the loads and trading behaviour of the market participants. For example, **Figure 19** shows the forecast electricity price for each state as prepared by ROAM Consulting (2011) as input to the Treasury modelling of the Clean Energy Future package. Variations between state wholesale prices can be observed however prices are relatively clustered and follow a similar profile. Except for the short term to 2013 and in the long run from about 2030-onwards, wholesale prices in Western Australia also follow a similar profile to the other states. As a result of using one electricity price for all states and territories, the actual take up of EVs in each state may be slightly higher or lower than those presented in **Section 3.4**. However, sensitivity analysis shows that take up is less sensitive to the electricity price than other factors such as vehicle purchase price and higher oil prices.

[5] The "global action" scenario assumes staged global action on climate change that is broadly consistent with low estimates of the national pledges incorporated in the Copenhagen Accord and Cancun agreement, continuing to at least 2050, but with no carbon price in Australia and no additional mitigation policies. The "high carbon" price scenario assumes a world with a more ambitious 450 ppm stabilisation target and an Australian emission target of a 25 percent cut on 2000 levels by 2020 and an 80 percent cut by 2050.

Figure 19: Wholesale pool electricity price forecasts for each state – core policy



Source: ROAM (2011)

The introduction of a carbon price under the Clean Energy Future package will favour traditional ICE vehicles over EVs. Whilst electricity prices will rise under the carbon price, traditional fuel sources such as petrol and diesel will be exempt for passenger and light commercial vehicles.

This study assumes electricity prices do not increase significantly as a result of EVs, that is, partial equilibrium. However, as discussed in subsequent sections of this report, there could be significant costs of integrating EVs into the electricity market, particularly if the majority of charging occurs in peak periods and results in a need for increased investment in peak load. For the purpose of forecasting take up of EVs, this study assumes that (1) measures are in place to minimise the impact on peak load and (2) any additional costs will be spread across all electricity customers. This is current practice for other higher electricity consuming goods such as air conditioners. Further, whilst the increase in peak load from EVs could be significant if it is unmanaged, it is small relative to the anticipated increases that will occur without EVs as shown in **Section 5.2.1.3**. It is possible that the increased costs from EVs will be charged to EV customers only. In this case, electricity prices could be significantly higher than assumed and take up of EVs lower. This would likely impact take up in vehicles that travel shorter distances more as these vehicles benefit less from fuel cost savings.

3.3.1.7 Fuel efficiency

Fuel consumption for all engine types has been retained from AECOM (2011). ICE consumption values were estimated from a survey of vehicles on Green Vehicle Guide and ABS data.[6] Efficiencies for hybrids are modelled relative to ICE efficiencies as investments in hybrid technology are expected to generate continued efficiency gains over ICE. Efficiencies for EVs were identified through a survey of current and planned models.

The efficiency of a PHEV is simply the efficiency of the ICE powertrain and EV powertrain applied to the respective distanced travelled propelled by each powertrain technology. Verdant Vision commented in

[6] http://www.greenvehicleguide.gov.au/

their submission (Verdant Vision, 2012, p8) that the utility factor of PHEVs may be too low. As there are no commercially available PHEVS in Australia at the moment there is no data available on what proportion of driving uses electricity. Data from the US indicates that two-thirds of Chevy Volt fleet miles are electrified (Peterson, 2011). However, this result is unique to that particular vehicle (which has a range of 40 miles) and is derived from US driving behaviour. AECOM have kept the assumption but undertaken sensitivity analysis with a higher proportion of electricity consumption from PHEVs to assess if this would significantly impact on electricity consumption. This shows that if a higher proportion of electricity is consumed, the cost per kilometre falls (because electricity is cheaper than petrol) resulting in higher take up of PHEVs, at the expense of BEVs. Whilst electricity usage increases, this is offset by a switch from BEVs to PHEVs. Overall, the increase in electricity usage increases but not enough to change the key conclusions of this study.

Future improvements in fuel efficiencies were estimated from a literature review and industry consultation. See AECOM (2011) for further discussion on these assumptions.

Table 8 summarises the assumed fuel efficiencies for each vehicle type in 2010 and the annual change (improvement) in efficiency.

Table 8: Fuel efficiency parameters in 2010 and annual change

	Petrol (L/100km)	Diesel (L/100km)	LPG (L/100km)	Electricity (kWh/100km)	Annual change
ICE					
Passenger small	7.8	5.9	12.3	N/A	0.84%
Passenger medium	9.7	7.3	15.3	N/A	0.84%
Passenger large	13.8	10.4	21.8	N/A	0.84%
Light Commercial Vehicle	11.2	8.4	12.0	N/A	0.84%
Taxi	13.8	10.4	21.8	N/A	0.84%
HEV					
Passenger small	5.3	N/A	N/A	N/A	0.43%
Passenger medium	7.3	N/A	N/A	N/A	0.43%
Passenger large	11.2	N/A	N/A	N/A	0.43%
Light Commercial Vehicle	8.4	N/A	N/A	N/A	0.43%
Taxi	11.2	N/A	N/A	N/A	0.43%
EV					
Passenger small	N/A	N/A	N/A	19.0	0.45%
Passenger medium	N/A	N/A	N/A	16.5	0.45%
Passenger large	N/A	N/A	N/A	21.5	0.45%
Light Commercial Vehicle	N/A	N/A	N/A	18.5	0.45%
Taxi	N/A	N/A	N/A	21.5	0.45%
PHEV					
Passenger small	7.8	N/A	N/A	19.0	0.84%/0.45%
Passenger medium	9.7	N/A	N/A	16.5	0.84%/0.45%
Passenger large	13.8	N/A	N/A	21.5	0.84%/0.45%
Light Commercial Vehicle	11.2	N/A	N/A	18.5	0.84%/0.45%
Taxi	13.8	N/A	N/A	21.5	0.84%/0.45%

Source: AECOM and Dr. Andrew Simpson; ABS; Green Vehicle Guide.

3.3.1.8 Vehicle range

One of the disadvantages of BEVs over ICE vehicles is the limited vehicle range. Even though the average daily distance travelled is around 12 to 14 kilometres a day (See **Section 2.0**) and drivers do not need a vehicle range of 550km (a typical vehicle range in an ICE vehicle) they still value the option to drive further and worry about the possibility of running out of charge – range anxiety. Vehicle range assumptions, based on a survey of electric vehicles undertaken for AECOM's previous studies, are shown in **Table 9.**

Table 9: Vehicle range assumptions for 2010 (km)

Category	ICE	HEV	PHEV	EV
Passenger Small	500	500	500	120
Passenger Medium	550	550	550	200
Passenger Large	550	550	550	300
LCV	550	550	550	160
Taxi	550	550	550	300

Source: AECOM (2009, section 4.13)

The vehicle range for all vehicles grows over time due to fuel efficiency improvements. ICE and HEV vehicle range increases in line with fuel efficiency improvements. EVs are assumed to grow due to fuel efficiency as well as battery improvements. It is assumed a battery storage capacity improvement of 5 percent per annum, equivalent to a doubling in vehicle range every 12-13 years. This is consistent with industry expectations which expect a doubling in vehicle range every 10 years. PHEV vehicle range will increase due to both increases in the ICE range and the EV range. It has been assumed to be the maximum of either the ICE range or EV range.

3.3.1.9 Infrastructure

A key factor in the vehicle choice model is the availability of public vehicle charging infrastructure relative to ICE vehicles (e.g. availability of battery swap stations or public charging points relative to the number of petrol stations). The assumptions of level of infrastructure are summarised in **Table 10**.

Table 10: Proportion of available EV charging infrastructure relative to ICE vehicles infrastructure (e.g. service stations)

Category	Low	Central	High
ICE	100%	100%	100%
HEV	100%	100%	100%
PHEV	100%	100%	100%
EV	40% By 2040	80% By 2040	120% By 2040

Source: AECOM

The costs of charging infrastructure are retained from AECOM (2011) and are presented in **Table 11**. The costs of residential charging is assumed to be an upfront cost, along with the vehicle price as set out in **Table 6** that is faced by the consumer. Business charging at dedicated work places will be a combination of residential charging and public charge units. The costs of installing charging infrastructure will vary in each property depending on the circuit available. See **Section 4.3.1** for more discussion on home charging.

If an EV owner is going to use either vehicle-to-grid (V2G) or vehicle-to-home (V2H) there will be additional infrastructure costs with wiring, metering and communication to the grid. The V2G and V2H concept is relatively new and as such the costs are less defined. Both of these concepts are discussed in more detail in **Section 7.0**.

Table 11: Cost of charging infrastructure

	Low	Central	High
Residential charging (Level 1 and 2 – single phase only)		$1,500	
Commercial charging - public charge unit (Level 2)		$3,000	
Commercial charging – dedicated commercial premises(DC fast charge or battery swap)		$500,000	
Reduction in cost by 2020	20%	50%	80%

Source: AECOM

3.3.2 Summary of assumptions

Table 12 summarises assumptions in the central, high and low scenario. Detailed discussion of assumptions can be found in AECOM (2011).

Table 12: Summary of key assumptions for each scenario

Assumptions	Scenarios		
	Low	Central	High
Vehicle sales	Current (2010): Taken from ABS (2010a) Annual growth: assumes a trend for fewer vehicles per household so the average long term trend decreases by 0.5% in each state relative to the central case scenario.	Current (2010): Taken from ABS (2010a) Annual growth: average trend growth continues (around 1-2.5% pa in each state)	Current (2010): Taken from (2010a) Annual growth: assumes a trend for more vehicles per household so the average long term trend increases by 0.5% in each state relative to the central case scenario.
Vehicle prices – current prices	Same as central scenario.	Prices in 2012: HEV: Small: $37,000, Medium: $44,000, Large: $66,000, LCV:$60,000 PHEV / EV: Small: $41,000, Medium: $57,000, Large: $98,000, LCV:$104,000 (A review of current prices suggests there has not been significant movement since the Victorian study was undertaken.)	Same as central scenario.
Vehicle prices – year in which reaches price parity with ICE	HEV: 2025 PHEV: 2030 EV: 2030	HEV: 2020 PHEV: 2025 EV: 2025 (As per Victorian study)	HEV: 2015 PHEV: 2020 EV: 2020

Assumptions	Scenarios		
	Low	Central	High
vehicle			
Supply constraints *There are expected to be global supply constraints until at least 2012 and as such, a supply constraint has been built into the model to ensure it reflects current market conditions.*	Supply into Australia becomes unconstrained at 2025 for HEVs, PHEVs and BEVs respectively.	HEV – 1,000,000 HEVs currently in global production, growing by 35% per year. Australia will receive 1% of global supply. Supply will be constrained until 2015. PHEV - by 2012 there will be 150,000 PHEVs in global production and 1% of these will reach Australia. Production will grow at 20% per year and be constrained until 2020. EV – by 2012 there will be around 500,000 BEVs in global production and 1% of these will reach Australia. Production will grow at 40% per year until 2015 and by 30% per year from 2016 onwards. Supply will be constrained until 2020.	Australia is seen as a key EV market and Supply of non-ICE vehicles to Australia is unconstrained from 2015.
Fuel efficiency	Same as central scenario.	ICE Small: 7.8L/100km, Medium: 9.7L/100km, Large: 13.8L/100km, LCV: 13.8L/100km 37% improvement between 2006 to 2050 HEV Small: 47% more efficient than ICE; Medium: 32% more efficient than ICE, Large: 23% more efficient than ICE, LCV: 33% more efficient than ICE. Improvements with an ICE will decrease by 18% between 2010 and 2050 PHEV Assumes currently use 50% EV drive train and 50% ICE power train. This increases to 80% EV / 20% ICE by 2035[7].	Same as central scenario.

[7] As there are no commercially available PHEVS in Australia in 2012, there is no data available on what proportion of driving uses electricity. Data from the US indicates that two-thirds of Chevy Volt fleet miles are electrified (Peterson, 2011). However, this result is unique to that particular vehicle (which has a range of 40 miles) and is derived from US driving behaviour, AECOM has undertaken sensitivity analysis with a higher proportion of

Assumptions	Scenarios		
	Low	Central	High
		EV Small: 19kWh/100km; Medium: 16.5kWh/100km, Large: 21.5kWh/100km, LCV: 18.5kWh/100km. 20% improvement between 2006 and 2050.	
Conventional fuel prices	Based on low EIA (2011) oil price forecasts. Oil price reaches around $53/barrel by 2020, and $50/barrel by 2030.	Based on reference EIA (2011) oil price forecasts. Oil price reaches around $110/barrel by 2020, and $125/barrel by 2030.	Based on high EIA (2011) oil price forecasts. Oil price reaches around $170/barrel by 2020, and $200/barrel by 2030.
Electricity prices	Based on Treasury (2011) forecasts under a high carbon price scenario once the scheme transitions to a flexible emissions trading scheme in 2015. Price reaches around $99/MWh by 2020, and $129/MWh by 2030.	Based on Treasury (2011) forecasts of wholesale energy price under the Clean Energy Future. Price reaches around $67/MWh by 2020, and $107/MWh by 2030.	Based on Treasury (2011) forecasts under a global action scenario which assumes no Australian carbon price. Price reaches around $52/MWh by 2020, and $68/MWh by 2030.
Maintenance costs	Same as central scenario	ICE Small: 5.86c/km, Medium: 4.45c/km, Large: 4.34c/km, LCV: 5.10c/km (Austroads, 2008) HEV 12% saving relative to ICE PHEV 25% saving relative to ICE EV 25% saving relative to ICE	Same as central scenario
Other vehicle costs	Same as central scenario (small proportion of total costs and does not vary significantly by vehicle type).	$1500 per annum for insurance, registration, etc.	Same as central scenario (small proportion of total costs and does not vary significantly by vehicle type).
Vehicle range	Same as central scenario.	ICE and HEV – 500km for small passenger; 550km for all other categories PHEV – range is equal to maximum of EV or ICE EV Small – 120km Medium – 200km	Same as central scenario.

electricity consumption from PHEVs to assess if this would significantly impact on electricity consumption. This shows that if a higher proportion of electricity is consumed, the cost per kilometre falls (because electricity is cheaper than petrol) resulting in higher take up of PHEVs, at the expense of BEVs. Whilst electricity usage increases this is offset by a switch from BEVs to PHEVs. Overall, the increase in electricity usage increases but not enough to change the key conclusions of this study.

Assumptions	Scenarios		
	Low	Central	High
		Large – 300km LCV – 160km All grow over time in line with increased fuel efficiencies. BEVs also grow 5% per annum from increases in battery storage.	
Infrastructure costs	Current costs same as central scenario. Cost of public charging units and dedicated charging stations assumed to decline by 20% by 2020.	Household and business charging: $1500 per household or business for Level 1 and 2 (single phase only) Commercial public charging unit: $3000 per Level 2 public charging unit Commercial charging – dedicated premises: $500,000 per charging station (battery swap or equipped with DC fast chargers) Cost of public charging units and dedicated charging stations assumed to decline by 50% by 2020.	Current costs same as central scenario. Cost of public charging units and dedicated charging stations assumed to decline by 80% by 2020.
Infrastructure provision	Household and business charging: Available to everyone. Commercial Charging - Public/dedicated commercial premises: 40% equivalent to traditional petrol stations by 2040.	Household and business charging: Available to everyone. Commercial Charging - Public/dedicated commercial premises: 80% equivalent to traditional petrol stations by 2040.	Household and business charging: Available to everyone. Commercial Charging - Public/dedicated commercial premises: 120% equivalent to traditional petrol stations by 2040, that is, more accessible than traditional petrol stations because available in car parks.

3.4 Estimated take up of electric vehicles

3.4.1 Key results

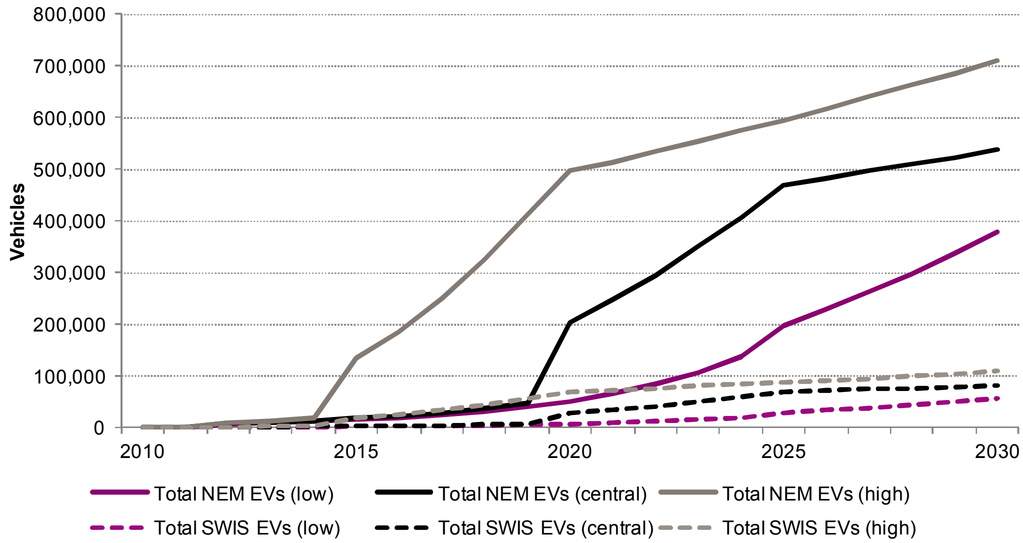
AECOM's analysis suggests that within 10 to 15 years EVs could have a significant presence in the Australian market. While vehicle sales are expected to be slow initially, accounting for around 1 to 2 percent until 2015, once vehicle prices fall, global supply constraints ease and infrastructure availability increases, vehicle sales are expected to be around 20 percent of sales by 2020 rising to around 45 percent of sales by 2030 (see **Table 13** and **Figure 20)**. Cumulative EVs are shown in **Figure 21**. Take up could be slower, as illustrated in our low scenario, if vehicle prices take longer to reach price parity and supply constraints remain in the Australian market. However, it is also possible that take up could be much quicker (as illustrated in our high scenario), if for example, battery prices fall much quicker than currently anticipated, Australia is seen as a key electric vehicle market with supply constraints easing quicker, or leasing arrangements evolve that reduce the upfront purchase cost.

Table 13: Estimated take up of electric vehicles in the NEM and SWIS as a proportion of new sales

	Central			Low			High		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
NEM									
PHEV	1.3%	18.7%	36.3%	1.4%	4.6%	31.0%	13.0%	41.0%	38.0%
BEV	0.7%	1.5%	7.6%	0.3%	0.6%	2.6%	1.3%	6.0%	15.4%
Total	2.0%	20.2%	43.9%	1.7%	5.3%	33.6%	14.4%	47.0%	53.4%
SWIS									
PHEV	1.3%	18.7%	37.5%	1.3%	4.4%	32.2%	12.8%	42.0%	38.6%
BEV	0.7%	1.6%	8.4%	0.3%	0.6%	2.9%	1.4%	6.6%	17.0%
Total	2.0%	20.3%	45.9%	1.7%	5.1%	35.1%	14.2%	48.6%	55.7%
Total									
PHEV	1.3%	18.7%	36.5%	1.3%	4.6%	31.2%	13.0%	41.1%	38.0%
BEV	0.7%	1.5%	7.7%	0.3%	0.6%	2.6%	1.3%	6.0%	15.6%
Total	2.0%	20.2%	44.2%	1.7%	5.2%	33.8%	14.3%	47.2%	53.6%

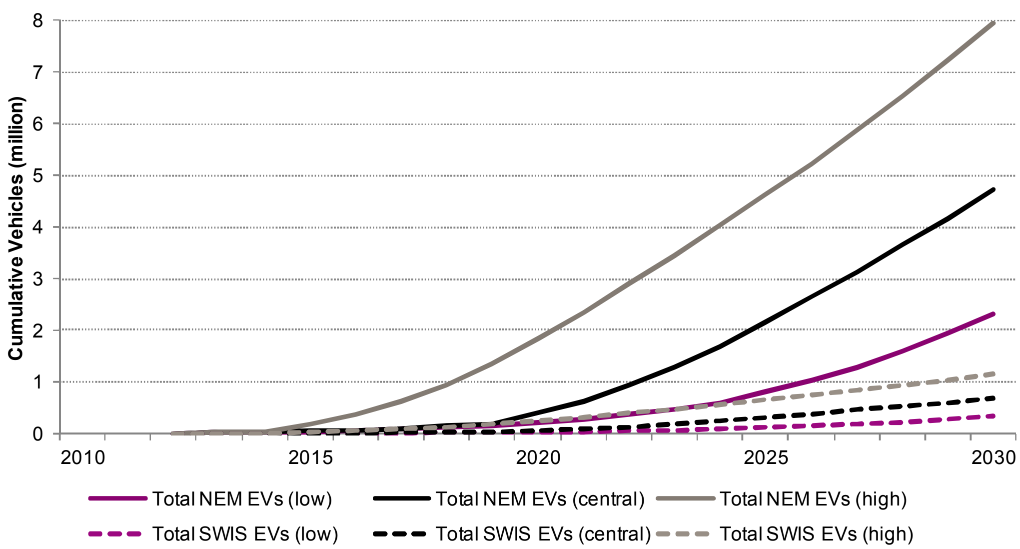
Source: AECOM

Figure 20: Estimated annual sales of electric vehicles in NEM and SWIS



Source: AECOM

Figure 21: Estimated number of electric vehicles in NEM and SWIS



Source: AECOM

More PHEVs than BEVs in the short-to-medium term

Estimated total annual PHEV and BEV sales for the NEM and SWIS are presented in **Figure 22** and **Figure 23** for the low, central and high take up scenarios.[8] In early years, the take-up of PHEVs is stronger than that of BEVs due to superior range and the ability to use both electricity and petrol as fuel. However, in later years there is a shift towards BEVs as purchase prices converge to parity with ICE, battery improvements result in increased vehicle range, the provision of more charging infrastructure, and higher fuel prices make BEVs more competitive. The higher take up of PHEVs in

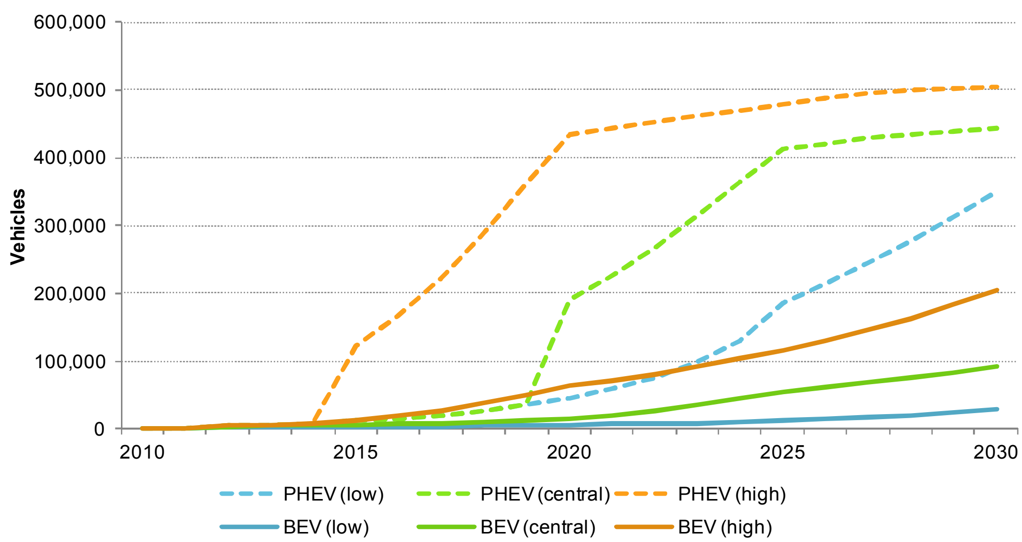
[8] For the purposes of this study, it is assumed that all take up of EVs in Western Australia occurs in the SWIS.

early years will minimise the impact that EVs will have on the electricity market as PHEVs will typically use less electricity and the dual charging is likely to reduce range anxiety and make PHEV charging more flexible which will in turn reduce the impact on peak load.

Initial sales of PHEVs are subject to supply constraints with sales rising in line with the assumed increase in available Australian PHEV supply. However BEV sales under the low and central scenarios are less than the (constrained) Australian BEV supply as they are relatively uncompetitive against alternative engine types in early years.

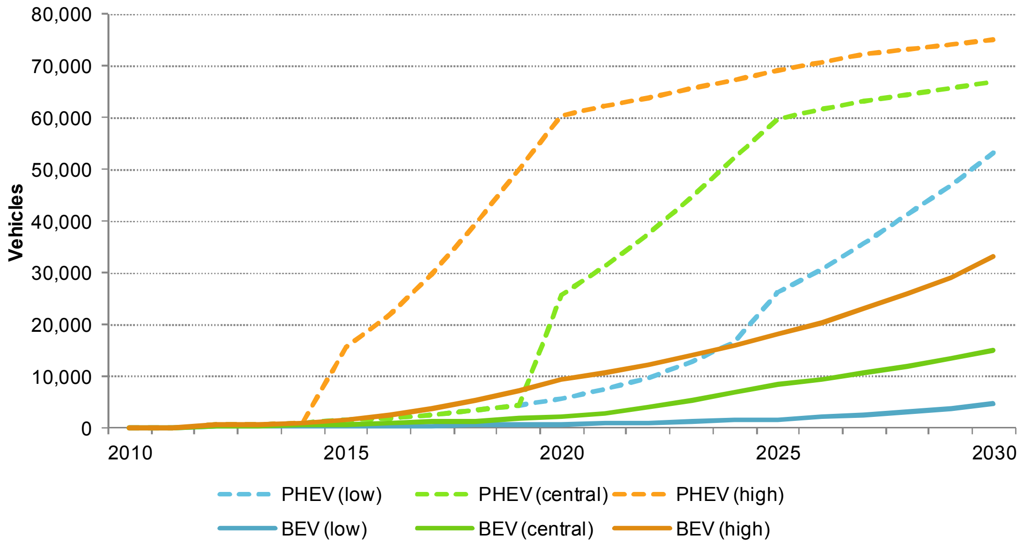
Of note are two inflection points in the estimated sales which are most prominent for PHEV sales. For the central scenario these occur at 2020 and 2025 and reflect the assumptions relating to supply constraints and vehicle price parity. Under the central scenario, supply of PHEVs and BEVs are assumed to become unconstrained in 2020 hence the large increase in vehicle sales. In 2025 of the central scenario, the purchase prices of PHEVs and BEVs are assumed to become equal to conventional ICE vehicles. At this point sales of PHEVs slow as BEVs become increasingly competitive. Similar characteristics are observed for the low and high take up scenarios with the differences being the magnitude of sales and the later / earlier dates corresponding with the alternate assumptions about supply constraints and vehicle price parity. This highlights the sensitivity of the results to the year in which price parity occurs and when the supply constraint is removed.

Figure 22: Estimated PHEV and EV sales – NEM



Source: AECOM

Figure 23: Estimated PHEV and EV sales – SWIS



Source: AECOM

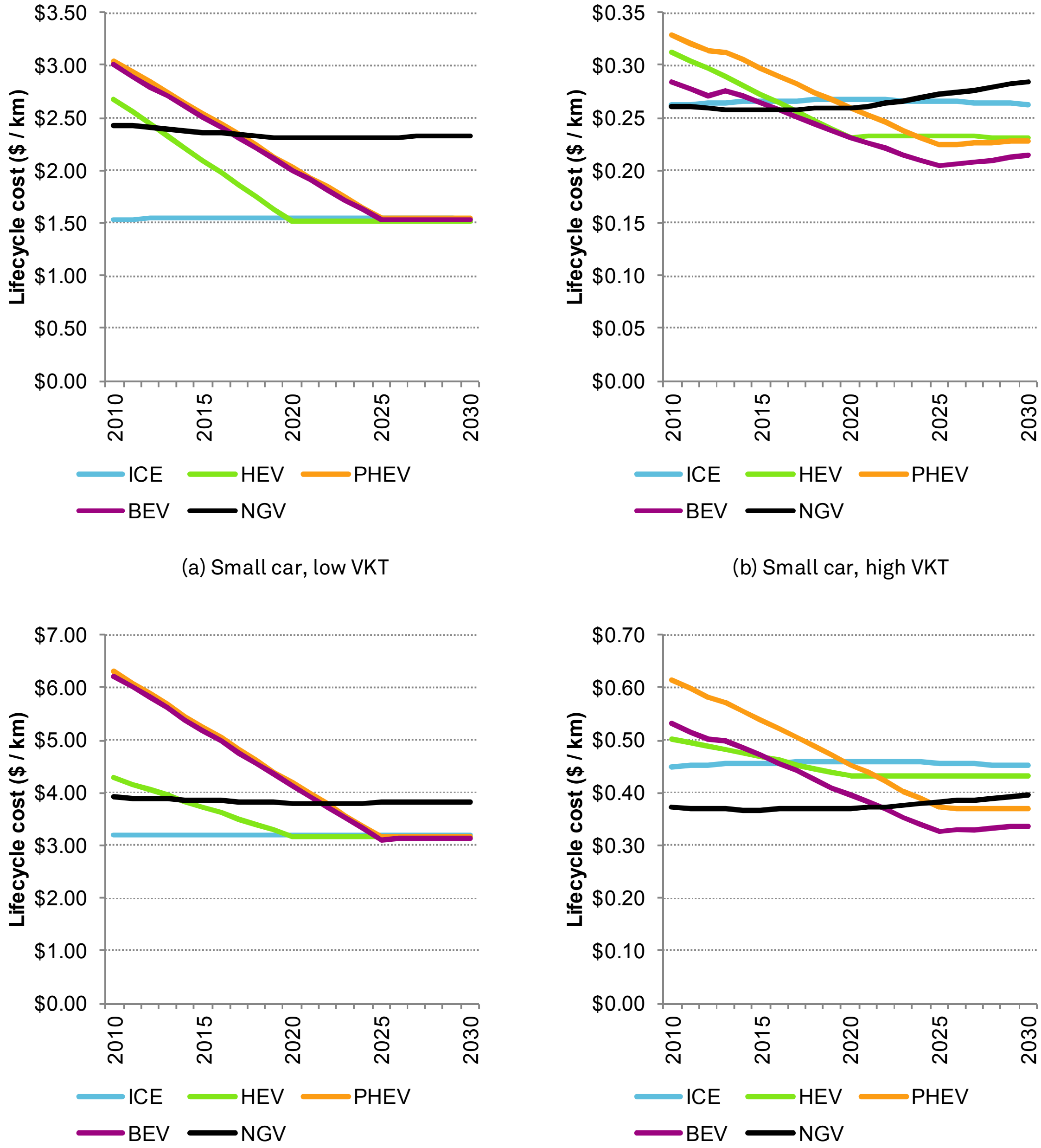
Higher take up for small, low distance vehicles in early years

As noted above, sales of PHEVs are forecast to dominate those of BEVs due to their superior range and ability to use both electricity and petrol as fuel. However, as prices gradually reach parity, vehicle range improves and more charging infrastructure becomes available, larger vehicles and vehicles that travel longer distances increase their share of BEV sales. This is primarily due to increased ICE operating costs for (as global oil prices rise) inducing these vehicle owners to switch to more efficient technologies to achieve fuel cost savings.

Figure 24 shows the lifecycle costs of small and large cars for low and high VKT. It is evident that over time the lifecycle costs of EVs falls, consistent with the reduction in the purchase price premium until price parity is reached in 2025 under the central scenario. However for both small and large vehicles that have low VKT, the lifecycle cost effectively matches that of ICE vehicles in the long run but does not fall any further. In contrast, for vehicles with high VKT, the lifecycle cost is equal to that of ICE vehicles by around 2015 to 2020 and continues to fall until 2025. After 2025 when price parity is reached the effect of rises in electricity prices causes the lifecycle cost to increase moderately. The lifecycle costs for medium VKT vehicles and medium sized vehicles fall in between the results shown in **Figure 24**.

These figures highlight that in the long run, once vehicle prices decrease, vehicle range increases and infrastructure availability improves, the take up of EVs is more likely by people who travel larger distances and will benefit more from fuel savings.

Figure 24: Lifecycle cost small and large car, low and high VKT



(a) Small car, low VKT

(b) Small car, high VKT

(c) Large car, low VKT

(d) Large car, high VKT

Source: AECOM.

Victoria, New South Wales and Queensland account for the most EVs

At a state and territory level within the NEM, equivalent results are observed in terms of the proportion of new sales; however the magnitude of sales varies between regions. The estimated number of vehicle sales in each region is shown in **Table 14**. New South Wales (and ACT), Victoria, and Queensland make up the majority of vehicle sales with approximately 90 percent of take up in the NEM. This is reflective of current vehicle sale patterns.

Corresponding tables for the low and high scenarios are presented in Tables A1 to A3 in **Appendix A**.

Table 14: PHEV and BEV sales by state

	PHEV			BEV			EVs		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
VIC	3,800	59,700	134,500	1,900	4,300	25,000	5,700	64,100	159,500
NSW	4,200	63,100	142,000	2,100	5,400	32,000	6,300	68,500	174,100
ACT	200	3,400	7,200	100	200	1,300	300	3,700	8,500
QLD	2,800	45,000	117,600	1,400	3,900	26,400	4,200	48,900	144,000
TAS	300	3,900	9,100	100	300	1,700	400	4,200	10,800
SA	900	14,300	34,200	400	1,000	6,300	1,300	15,300	40,500
Total NEM	12,200	189,400	444,600	6,000	15,100	92,700	18,200	204,700	537,400
WA	1,600	25,800	67,000	800	2,200	15,100	2,400	28,000	82,100

Source: AECOM. Values are rounded to the nearest 100 vehicles.

3.4.2 Spatial take up

The take up modelling in the present study was conducted at a state-wide level, but it is important to note that EV penetration is likely to initially cluster around early adopters and not penetrate the mass market evenly until electric vehicle prices approach parity with ICEs.

Studies have revealed that early adopters of HEVs share a number of characteristics such as: higher average income, higher levels of education, above-average technological skills and above-average age groups (de Haan et al, 2006; Klein, 2007; Scarborough, 2007), and this is likely to be replicated for EVs.

A recent social study conducted by Gardner et al (2011) on attitudes towards EV adoption provides further evidence to this, as the results from their surveys reveal that the most important predictor of take up was concern about climate change. Furthermore, qualitative responses to open-ended questions showed that low vehicle purchase price was the predominant consideration, followed by environmental benefits, running costs, range and recharging issues.

The combination of these factors suggests that short to medium term use of EVs will be concentrated in urban and major hub areas, where charging locations will also initially cluster.

3.4.3 Discussion

AECOM's analysis indicates that within 10 to 15 years EVs will have a significant presence in the Australian market. EV sales are expected to be slow initially, accounting for around 1 to 2 percent of total passenger vehicle sales until 2015. However, once vehicle prices fall, global supply constraints ease and infrastructure availability increases, vehicle sales are expected to be around 20 percent of sales by 2020 rising to around 45 percent of sales by 2030. Take up could be slower, as illustrated in our low scenario, if vehicle prices take longer to reach price parity and supply constraints remain in the Australian market. However, it is also possible that take up could be much quicker (as illustrated in our high scenario) if, for example, battery prices fall much quicker than currently anticipated or Australia is seen as a key electric vehicle market with supply constraints easing quicker and the emergence of leasing the battery which reduces the upfront purchase cost.

These results are broadly in line with those presented in other studies. **Table 15** compares the results of AECOM's three scenarios with the forecast penetration of EVs into the Australian market by ChargePoint and AGL. ChargePoint only forecasts in terms of percentage of sales to 2020 rather than absolute volumes of sales. The take up of EVs in AECOM's central scenario is consistent with ChargePoint's forecast.

In contrast, AECOM's central estimate is substantially higher than AGL's medium forecast, which suggested that sales of EVs might reach 25 percent by 2030. Indeed, AECOM's central scenario more closely matches AGL's high forecast. Therefore AECOM's central case for take up of EVs may provide conservatively high estimates for the impact on the electricity market in subsequent analysis.

Table 15: Comparison of AECOM results with ChargePoint and AGL

Share of new vehicle sales	2015	2020	2025	2030
AECOM - Low	1.7%	5.2%	18.8%	33.8%
AECOM - Central	2.0%	20.2%	42.2%	44.2%
AECOM - High	14.3%	47.8%	50.4%	53.6%
AGL – Low	1.5%	2.5%	3%	5%
AGL – Medium	2%	6%	13%	25%
AGL – High	3%	20%	37%	50%
ChargePoint	2.5%	18.2%	N/A	N/A

Source: AECOM, ChargePoint submission (2011), AGL submission (2011). Note: AGL values are estimates made from chart.

The estimated take up is also comparable with the targets of international governments (see **Table 16**). The take up in 2015 of the central scenario is somewhat higher than the US target of 0.4 percent while it is lower than the Spanish target of 4.4 percent in 2014. However there is a wider range of government targets for 2020 ranging from 2.2 percent (Germany) to 50 percent (Japan). The estimated central take up is approximately midway between these bounds, and indeed the low and high take up for 2020 are much closer to the German and Japanese targets respectively. As the Australian Electric Vehicle Association points out in their submission (2012), care needs to be taken when undertaking international comparisons as different countries have different levels of subsidies.

Table 16: Global government EV targets

Country	Vehicles	% of total	Date
US	1,000,000	0.4%	2015
China	500,000	0.3%	2012
UK	100,000	0.4%	-
France	2,000,000	6.2%	2020
Germany	1,000,000	2.2%	2020
Spain	1,000,000	4.4%	2014
Israel	500,000	25%	-
Japan	34,583,670	50%	2020
Denmark	-	-	-
Netherlands	200,000	2.6%	2020
Ireland	250,000	10.3%	2020
Australia	-		-

Source: AGL submission (2011)

It is important to recognise that there are a number of factors that impact on the take up of EVs and these factors are continuously changing. National forecasts should be updated regularly to assist in the preparation for EVs.

3.4.4 Summary

The take up of EVs starts with small quantities with PHEV sales constrained by limited Australian supply. Take up of PHEVs is greater than BEVs in the short-to-medium term as they have better range, are able to use either petrol or electricity and have refuelling / recharging infrastructure widely available. As such, in the period to 2020, the impact of EV take up on the electricity network is likely to be modest.

Following supply becoming unconstrained in 2020, take up of PHEVs expands markedly due to their continued competitiveness over other engine types because of improving fuel / electricity costs (compared to ICE vehicles) and improving range. In parallel, BEV sales continue to rise however at a more gradual rate.

However, once price parity for both PHEVs and BEVs is achieved in 2025, sales of PHEVs plateaus with take up shifting towards BEVs which by 2025 have become competitive with all other engine types. Similar characteristics are observed for the low and high take up scenarios with the key dates shifting later or earlier reflecting the change in assumptions for each scenario.

As expected, Victoria, New South Wales (and Australian Capital Territory) and Queensland dominate the take up of EVs with approximately 80 percent of total national sales (90 percent of NEM sales).

3.5 Estimated energy usage

Table 17 and **Table 18** set out the energy consumption of PHEVs and BEVS over time under the three take up scenarios for the NEM and SWIS respectively.

Energy consumption remains relatively low as a proportion of total energy demand even in the high take up scenario for both the NEM and SWIS at 3.7and 4.3 percent respectively. The proportion of total energy demand is slightly higher in the SWIS than the NEM but remains low. Energy consumption of PHEVs increases over time as drivers use a larger share of the electric drive-train. As highlighted in **Table 19**, the energy usage of EVs depends on the size of the vehicle and the distance travelled. Small EVs travelling low distances may use less than 1MWh per annum, where as large EVs travelling longer distances could use around 10 MWh per annum. Importantly the proportion of vehicle size and average distance travelled varies by state.[9]

Table A 4 to **Table A 9** in Appendix A provides more detailed data on energy consumption and proportion of energy demand for each state. The energy consumption from EVs as proportions of total energy consumption in New South Wales and Australian Capital Territory, Victoria and South Australia are slightly higher than the total for the NEM, whereas Queensland and Tasmania have lower proportions than the total for the NEM.

Some of the submissions, including Better Place (Better Place, 2012, p13) and Verdant Vision (Verdant Vision, 2012, p5) thought that BEVS may be a higher proportion of total EVs by 2020. As such, sensitivity analysis was undertaken to assess the energy consumption from EVs if there was a higher proportion of BEVs. Currently, PHEV's make up between 70 percent and 90 percent of total EVS depending on the time and state considered. If this proportion is reversed, total energy consumption does not change significantly in the long term (less than 10%) due to a shift towards more BEVs anyway and PHEVs using a higher proportion of their electric drivetrain as more charging infrastructure becomes available. However, in the short term (2015) energy consumption could be 25% higher and in the medium term (2020) could be 270% higher. Essentially, a higher proportion of BEVs brings forward the higher energy use seen towards the end of the study period. As discussed

[9] This study uses the proportion of vehicle type and VKT from VIC and NSW and applies this to other studies as data was not available for other States within the study period. For the purposes of estimating the magnitude of impacts this is sufficient but it is suggested this assumption be refined in the future given its importance on take up and electricity consumption.

elsewhere in this report, this analysis provides an indication of how the EV market may evolve, and it will be important to monitor the actual take up of EVs and the key factors affecting take up. If a higher proportion of BEVs occurs, this will place greater emphasis on managed charging options which use real time information to encourage off peak charging.

Table 17: Energy consumption from EVs in selected years - NEM

EVs	2015		2020		2030	
	MWh	% of total MWh in NEM	MWh	% of total MWh in NEM	MWh	% of total MWh in NEM
Central take up scenario						
PHEV	40,400	0.0%	462,200	0.2%	6,907,600	1.8%
BEV	48,000	0.0%	186,600	0.1%	1,629,100	0.4%
Total	88,300	0.0%	648,800	0.2%	8,536,700	2.2%
Low take up scenario						
PHEV	40,100	0.0%	240,200	0.1%	3,588,700	0.9%
BEV	26,300	0.0%	83,500	0.0%	450,700	0.1%
Total	66,400	0.0%	323,700	0.1%	4,039,300	1.1%
High take up scenario						
PHEV	190,700	0.1%	2,418,100	0.9%	10,335,100	2.7%
BEV	82,400	0.0%	617,400	0.2%	3,926,200	1.0%
Total	273,100	0.1%	3,035,400	1.1%	14,261,400	3.7%

Source: MWh: AECOM based on take up results presented above; assumptions on fuel efficiency (as presented in **Section 3.3.1.7**); and average annual distance travelled as presented in **Table 19**. Forecasts of total MWh in NEM based on AEMO (2011a), medium forecasts (See **Section 6.1.1.2** for more details).

Table 18: Energy consumption from EVs in selected years - SWIS

EVs	2015		2020		2030	
	MWh	% of total MWh in SWIS	MWh	% of total MWh in SWIS	MWh	% of total MWh in SWIS
Central take up scenario						
PHEV	4,800	0.0%	57,100	0.1%	937,600	2.1%
BEV	5,600	0.0%	23,700	0.1%	236,200	0.5%
Total	10,400	0.0%	80,900	0.2%	1,173,800	2.6%
Low take up scenario						
PHEV	4,800	0.0%	28,700	0.1%	481,800	1.1%
BEV	3,000	0.0%	10,200	0.0%	64,000	0.1%
Total	7,800	0.0%	38,900	0.1%	545,800	1.2%
High take up scenario						
PHEV	22,600	0.1%	306,400	0.8%	1,380,500	3.0%
BEV	10,000	0.0%	82,600	0.2%	568,100	1.2%
Total	32,600	0.1%	389,000	1.0%	1,948,700	4.3%

Source: As above for Table 13. Forecasts for total MWh in WA from The Chamber of Minerals and Energy of Western Australia (2011)

Table 19: Average annual energy usage in Victoria and New South Wales by passenger vehicle type and distance travelled, 2011

Passenger vehicle type	kWh/100km	Victoria		New South Wales	
		Average annual VKT	Average annual MWh per vehicle	Average annual VKT	Average annual MWh per vehicle
Small car, low VKT	19	3,622	0.7	4,160	0.8
Small car, medium VKT	19	13,422	2.6	14,342	2.7
Small car, high VKT	19	48,565	9.2	40,598	7.7
Medium car, low VKT	16.5	3,621	0.6	4,135	0.7
Medium car, medium VKT	16.5	13,600	2.2	14,719	2.4
Medium car, high VKT	16.5	52,811	8.7	42,475	7.0
Large car, low VKT	21.5	4,037	0.9	4,220	0.9
Large car, medium VKT	21.5	14,785	3.2	14,665	3.2
Large car, high VKT	21.5	52,484	11.3	45,907	9.9
LCV	18.5	22,742	4.2	23,518	4.4
Taxi	21.5	116,079	25.0	130,029	28.0

Source: AECOM calculations based on assumptions as set out in **Section 3.3.1.7** on fuel efficiency and average annual VKT from various state Transport Departments.

3.5.1 Renewable energy

An often discussed concept is the ability of renewable energy generation to supply some or all of the energy demanded by EVs to recharge. **Table 20** shows the megawatt-hour demand by EVs under each scenario for selected years and the proportion of renewable generation that the demand represents. Renewable energy generation has been estimated from Treasury (2011) which forecasts the proportion of electricity generation by fuel source. These proportions were then multiplied by forecast energy demand for the NEM and SWIS from AEMO (2011b) to develop renewable energy generation estimates in megawatt-hours.

It is clear that in the next 5 to 10 years, renewable generation is more than capable of supplying the aggregate energy requirements of EVs, which is in the order of 0.3 percent to 8 percent under the central scenario. Even under the high take up scenario, EV energy demand is only around 13 percent of total renewable energy generation in 2030.

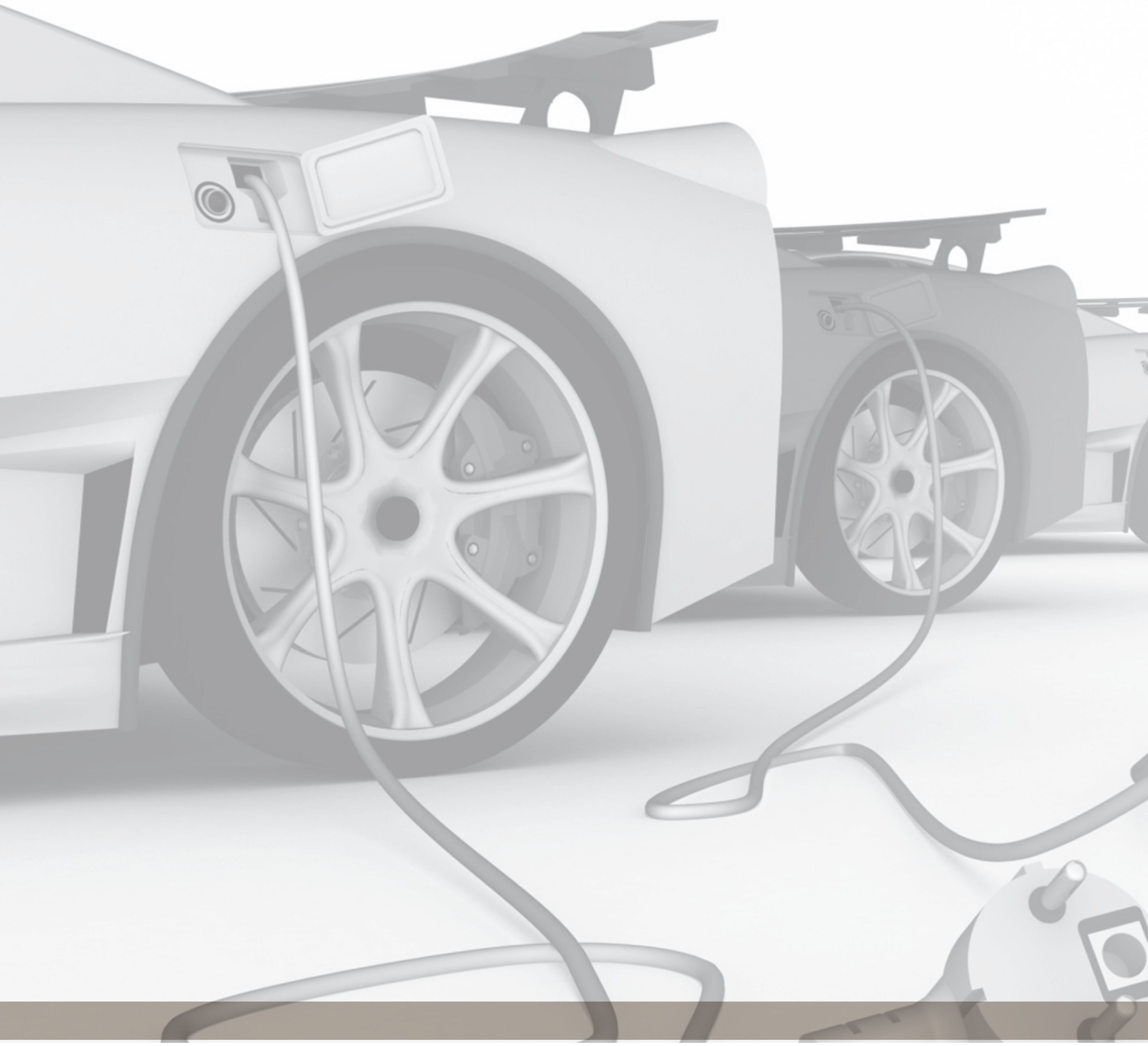
For comparison, **Table 20** also shows EV energy demand as a proportion of the Large-scale Renewable Energy Target (LRET). Annual targets are set at 10,400 GWh in 2011 rising gradually to 41,000 GWh in 2020. From 2020 to 2030 the annual target is held constant at 41,000 GWh (ORER, 2011). These targets are lower than the renewable energy generation calculated from Treasury (2011) and AEMO (2011b) and therefore represent a more conservative estimate of national renewable energy generation. Even with this lower generation, EV energy demand is only estimated to be around 0.5 percent of the LRET in 2015 rising to 1.8 percent in 2020 under the central scenario. In 2030, this proportion rises to 24 percent however the LRET is held constant from 2020 to 2030 whereas it is much more likely that renewable generation will continue to increase over this period.

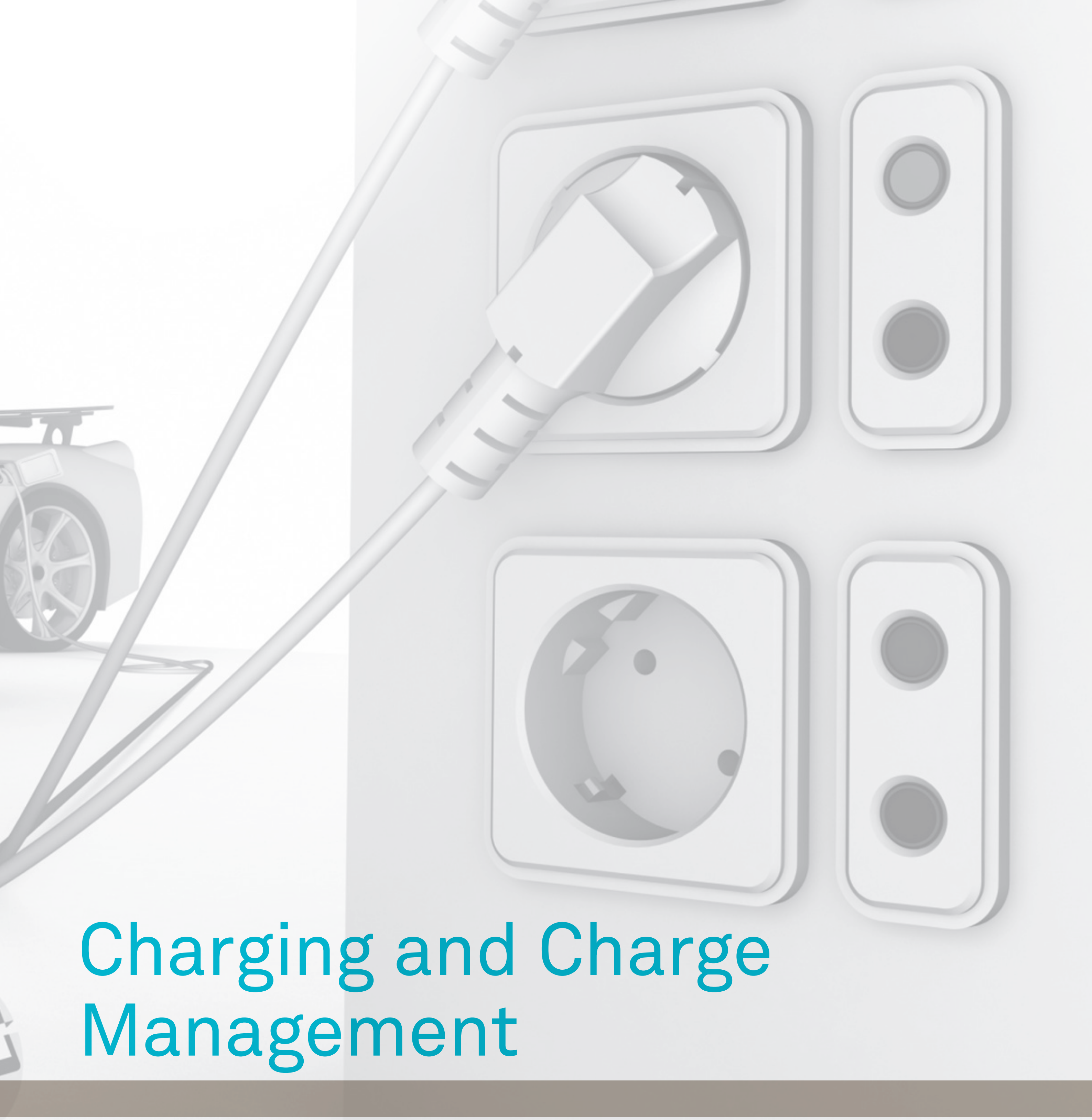
Table 20: EV energy demand as proportion of renewable energy generation

	2015			2020			2030		
	MWh	% of total MWh in NEM or SWIS	% of LRET target	MWh	% of total MWh in NEM or SWIS	% of LRET target	MWh	% of total MWh in NEM or SWIS	% of LRET target
Central take up scenario									
NEM	88,300	0.3%		648,800	1.3%		8,536,700	7.9%	
SWIS	10,400	0.3%		80,900	1.1%		1,173,800	9.1%	
Total	98,800	0.3%	0.5%	729,700	1.2%	1.8%	9,710,500	8.0%	23.7%
Low take up scenario									
NEM	66,400	0.2%		323,700	0.6%		4,039,300	3.7%	
SWIS	7,800	0.2%		38,900	0.5%		545,800	4.2%	
Total	74,200	0.2%	0.4%	362,600	0.6%	0.9%	4,585,100	3.8%	11.2%
High take up scenario									
NEM	273,100	1.0%		3,035,400	6.0%		14,261,400	13.2%	
SWIS	32,600	0.8%		389,000	5.2%		1,948,700	15.1%	
Total	305,700	1.0%	1.7%	3,424,500	5.9%	8.4%	16,210,000	13.4%	39.5%

Source: AECOM.

Market arrangements enable EV owners to purchase GreenPower from their electricity retailer. AECOM's analysis suggests that there may be enough supply of energy from renewable generation to charge EVs. However increased demand for renewable energy may impact on the price of Large-Scale Generation Certificates (LGCs). When customers purchase GreenPower, the electricity retailer purchases LGCs, in order to surrender these to the Office of the Renewable Energy Regulator (ORER). As such GreenPower is fully additional to the Government's Renewable Energy Target. If there is a high take up of GreenPower to charge EVs, then demand for LGCs could increase and push the price of LGCs higher.





Charging and Charge Management

4.0

Charging and Charge Management

4.1 Introduction

EVs only affect the electricity system when charging (or discharging in the case of V2G). This section considers our charging assumptions and scenarios, focusing on the details that are most likely to impact the electricity market. We focus on three choices in particular:

- *Where will EVs charge?* the wide spread deployment of charging units will decrease the amount of charging needed at any one time and consequently help spread charging over the entire day. Alternatively, if EVs can only charge at home, many users will charge during the period between when they arrive home and go to work.
- *How much power will EV chargers require?* faster charging will be more convenient for EV drivers but will also increase the power that charging units draw from the network.
- *When will EVs charge (or discharge)?* from a network perspective, the most important choice is when EVs charge. In the worst case scenario, if EV charging is unmanaged and occurs during existing load peaks, peak load will increase. As a result distribution and transmission systems will need to be strengthened and more generation built. Conversely, if charging happens in off-peak periods, then it is not expected to increase peak load, even in high take up scenarios.

Here we examine the worst case scenario of unmanaged charging and then consider three approaches for managed charging scenarios. In each case, we consider how much charging activity might be moved to off-peak periods and how much might remain in the existing late afternoon / evening peak. We also examine the potential for V2G solutions, which not only manage charging but can also feedback into the grid (See **Section 7.0**).

4.1.1 Information limitations

If we were to estimate the full impact of charging, we would need to determine how many users are likely to be charging at a time coincident with the annual system peak. This is not a simple task and there is only limited (and often speculative) information with which to do this. However, the analysis in this report is intended to provide an order of magnitude of the potential impacts and how these may vary between different charging scenarios. As such, a number of assumptions have been made based on best available information at the time and, where possible, adopting a conservative approach to ensure estimates are likely to overestimate rather than underestimate the potential impacts.

By way of example, if we were to estimate the full impact of charging accurately we would need good information on at least the following factors:

- *When EV users begin charging:* this is likely to be when users get home. However, it is unclear whether EV drivers have the same driving habits as other drivers. Additionally, driving habits are likely to be different during the summer months when maximum annual load tends to occur.
- *How EV users respond to charging incentives:* it is unclear, to what degree users will respond to ToU tariffs. Currently, there is only a little information on how electricity consumers respond to ToU tariffs generally. Work undertaken in California on mandatory ToU pricing for commercial and industrial firms finds little evidence of change in usage or load (Jessoe and Rapson, 2011). We were unable to find any reliable data on how residential EV users will respond to ToU incentives.
- *Duration and power of charging:* higher power charging results in shorter charging duration, reducing the likelihood that charging will coincide with system peaks. However, higher power chargers also have a greater impact on peak load.

- *Amount of charge:* the duration of charging is also related to the amount of charge required. This will depend not just on the daily energy requirement of an EV but also on the provision of fast charging and charging facilities near work locations.
- *When system peaks occur:* this will change year to year, by region and will likely be different in different parts of the market (distribution, transmission and generation).

4.2 Where will EVs charge?

Four main locations for EV charging commonly identified in EV literature are:

- *Home based charging:* households will be able to charge their vehicle at home.
- *Business charging:* EV drivers will be able to charge their vehicle at their place of work.
- *Commercial charging - public:* charging points will be available in public places as well as in the home. For instance, charging facilities provided in public spaces such as car parks, hotels, shopping centres, street parking.
- *Commercial charging – dedicated commercial premises:* commercial charging will replace existing petrol stations by providing fast charge facilities either through a battery swap or a quick DC (direct current) charge.

For further details on charging infrastructure see AECOM (2011).

Preliminary research, industry consultation and EV trials suggest that, whilst the provision of charging infrastructure is necessary to reduce range anxiety, the majority of charging will take place at home.

As previously discussed in **Section 3.0**, the prevalence of public and dedicated commercial charging facilities is likely to be a key determinant of take up. However, home based charging is likely to be responsible for the majority of charging activity, especially over the short to medium term. Our assumptions on the prevalence of charging locations are shown in **Table 21**.

Table 21: Charging location assumptions

Assumptions	Scenarios		
	Low	Central	High
Infrastructure provision	Household and business charging: Available to everyone. Commercial Charging - Public/dedicated commercial premises: 40% equivalent to traditional petrol stations by 2040.	Household and business charging: Available to everyone. Commercial Charging - Public/dedicated commercial premises: 80% equivalent to traditional petrol stations by 2040.	Household and business charging: Available to everyone. Commercial Charging - Public/dedicated commercial premises: 120% equivalent to traditional petrol stations by 2040, that is, more accessible than traditional petrol stations because available in car parks.

4.3 How much power will EV chargers require?

There are many different types of proposed chargers, charging systems and schemes for categorising. In this report we have used a charging scheme proposed by ChargePoint, which distinguishes three levels of chargers as shown below in **Table 22**. Charging systems with higher current and higher voltage charge faster, but also have a higher power requirement and consequently higher potential electricity market impacts.

Table 22: EV charger power

Level	Voltage / Current	Power
Level 1	15A, 240V AC	3.6 kW
Level 2	32A, 240V AC	7.7 kW
Level 3	125A, 400V – 600V DC	>50-75 kW

Source: ChargePoint presentation, Early Driver Challenges of EV Transportation

4.3.1 Home and work based chargers

Home and work based charging is likely to occur at levels 1 and 2. Level 1 charging units could be installed in most Australian homes, which are commonly built with at least twenty amp circuits but multiple power points (Usher et al, 2011). However Level 1, 15 amp, power points should be installed on a single circuit to avoid overloading from other appliances on the circuit. Few residences have 15 amp outlets in their garage, so some re-wiring may be required.

Although level 1 charging would be easy to accommodate, several submitters, including BetterPlace and Ergon Energy, note that there will likely be demand for faster, more powerful chargers. BetterPlace notes in their submission that in fact most Australian homes have a 14kW to 28kW capacity[10]. However, Level 2 charging may require strengthening of household connections to reduce the risk of overloading. The Energy Networks Association (ENA) states in their submission that "the increase in load could cause problems for electrical systems within the household or premises where charging occurs this may also necessitate in system augmentation at the premises or site level" (Energy Networks Association, 2011, p.3). Energex additionally notes that strengthening will probably require upgrading effected residential connections to a three phase supply, which is a common way of increasing the capacity of a connection. Currently, the vast majority of homes are on a single phase supply. We understand that where three phase supply is present, this is likely associated with an existing heavy load.

It is still very unclear how home based charger power will evolve. However, for the purposes of modelling EV impacts we assume everyone has a Level 1 charger with a charger power of 3.6kW (15A) Level 2 charging may require strengthening of the household connection and possibly the distribution network in the street and as such is likely to be limited especially in the short term. The costs of installing charging infrastructure (discussed in **Section 3.3.1.8**) will vary in each property depending on the circuit available.

It is also worth highlighting that there may be a lack of consumer understanding about the requirements for home charging and the impact home charging may have on their household. It will be important to ensure consumers have the right information to understand the full requirements and impacts of home charging.

4.3.2 Fast charging at commercial charging stations

Commercial fast charging stations will require stronger supply, both on account of higher charging power (level 3 or more) and multiple charging bays. Given the high power use of charging stations, connecting to the local distribution network is likely to be costly and will probably require an upgrade of local network assets near the point of connection. TRUenergy's submission also notes a concern that fast charging stations may degrade network performance (TRUenergy, 2011, p2,3). However, these costs should and are also likely to be borne by the station developer, rather than existing market participants. This may include paying for network protection schemes and on site facilities to ensure load quality. Also, although commercial charging stations are high power, their overall market share is expected to be low on account of low usage as a percentage of overall charging. AECOM is also aware of possible developments in ultra fast charging, as noted by Blade in their submission (Blade, 2011).

[10] This range is considered reasonable.

Ultra fast charging will increase the power requirements, but as discussed above, these costs will likely be borne by the station developer as part of their investment costs.

4.4 When will EVs charge?

When EVs charge will determine whether EVs contribute to existing load peaks - leading to increased expenditure to strengthen the network - or instead occur during the off-peak period. Our analysis below shows that, even in the high take up scenario, networks should be able to accommodate charging during off-peak periods without increasing the peak load. Consequently, the key question is: how many EVs will be charging during peak periods? In the worst case, unmanaged charging could see a majority of EVs charging during peak periods, leading to an increase in peak load and greater network costs. However, as is pointed out in many of the submissions to the AEMC approach paper, if EV charging can be incentivised or mandated to occur in off-peak periods, there will be potential benefits to residential customers through spreading the fixed network costs over a larger customer base. Work undertaken by the AEMC suggests fixed costs average around 25% of electricity bills for small residential customers (AEMC, 2011).

The rest of this section sets out four charge management scenarios which are used in subsequent analysis:

- Unmanaged charging – charging occurs when people arrive home from work and coincides with the peak period. This scenario requires no change to the current technology.
- Controlled charging – charging is forced to occur in off-peak periods, for example, by using controlled load such as ripple control. This scenario would require a meter if controlled load is to be billed at a different tariff.
- ToU charging – EV drivers have time of use tariffs that will incentivise a proportion of these to charge during off-peak periods. This scenario would require a meter either on the vehicle or at the property.
- Smart charging – EV drivers have smart chargers that respond to signals such as real time pricing and provide better incentives than ToU pricing for off-peak charging. This scenario would require a smart meter with two way communication.

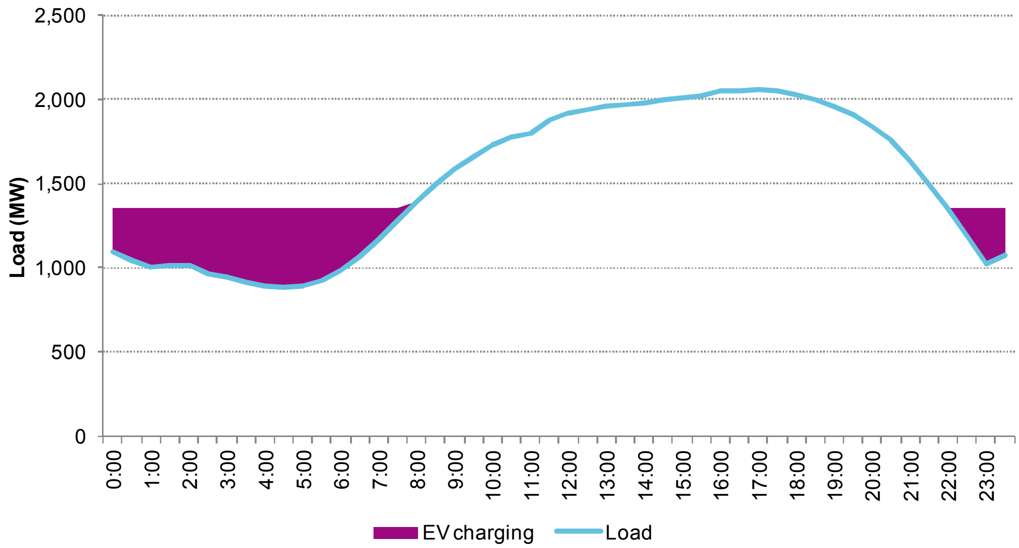
The charge management scenarios represent a spectrum of possible situations from unmanaged charging through incentives designed to encourage off-peak charging, to mandating that charging occurs in off-peak periods. The disadvantage of shifting charging to the off-peak period is that users forgo the option of having a fully charged vehicle later in the evening. Even if users do not plan on using their vehicles, they are likely to value this option and worry about the possibility of running out of charge-range anxiety. Whilst controlled charging ensures off-peak charging of EVs, it may impact on drivers' range anxiety and deter people from purchasing EVs. Therefore approaches that successfully incentivise off-peak charging should be favoured over an approach that mandates off-peak charging.

The purpose of this study is to illustrate how the impact of EVs varies with different charge management scenarios. As such, we have not considered the specific feasibility, in terms of technology or financial viability, of each of these scenarios.

Off-peak charging will not increase peak load

Many reports have noted that there is enough capacity for EVs to charge during the off-peak period and not result in increased annual peak load. We demonstrate that this is clearly the case by modelling off-peak charging in South Australia, using the NSLP from last year's maximum load day and using the daily energy requirements of EVs in 2030, under the high up-take scenario, as shown in **Figure 25**. The NSLP measures the system load that is not metered on a half hourly basis and generally consists of residential and SME load connected to the distribution network. As such, the NSLP provides a very conservative estimate of unused capacity during off-peak periods. Based on NSLPs in the NEM, South Australia had the least available off-peak charging capacity during its day with the highest peak load in 2010. South Australia therefore provides the toughest test of the ability to accommodate EV charging in the off-peak. AECOM also tested that there is sufficient charging capacity below the annual peak on a 'typical' day for each state.

Figure 25: Accommodating off-peak EV charging without increasing peak load, South Australia



Source: Net System Load Profiles from AEMO (2011a), EV charging AECOM

AECOM tested this assumption by comparing the minimum available daily charge, for the NSLP of each state in 2010 (where NSLPs were available) to the average daily energy need of EVs in 2030 under the high take-up scenario. The results are shown in **Table 23**. Although this test is not a precise measure of available charging, the fact that the available charging clearly exceeds average EV consumption by a wide margin, even under an extreme test, demonstrates the ability of the network to cope with managed charging. Off-peak charging also has the added benefit in the night time when temperatures are generally lower. At lower temperatures, transmission and distribution network components, especially conductors and transformers, can actually take higher loads without being damaged. Consequently, overall transmission and distribution capacity is actually higher at night time.

Table 23: Capacity for off-peak charging

State	Mean daily EV energy consumption (MWh)	Minimum available daily charging (MWh)*	Maximum daily utilisation with managed EV charging (%)
VIC	12,784	43,128	75%
NSW	12,128	50,136	71%
ACT	699	3,201	75%
QLD	9,405	29,356	81%
TAS	873	N/A	N/A
SA	3,183	13,053	80%
WA	5,339	N/A	N/A

*This is the available charging capacity below the NSLP maximum annual load for 2010.

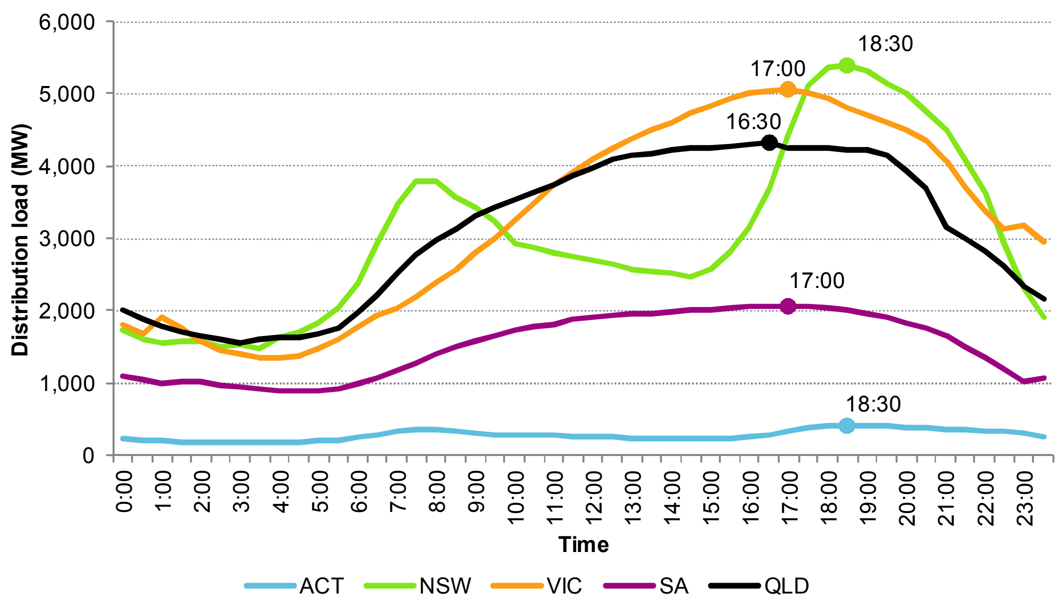
EV charging in off-peak periods increasing peak load could nevertheless cause other impacts in the electricity market. In particular, concern has been raised that there may be issues regarding the adequacy of system capacity, particularly at the generation level. Given off-peak generation is predominantly base load coal and gas, there is unlikely to be major capacity issues as a direct result of

EVs charging in off-peak periods. The increased demand in off-peak electricity will likely increase off-peak prices which would encourage generators to bid into the market. There could be potential frequency issues if all EVs start charging at the same time. However, the Frequency Control Ancillary Services (FCAS) market is designed to address this issue. AECOM believes the current electricity market design provides the right incentives and is capable of responding to this issue, particularly given the long lead times before there is significant take up of EVs.

4.4.1 Unmanaged charging (worst case scenario)

Without any form of charge management it is likely that EV owners will simply charge when they arrive home in the evenings. This would roughly correlate with existing periods of peak load (as estimated from NSLPs) which occur between 16:30 and 18:30, as shown in **Figure 26**.

Figure 26: Distribution level load during maximum load days in 2010



Source: Net System Load Profiles from AEMO (2011a). Data for Tasmania and WA was not available.

Verdant's submission notes that charging of EVs coincident with the system peak may be 52 percent of electric vehicle motorists, based on Australian home arrive times and estimated level 1 charging duration (Verdant Vision, 2012, p12,13). Additionally, they note that the EV charging peak is likely to be only partially coincident with the system peak in any one year. Although EV charging peak is unlikely to be fully coincident with system peaks in any one year, this remains a possibility in the long term, especially because the two peaks are likely to be so close. Consequently, it is unclear how this will affect system planning. As a result, our unmanaged charging scenario assumes 50 percent coincident EV demand, based on full coincidence of EV and system peak times but only around 50 percent of EVs are charging at that peak. This is a conservative scenario and is intended to model an upper level of impact. Following Verdant's submission, we have also modelled a sensitivity of 25 percent coincident EV demand, based on 50 percent coincidence of EV and system peak times with 50 percent EVs charging at that time. We have also modelled 100 percent coincidence of EV demand, comprising all vehicles charging using a level 1 charger (15A) and a full coincidence of EV and system peaks. Whilst this is extremely conservative it is also representative of 50 percent of vehicles charging using a Level 2 (32A) charger at system peak. Table 24 summarises the modelling scenarios.

Table 24: Modelling unmanaged charging

Number of vehicles charging/ Coincidence with system peak	50%	100%
50%	25% EV demand (sensitivity)	50% EV demand (core analysis)
100%	50% EV demand (core analysis)	100% EV demand (sensitivity)- equivalent to core analysis with a Level 2 charger

Source: AECOM

Although EVs charging during the existing early evening peak is clearly conservatively high, preliminary research suggests this is likely. Due to EVs being relatively new to the market, there is limited data on how people will charge their vehicles. Early feedback from the Victorian Electric Vehicle Trial suggests that people typically arrive home and start charging their vehicle[11]. Those that are interested in different charging behaviour do not have the right information to understand their options and the impacts on their electricity bills.

ChargePoint found that business customers charged throughout the workday with a peak from 3pm to 5pm. Private charging also occurred throughout the day but peaked between 6pm and 9pm (ChargePoint, 2011). SP AusNet (2011) also suggests the likelihood of unmanaged charging occurring predominantly in peak periods. However AGL (2011) suggests that diversity could be higher, noting that only 12% of vehicles arrive home during periods of peak demand.

Other research by the Commonwealth Scientific Industrial Research Organisation (CSIRO) and AGL examines the availability of EVs for charging by examining transport data in Victoria. This shows the majority of EVs are likely to arrive home between 5pm and 8pm. However, night time charging is likely to continue for several hours, especially if EVs do not have access to chargers during the work day. Consequently, charging activity from motorists returning home would likely occur in peak periods, clustering around 8pm. As discussed above, Verdant Vision presents a similar line of reasoning in their submission, modelling level 1 charging based on home arrival time of motorists in Australia. In this modelling they suggest 52 percent of motorists may charge at the same time, but this is unlikely to be coincident with the system peak, leading to 25 percent coincident demand. A similar line of reasoning has been used by AEMO in their National Transmission Network Development Plan 2011.

The Smart Grid Smart City Project suggests that people are charging their vehicles when they arrive at work. However, this is a unique characteristic of the stage in the EV trial as people do not have charging facilities available at home (Smart Grid Smart City, 2011).

The charging behaviour of EV drivers will likely evolve over time depending on the availability of charging infrastructure.

4.4.2 Controlled charging

Under a controlled charging approach users would be required to install a switch that allows their EV charging to be turned off during periods when the network is experiencing high demand. This could be controlled by a distribution company, a retailer or an aggregator. Consequently, all charging under this scenario will occur during off-peak periods.

Controlled charging could operate in a similar way to existing active controlled load schemes that allow distribution businesses to control water heaters.[12] This is commonly implemented using ripple control which injects a high frequency signal into the electricity supply which is then picked up by

[11] Discussions with Project Manager for the Victorian Electric Vehicle Trial. Actual data will be available within the coming months.

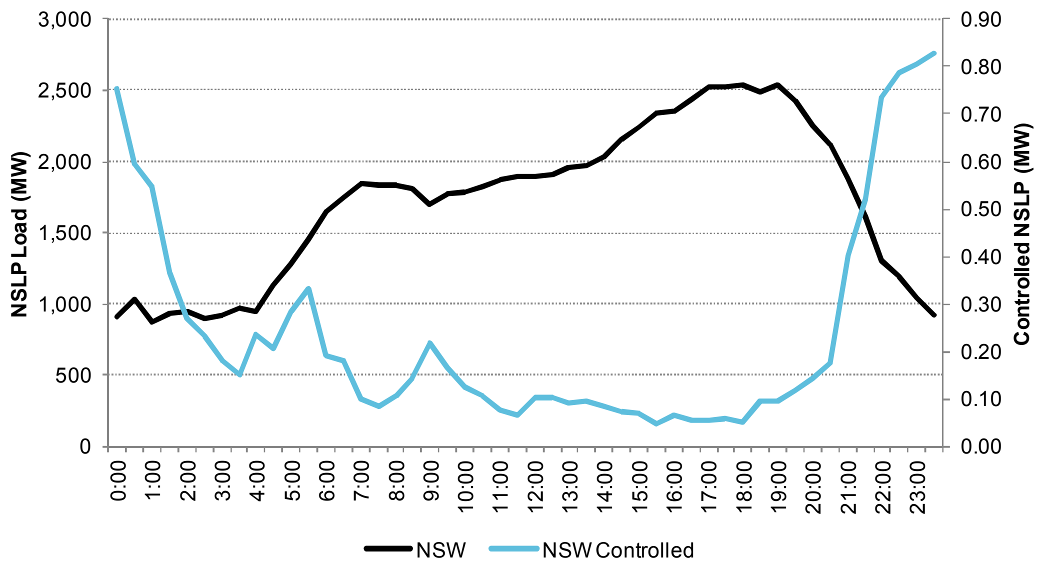
[12] Passive load control schemes move load to non-peak periods using a timer and are not controlled by the distribution business in real time.

switching equipment on the hot water cylinder. SP AusNet notes that controlled charging would need to be staggered to eliminate step changes. Staggering charging could also help coordinate charging in areas where EV take up is very high.

In Australia controlled load is currently used in NSW, South Australia and Queensland. As can be seen in **Figure 27**, controlled load in NSW successfully moves the bulk of hot water heating to the off-peak period, although using time switches rather than ripple control.

As well as moving load to off-peak periods, controlled charging would allow the market to reduce EV charging in response to unexpected network demand and increase EV charging if demand was lower. This dynamic response enables benefits beyond a peak load reduction. These are discussed further in **Section 6.2**.

Figure 27: Net system load profile for NSW: normal and controlled load (23 February 2011)



Source: AEMO (2011a)

4.4.3 Time of use charging

ToU charging would give EV drivers an incentive to charge during off-peak periods by offering a reduced tariff in off-peak periods. Similar schemes are already offered in Australia, for example Origin offer an almost 30 cents difference between peak / off-peak tariffs as shown in **Table 25.** The amount of savings will vary depending on the amount of electricity used to charge the vehicle, which varies by distance travelled. A small vehicle with medium VKT consuming around 0.2MWh a month could expect to save around $65 a month. However, a large vehicle with high VKT consuming around 0.9MWh a month could expect to save around $280 a month.[13] ToU charging could also be conveniently implemented as an automated default charging option for EV chargers, eliminating the need to remember to switch EV chargers on. However, large switching of off-peak load at a particular time can require fast response generation, priced as frequency response services in the ancillary services market.

[13] See **Table 19** for charging requirements for different vehicle types.

Table 25: Time of use tariff offered by Origin

Usage	Rate (inc. GST)
Peak Energy (Mon-Fri, 7am-9pm)	43.472 (c/kWh)
Off-peak Energy (all other times)	13.640(c/kWh)
Supply Charge	57.387 (c/day)

Source: http://www.originenergy.com.au/2933/Smart-Time-of-Use, accessed 2011

It is currently unclear how effective ToU charging is generally, and there is very little data on the impact of ToU on EVs specifically. A study of Canadian initiatives by the National Research Council Canada (Newsham 2010) reported results for general electricity demand, ranging from negligible or even negative effects on peak demand up to a 30 percent reduction in peak demand. However, EVs are likely to be more responsive to ToU pricing because EV charging is less time critical. The exception to this is a situation where EV users run the risk of not having a reliable private transport option, if they do not charge when they arrive home. As described below, this range anxiety is the basis of our ToU scenario.

The disadvantage of shifting charging to the off-peak period is that it may exacerbate range anxiety. As such, not everyone will be incentivised to charge in off-peak periods. However, two groups of users are unlikely to be affected by this concern: households with two or more vehicles (assuming at least one is a PHEV or ICE vehicle) and PHEV drivers. Our ToU scenario assumes these EV users will shift charging in response to ToU pricing and the remaining drivers will follow an unmanaged charging pattern. Households with more than one vehicle can switch to their PHEV or ICE vehicle if need be and so are unlikely to experience range anxiety. Similarly, PHEV drivers are unlikely to experience range anxiety because they can refuel at conventional service stations, if they run out of charge.

The 2006 census showed that 35. 5 percent of households in Australia owned more than one car (ABS, 2006). For the purpose of modelling the impact of ToU charging, we assume 35. 5% of EV drivers and all PHEV drivers charge during off-peak periods.

Importantly, because take up of PHEVs is higher than for BEVs in the early years, and it is believed PHEV drivers may be more likely to respond to ToU tariffs, ToU charging may be sufficient to manage the charging in off-peak periods in the early years.

According to Ausgrid (2011), implementation of ToU pricing had reached 334,000 customers at the time of release of their discussion paper, *AEMC review of strategic priorities for Energy Market Development* in May 2011. Ausgrid reports the need to service a further 1.25 million customers who are currently using an accumulation meter.

Trials have shown that technology can play a significant role in communicating price signals to customers, especially if the impact of their own behaviour can be made visible to them. In-home displays (IHDs) or web-based interfaces (portals) that can display energy usage and its consequence on price and bills allow consumers to make informed decisions about their consumption patterns leading to increased response to changes in tariffs.

4.4.4 Smart charging

Smart charging will provide the EV charger with a sophisticated communication and load management system. This will enable EV chargers to decide whether to turn on or off based on better real time information from a variety of data sources. Some of the information likely to be considered includes:

- *A retail electricity price signal:* in the simplest case retailers offer a static ToU tariff. However, retailers could also offer a changing tariff based on the time, overall household demand, and the wholesale electricity price. This would reduce wholesale price risk for retailers and possibly give EV users access to low price charging windows, throughout the day.
- *Distribution and transmission grid conditions:* distribution businesses and transmission operators may offer incentives to reduce or increase EV charging to address congestion, intermittent generation and planned and unplanned outages. Incentives could be offered

directly but are more likely to come from an aggregator who maintains demand response arrangements with EV owners.

- *Household electricity demand and available capacity:* smart charging may integrate EV charging into a wider energy management system for managing major household load including heating, air conditioning, water heating and pool pumps. By managing major loads, a household can flatten its overall load profile to stay within the physical capacity of the home circuit (avoiding upgrade costs) or any capacity limit imposed by the local distribution business.
- *User preferences:* crucially, smart charging systems will learn how much charge users need, when and how concerned their user is about running out of charge. A good example of this approach is the recently released Nest thermostat which adapts home heating to suit individual users but also allows users to adjust the temperature at will. Overtime, the Nest uses this information to determine each user preferences (Nest, 2011).

Under a smart charging scenario users are likely to face incentives at least as strong as those under ToU. However, incentives may be even stronger during periods of actual, as opposed to anticipated, periods of high demand. Consequently, smart charging is better able to shift EV charging when it counts and less likely to incentivise shifting when it is not needed. The ability to learn user preferences, will also encourage users to entrust charging to their smart charger rather than default to charging as soon as they arrive home.

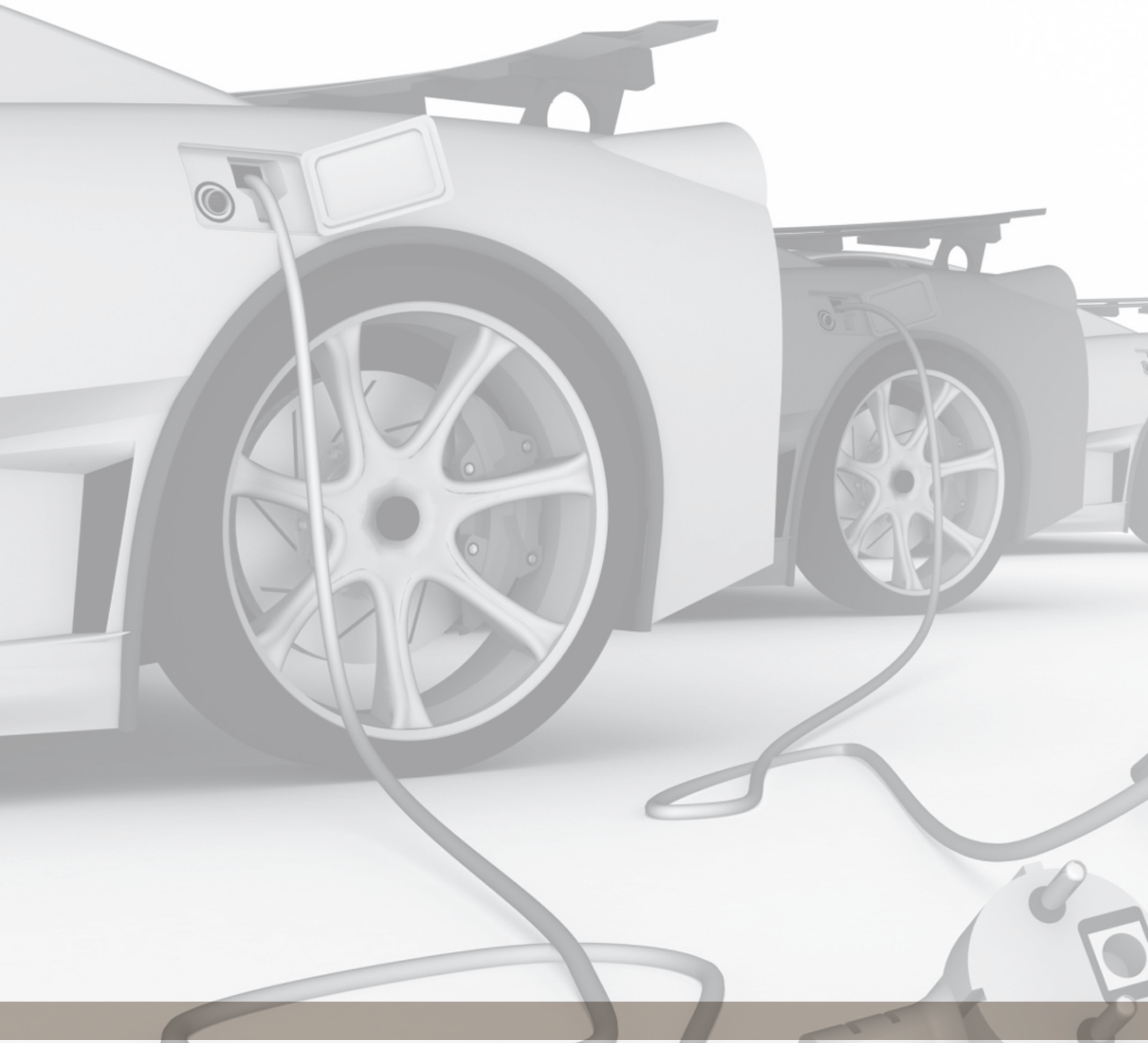
The success of smart metering in shifting EV charging activity will depend on the development and more importantly the adoption of new technology, as well as the development of business models that incentivise charging behaviour. For simplicity, we have assumed that smart charging will achieve a further 50 percent reduction in additional peak load compared to the ToU charging option.

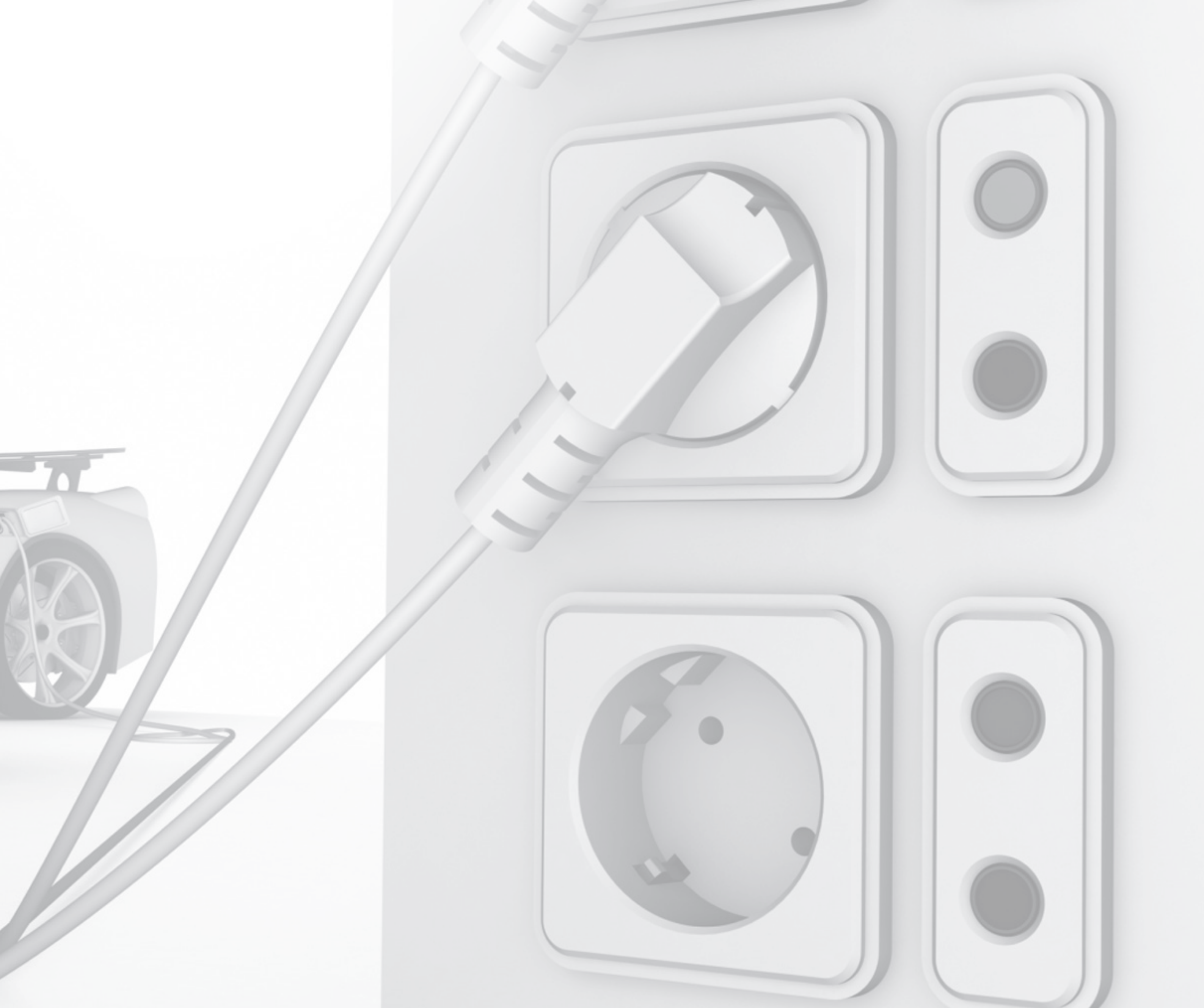
4.5 Summary of assumptions

Table 26 summarises the key assumptions on where people will charge, how much power will be required and the timing of charging.

Table 26: Summary of charge management assumptions

Assumption	Description
Where will EVs charge?	EV charging could occur at work, in parking spaces, at commercial re-charge stations and in the home. However, most charging will occur at home.
How much power will EV chargers require?	For the purposes of modelling EV impacts we assume everyone has a Level 1 charger with a charger power of 3.6kW (15A).
When will EVs charge?	
Unmanaged (Worst case scenario)	Majority of EVs are charging over the existing early evening peak load period (around 50% charging in evening peak and sensitivity with 100% and 25% charging in evening peak).
Controlled charging	All home, work and public EV chargers are controlled through time switches or ripple control scheme managed by a distribution company, a retailer or an aggregator. All EV charging occurs during off-peak periods.
Time of Use	PHEVs and households with more than one vehicle charge in off-peak periods.
Smart charging	Compared to ToU, a further 50% of users charge in the off-peak period, due to stronger incentives during critical periods.





Potential Cost to the Electricity Market

5.0

Potential Cost to the Electricity Market

This section estimates the cost to the electricity wholesale, network and retail markets of accommodating EVs. Our research and the submissions received show that the cost of increasing capacity is by far the most significant cost resulting to the electricity market from the introduction of EVs.

5.1 Assumptions and Approach

Demand for electricity has been steadily increasing and is forecast to keep growing over the foreseeable future. For all but the most extreme scenarios - unmanaged high take up-EVs will add only a fraction of the already forecast growth. Like other types of load the main determinant of cost will be the increase in peak load. Our approach focuses on estimating the additional cost of this additional peak load and then considers factors and costs unique to EVs.

Reliability

EVs will increase the overall demand for energy. All else equal, the amount of load lost due to specific network failures will increase. However, apart from this, it is unlikely that EVs will have a significant impact on the reliability of the electricity market, at either the generation or network level. In particular, it seems unlikely that the frequency or duration of outages per customer will change, for the following reasons:

- take up is likely to be gradual with enough lead time for the market to respond
- there will be appropriate intervention to prevent unmanaged charging
- we assume the electricity markets and regulation continue to work effectively and provide the right incentives for the generation and network businesses to respond to the take up of EVs.

The direct effect of any increase in peak load on electricity supply (holding everything else constant) is a decrease in the quality of service: distribution networks become less reliable, transmission becomes congested and demand may exceed the supply of generation; resulting in an increase in black-outs. However, all of these quality-of-service issues can be addressed by investing in increased capacity. The electricity market has two mechanisms for ensuring this happens:

- *The revenue and quality regulation of transmission and distribution companies by the AER:* The current regulatory system includes strong incentives for utilities to maintain and improve their quality of service.
- *The competitive market for electricity supply:* the electricity Statement of Opportunities (SoO) by AEMO is produced annually and includes assumptions about the adoption of EVs. Provided the take up of EVs is monitored and included in the SoO the market will provide the additional generation required to support EVs. Generators sell electricity into a competitive market. As supply becomes tight prices increase, providing a strong incentive for new generation. In the NEM this new generation need not be from the same state but could instead be imported via an interconnector. We assume the market will respond to EV's in the same way in the future.

The effectiveness of these mechanisms will be improved by good forecasting of EV load.

Consequently, our analysis assumes quality of service (including reliability, congestion and availability of generation) remain unchanged and the cost of maintaining this service is fully reflected in the cost of increased capacity.

Peak demand growth

Our modelling of the cost of increasing capacity to cope with EVs assumes that peak load will continue to grow or, at the very least, not diminish. If peak load does diminish, then this would provide spare system capacity for EVs to charge, reducing the cost imposed by EVs. It seems highly unlikely that peak generation demand will diminish. At the distribution level, this is less clear. In particular, developments in energy efficient appliances and in-home energy management systems could make this a reality in some locations.

Transaction Costs

This analysis does not consider the cost of transactions between DNSPs, retailers, customers and charge providers or the way these costs are affected by various business models. However, issues relating to these costs, such as metering are being considered in the AEMC review.

Our approach to estimating the cost of increased capacity

The cost of increasing capacity has been estimated in three steps:

- First, we estimate the cost of expanding distribution, transmission and generation capacity to allow for increased peak load. This approach is necessarily high level and designed to provide an indication of the magnitude of costs. As such, many issues such as losses and diversity have not been addressed in any detail. The analysis below uses published data to estimate the potential costs but utilities will have better information on the costs applicable to their local area.
- Second, we estimate the increase in peak load based on the number of EV vehicles (see **Section 3.4**) and the proportion of these vehicles charging at times of existing peak demand. **Section 4.0** develops our assumptions regarding these proportions under the four charge management scenarios and the likely power of the most common EV chargers.
- Third, we multiply the estimated cost of expansion by the estimated increase in peak load.

This approach models costs through all sections of the electricity market (distribution, transmission and generation) but only at the state level of granularity. It is likely that certain areas (particularly in early years where the market is dominated by early adopters) may experience network issues at a local level.

Many submissions, including Ergon Energy (Ergon Energy, 2012, p1), Origin Energy (Origin Energy, 2012, p8,9) and the Centre for Energy and Environmental Markets (Centre for Energy and Environmental Markets, 2012, p3), suggested more localised and dynamic analysis be undertaken to model the impacts of EVs on the electricity market. AECOM acknowledges the importance of network simulation and dynamic analysis. However, for the purpose of this study, and in agreement with AEMC, a simple approach was adopted for estimating the scale of potential impacts within the resources available to undertake this study. The additional complexity is unlikely to significantly improve the accuracy of the analysis when there is so much uncertainty around the key assumptions. Further, to undertake more detailed analysis would have required more assumptions with limited evidence to support these assumptions.

We anticipate that in due course utilities will incorporate EVs into their demand forecasting, providing much more detailed projections of system impacts.

5.1.1 Cost of increasing transmission and distribution capacity

We have estimated the cost of increasing capacity in transmission and distribution networks by analysing recent regulatory determinations by the AER. Each determination contains an estimate of capital expenditure and peak load growth during the regulatory period. A high level estimate of the cost of capacity for each distribution network service provider (DNSP) or transmission network service provider (TNSP) can be made by dividing growth related investment in one year by growth in the next, as shown below in **Table 27**, for distribution and **Table 28**, for transmission.[14] Expenditure was only categorised as *growth* if there it was clearly growth related. For instance items like "Augmentation" and "Growth". Other expenditure items, for example those related to reliability, will also be partially affected by peak load growth, but have not been included in these estimates.

Table 27: Cost of increasing capacity in distribution networks (2011$)

DNSP	state	Location	Estimated Capex / Growth ($M/MW)
Energex	QLD	Gold Coast, Sunshine Coast and Brisbane	2.8
Ergon	QLD	Country and regional Queensland	3.7
Ausgrid	NSW	Inner, northern and eastern metropolitan Sydney	2.7
Essential Energy	NSW	Country and regional NSW; southern regional Queensland	3.3
ActewAGL	ACT	ACT	2.9
Powercor	VIC	Western Victoria	2.1
SP Ausnet Distr	VIC	Eastern Victoria	2.2
United Energy	VIC	South eastern metropolitan Melbourne	2.7
Citipower	VIC	Inner metropolitan Melbourne	3.3
Jemena	VIC	Western metropolitan Melbourne	2.2
ETSA Utilities	SA	South Australia	3.5
Aurora Energy	TAS	Tasmania	4.8
Capacity weighted average			**2.9**
AusGrid Estimate			**1.2 - 4.0**

Source: AECOM estimation based on various AER regulatory determinations. See for example, Energex (2011); Ausgrid (2011); ActewAGL (2008); Powercor (2010); SP Ausnet (2010); United Energy Distribution (2010); Citipower (2010); Jemena (2010). Note: currency in 2011 prices.

Our analysis suggests that the cost of capacity is between $2.1 and $4.8 million per MW. This range is close to that proposed by AusGrid in their recent submission to AEMC, namely $1.2 to $4 million per MW.[15] Growth tends to be more expensive in the DNSPs that service rural areas, for example Aurora Energy, Ergon and ETSA Utilities. This makes sense since networks in rural areas tend to be less connected and less dense, reducing the opportunity for load sharing. In the absence of better data, the weighted average of $2.9 million per MW was used as the cost of distribution growth in Western Australia.

[14] Capex is divided by growth in the following because investments necessarily need to occur before growth actually takes place.
[15] AusGrid (2011), AEMC review of strategic priorities for Energy Market Development

Table 28: Cost of increasing capacity in transmission networks

TNSP	state	Estimated Capex / Growth (Million $ / MW)
Powerlink	QLD	0.85
Transgrid	NSW	0.90
SP AusNet	ACT	0.90
SP AusNet	VIC	0.47
ElectraNet	SA	0.37
Transend	TAS	1.66
Capacity weighted average		**0.66**
AusGrid estimate		**0.4 – 1.1**

Source: AECOM estimation based on AER (2007; 2008; 2009b); Powerlink (2011) and ElectraNet (2008).

The cost of transmission growth was estimated to be between $0.37 and $1.66 million per MW, with a weighted average of $0.66 million. Again, the range was consistent with the estimate reported by AusGrid (2011) of $0.4 to $1.1 million per MW, with the exception of Transend (again in Tasmania), which had the most expensive growth. It is worth noting that Transend owns many distribution assets which may influence their cost estimates.

It is important to note that the cost of growth may be significantly different in the future. Several factors could affect this including: changes in technology, network topology and the approach to planning and building networks. Further, as highlighted above, this analysis has been undertaken based on published data to provide an order of magnitude of the likely costs. This approach is reasonable for the purposes of this study but should not be used for any other purpose.

5.1.2 Cost of increasing generation capacity

Increases in peak load will also require an increase in generation capacity. We have assumed that the increase in generation will be met by new gas fired peaking generation. AusGrid (2011) estimates new peaking generation will cost in the range of $0.75 - $1.5 million per MW. Consistent with this range, ACIL Tasman (2008) reports that the cost of new Open Cycle Gas Turbine generation is around $0.94 million per MW (adjusted to 2011 dollars). We use the ACIL figure in our modelling.

5.1.3 Summary of estimated costs of increasing capacity

Our assumptions on costs per MW of installed capacity are summarised in **Table 29**. The total costs of increasing capacity are around $5 million per MW but vary by state. Distribution makes up the largest component of this cost accounting for between 60 to 75 percent of the total cost. Generation accounts for around 15 to 25 percent and transmission accounts for around 10 to 20 percent. Whilst the proportions vary between each state, distribution is the largest proportion for each state and will be where the majority of additional costs from EVS will be incurred. In their submission Energex commented that they believed the costs estimated in this study were reasonable (Energex, 2012, p2).

Table 29: Summary of capacity cost assumptions

State	Generation (Million $ / MW)	Transmission (Million $ / MW)	Distribution (Million $ / MW)	Total (Million $ / MW)
QLD	0.94	0.85	3.10	4.88
NSW	0.94	0.90	2.92	4.76
ACT	0.94	0.90	2.94	4.78
VIC	0.94	0.47	2.49	3.89
SA	0.94	0.37	3.54	4.85
WA	0.94	0.66	2.93	4.53
TAS	0.94	1.66	4.77	7.37

Source: Estimated by AECOM based on published information.

5.1.4 Diversity and losses

There is very little information available on diversity in EV charging load beyond that discussed in **Section 4.4**. We have taken a conservative approach to diversity, essentially assuming there is no diversity at the distribution or transmission level, beyond that outlined under the charge management scenarios. This approach, allows us to estimate the worst case scenario. However, significant diversity is likely at the state level, even in the unmanaged case, which will decrease the need for transmission and new generation.

Network losses have not been included in the analysis at this point. However, their inclusion would require slightly more transmission and generation capacity. Network losses tend to be between 2 and 5 percent of sent out generation.

5.1.5 Distribution and transmission opex

Increased system capacity may or may not lead to slightly higher operational costs in the long-term. However, we have assumed these costs are likely to be negligible for the following reasons:

- *Opex is not strongly related to peak load:* opex is mostly determined by line length and customer density rather than being directly related to peak load.
- *Capacity upgrades will replace and augment old assets with new assets.* new assets typically have lower opex.
- *On an annualised basis capital costs tend to dominate opex.* for example, an AER determination of Energex and Ergon Energy in 2009 (AER, 2009) showed annualised capital costs accounting for 75 percent of costs and opex for only 23 percent.

Although an EV related increase in peak load is unlikely to have a significant impact on opex, higher utilisation could and is discussed in **Section 6.1**.

5.2 Results

5.2.1 Impact on system peak demand

The results presented in this section refer to system peak demand as opposed to localised network peak demand.

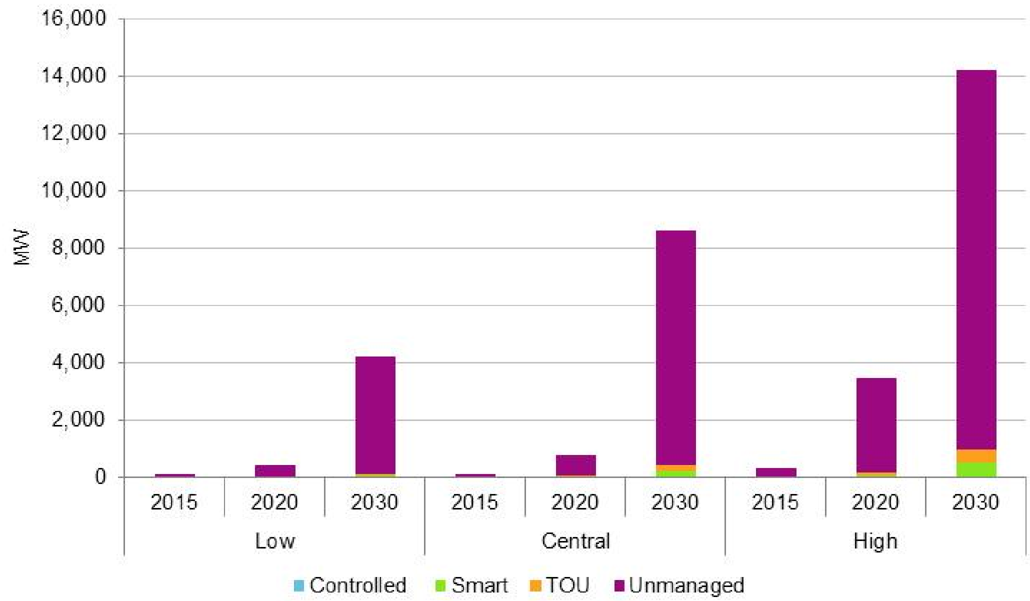
As highlighted in **Figure 28**, the impact of EVs on system peak demand depends to a large degree on the level and rate of take up of EVs as well as when charging of the vehicle occurs.

In the central take up scenario, unmanaged charging of EVs starts to have a significant impact on system peak demand around 2020. This should allow sufficient time for the electricity market to plan and manage the additional increase in peak load that may be required. However, it is possible that take up could be much quicker (as illustrated in our high take up scenario), if for example, battery prices fall much quicker than currently anticipated, in which case the impact of EVs on peak demand, if unmanaged, could be felt as early as 2015 which is just inside the five year planning cycle.

5.2.1.1 Impact of system peak demand in the National Electricity Market

If charging is unmanaged and around 50 percent of EV users come home and charge at peak periods, under the central take up scenario, peak demand is expected to increase by around 730MW by 2020 and 8.6 GW by 2030. However, if charging occurs in off-peak periods, either through incentivising customers to charge at off-peak times through time of use charging or smart metering, or enforcing off-peak charging through ripple control or regulation, the costs fall significantly. ToU charging is expected to result in an increase in system peak demand of 50MW in 2020 and around 410 MW by 2030. Smart metering could reduce this even further to an increase in system peak demand of around 25 MW in 2020 and 205MW by 2030. Controlled charging, which would ensure all charging occurs off-peak, would result in no additional increase in system peak demand.

Figure 28: Estimated additional system peak demand in NEM (MW)



Source: AECOM. Note: The above chart shows estimated additional peak demand, with increments attributable to each charging type. For example, under the central take up scenario, by 2030, with unmanaged charging 8,600 additional MW are required; for ToU charging this is 410MW and for smart charging an additional 205MW.

Table 30: Estimated additional peak demand in the NEM for various charge management options under the central take up scenario

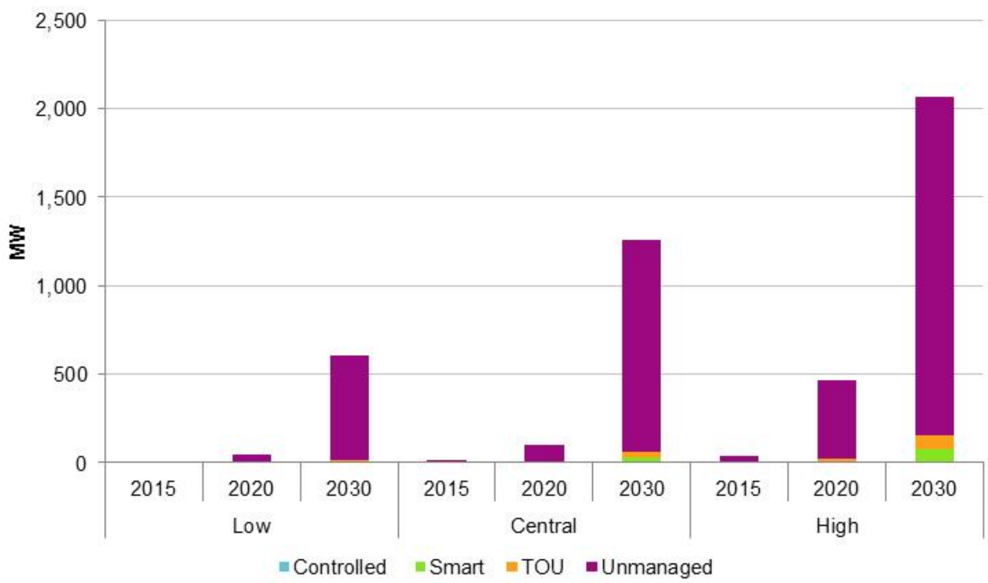
	Estimated additional EV related peak demand			
Charge management option	2020 (MW)	As a percentage of estimated growth in overall peak demand in 2020	2030 (MW)	As percentage of estimated peak demand growth in 2030
Unmanaged	730	7.3%	8600	36.5 %
Time of use	50	0.5%	410	1.7%
Smart charging	25	0.2%	205	0.9%
Controlled charging	0	0%	0	0%

Source: AECOM, MW values rounded to nearest 5MWs

5.2.1.2 Impact of system peak demand in the South West Interconnected System

If charging is unmanaged and around 50 percent of EV users come home and charge at peak periods, under the central take up scenario, system peak demand is expected to increase by around 100 MW by 2020 and 1,260 MW by 2030. However, if charging occurs in off-peak periods the costs fall significantly. Time of Use charging is expected to result in an increase in system peak demand of 7 MW in 2020 and around 65 MW by 2030. Smart metering could reduce this even further to an increase in system peak demand of around 3 MW in 2020 and 30 MW by 2030. Controlled charging, which would ensure all charging occurs off-peak, would result in no additional increase in system peak demand.

Figure 29: Estimated additional system peak demand in SWIS (MW)



Source: AECOM

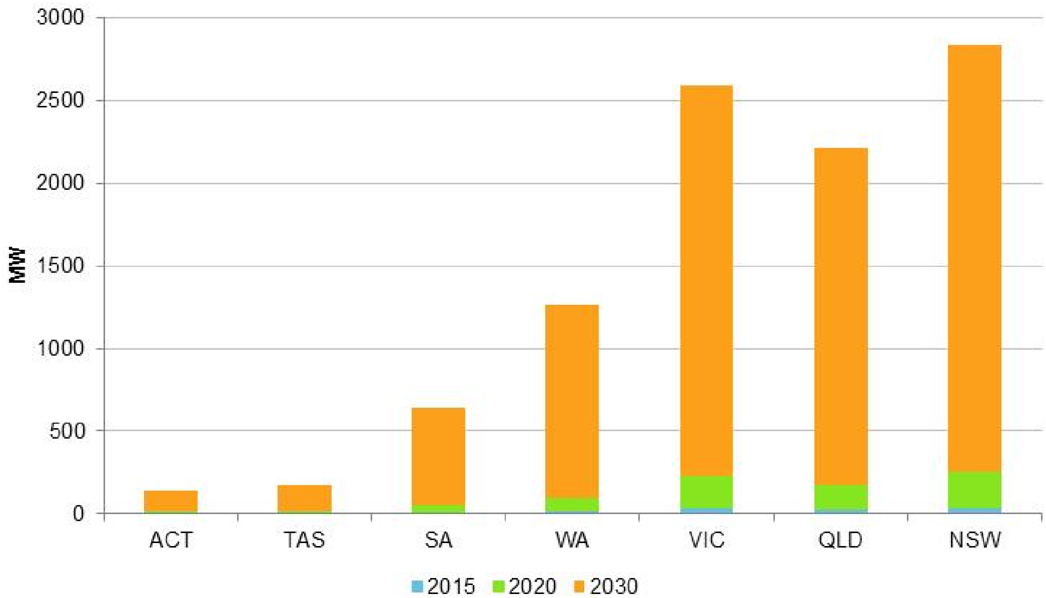
Table 31: Estimated additional peak demand in the SWIS for various charge management options under the central take up scenario

	Estimated additional EV related peak demand			
Charge management option	2020 (MW)	As a percentage of estimated growth in overall peak demand in 2020	2030 (MW)	As percentage of estimated peak demand growth in 2030
Unmanaged	100	4.8%	126 0	27.2%
Time of use	7	0.3%	65	1.4%
Smart charging	3	0.2%	30	0.7%
Controlled charging	0	0%	0	0%

Source: AECOM, MW values rounded to nearest 5MWs unless under 5MW in which case they have been rounded to the nearest 0.5MW.

The largest increases in system peak load occur in states with the largest take up of EVs (including PHEVs). As shown in **Figure 30**, the state with the largest increase in peak load is NSW, followed closely by Victoria. The increase in system peak demand is lower in more rural states (such as Queensland) and states with smaller populations.

Figure 30: Additional peak demand by state in central take up scenario if charging is unmanaged

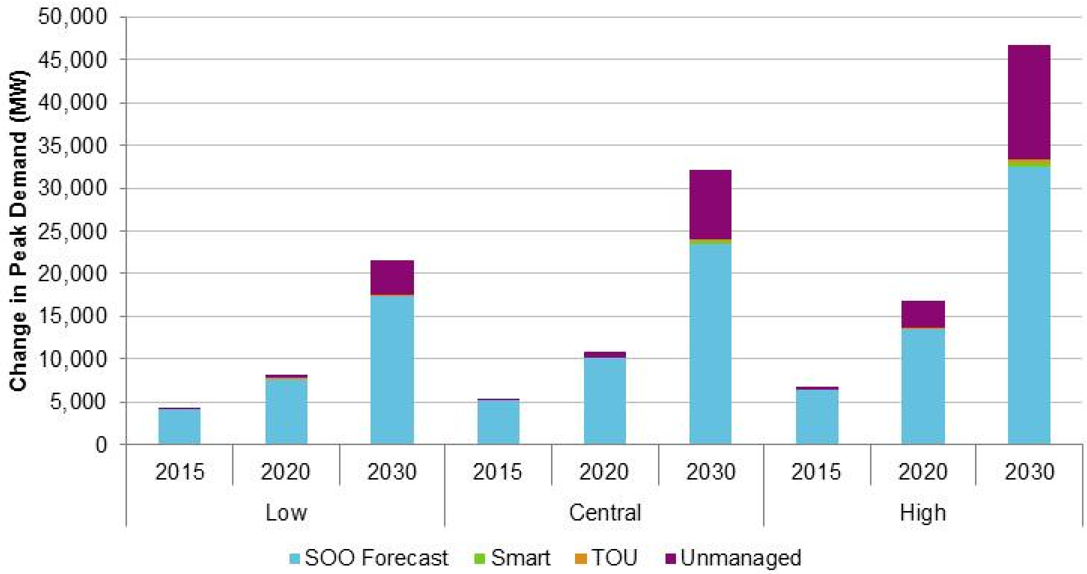


Source: AECOM

5.2.1.3 Impact of Electric Vehicles on system peak demand compared to peak demand required without Electric Vehicles

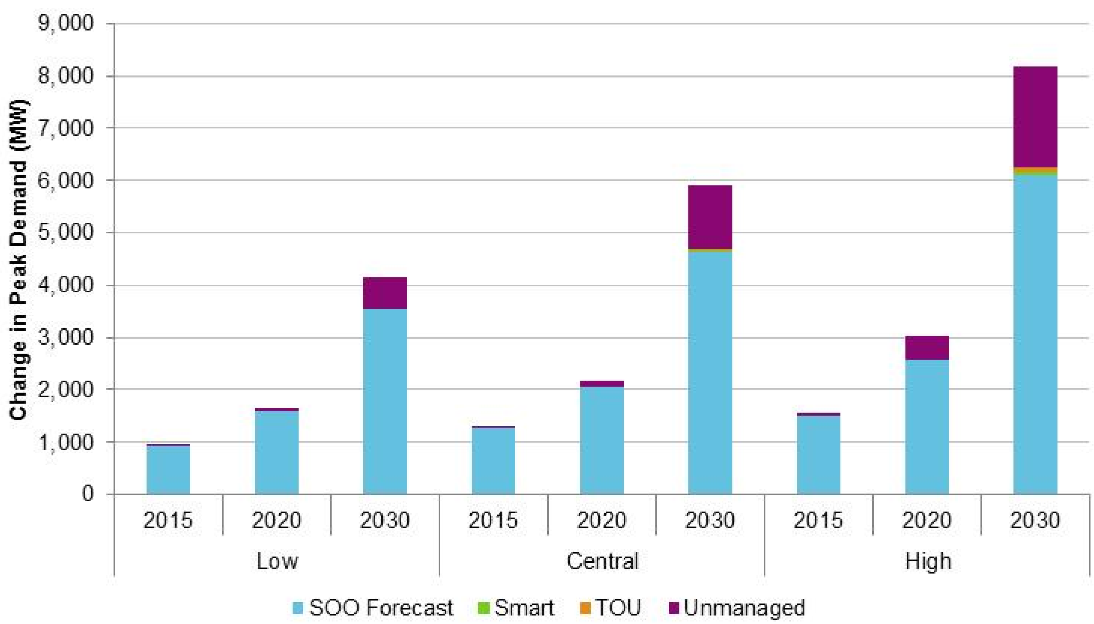
Figure 31 and **Figure 32** highlights the importance of managing charging. For both the NEM and SWIS, the increased system peak demand from unmanaged EVs is significant by 2030 compared to the increase in system peak demand required anyway. However, in the managed charging scenarios, the forecast growth due to EVs is small in comparison to growth already forecast. As a proportion of already forecast growth, EV related growth is greatest in Victoria, South Australia, and New South Wales and Australian Capital Territory. **Appendix A** shows detailed graphs for each state. This analysis is based on the AEMO 50 percent probability of exceedance (PoE) forecasts. If the 10 percent PoE forecasts are used the proportional increase is even smaller.

Figure 31: Additional system peak demand for EVs compared to additional peak demand needed without EVs - NEM



Source: AECOM and AEMO (2011a). SoO forecasts are based on the 50% probability of exceedance. SoO forecasts include a medium, low and high growth scenario representing different economic growth scenarios. These scenarios have been matched with the core, low and high take up scenarios.

Figure 32: Additional system peak demand for EVs compared to additional peak demand needed without EVs – SWIS



Source: AECOM and AEMO (2011a)

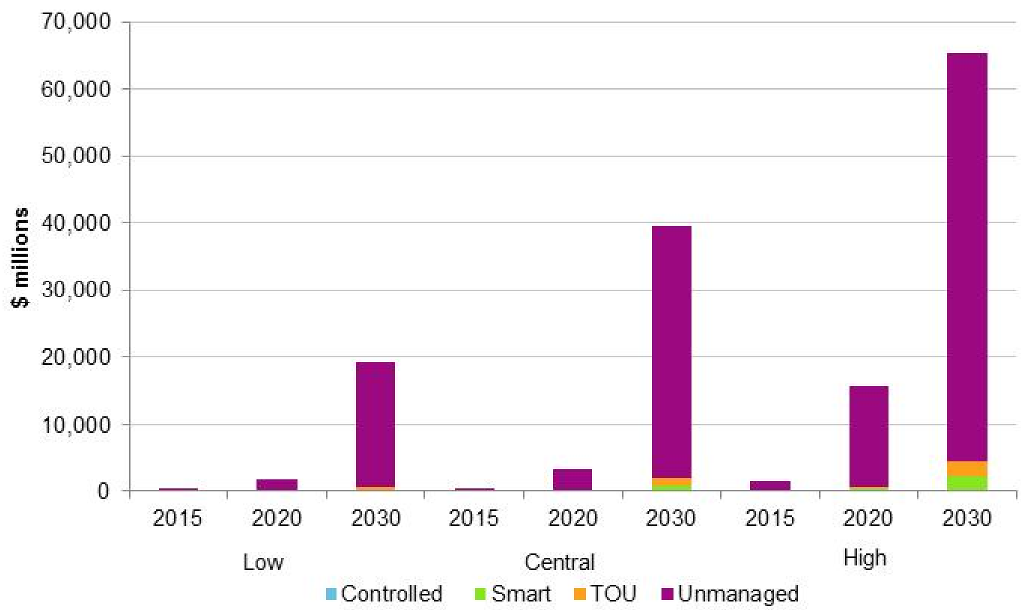
5.2.2 Cost of increased capacity

5.2.2.1 Cost of increased capacity in the National Energy Market

As described above, the estimated impact, and hence costs, of EVs on additional peak demand depends on the rate of take up and the demand management scenario used to managing charging.

Figure 33 shows that, if charging is unmanaged and everyone comes home and charges at peak periods, under the central take up scenario the cost of increased capacity in the NEM could be around $3.3 billion by 2020 and $39.5 billion by 2030. This equates to around $10,000 per EV, although the actual amount will vary by location and use profile. However, if charging occurs in off-peak periods, either through incentivising customers to charge at off-peak times through time of use charging or smart metering, or enforcing off-peak charging through regulation, the costs fall significantly. ToU charging is expected to result in additional costs of around $220 million by 2020 and $1.9 billion by 2030. Smart metering could reduce this even further to around $110 million by 2020 and $940 million by 2030. Controlled charging, which would ensure all charging occurs off-peak, would result in no additional increase in peak demand. These estimates have not been discounted to reflect timing of investments. As discussed above, in **Section 5.1.3**, the largest component of this cost will be driven by investment in distribution, which will account for between 60 and 75 percent depending on the state. Generation accounts for around 15 to 25 percent and transmission accounts for around 10 to 20 percent

Figure 33: Estimated cost (for both generation and network upgrades) of additional peak demand in NEM ($ millions undiscounted)



Source: AECOM

Table 32: Estimated cost to meet additional system peak demand in the NEM

	Estimated cost to meet additional system peak demand ($)	
Charge management option	2020	2030
Unmanaged	3.3 billion	39.5 billion
Time of use	220 million	1.9 billion
Smart charging	110 million	940 million
Controlled charging	0	0

Source: AECOM

5.2.2.2 Cost of increased capacity in the South West Interconnected System

Figure 34 shows that, if charging is unmanaged and everyone comes home and charges at peak periods, under the central take up scenario the cost of increased capacity could be around $440 million by 2020 and $5.7 billion by 2030. This equates to around $9,000 per EV, although the actual amount will vary by location and use profile. However, if charging occurs in off-peak periods the costs fall significantly. ToU charging is expected to result in additional costs of around $30 million by 2020 and $290 million by 2030. Smart metering could reduce this even further to around $15 million by 2020 and $145 million by 2030. Controlled charging, which would ensure all charging occurs off-peak, would result in no additional increase in peak demand. These estimates have not been discounted to reflect timing of investments.

Figure 34: Estimated cost (for both generation and network upgrades) of additional peak demand in SWIS ($ millions undiscounted)

Source: AECOM

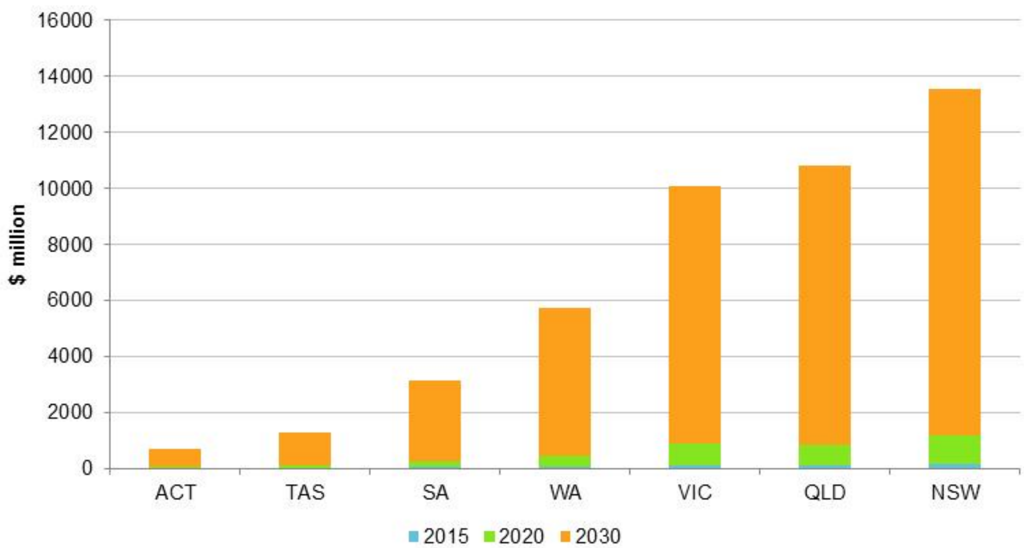
Table 33: Estimated cost to meet additional system peak demand in the SWIS

	Estimated cost to meet additional system peak demand ($)	
Charge management option	2020	2030
Unmanaged	440 million	5.7 billion
Time of use	30 million	290 million
Smart charging	15 million	145 million
Controlled charging	0	0

Source: AECOM

The impacts and costs also vary significantly by state depending on the take up of vehicles in each state. As can be seen in **Figure 35**, the impact is expected to be bigger in New South Wales, Queensland and Victoria, the states with the largest take up of EVs. Interestingly, the cost of increasing capacity in Queensland is likely to be higher than in Victoria, even though Victoria has a higher estimated increase in peak load. This is because cost of upgrading capacity in Queensland seems to be higher.

Figure 35: Costs of additional peak demand in central take up scenario if charging is unmanaged ($million undiscounted)



Source: AECOM

Overall, the analysis shows that the impact of EVs on peak demand depends on the level and rate of take up and the ability to induce charging in off-peak periods either through incentivising customers to charge at off-peak times through time of use charging or smart metering, or enforcing off-peak charging through regulation. The impacts also vary by state in line with vehicle usage and take up of EVs.

Whilst the analysis above provides some guidance to the likely take up and charging of EVs, there is considerable uncertainty, so therefore it is difficult to make precise assessments of the implications for electricity networks. The costs above are based on planned upgrades built into longer-term asset replacement plans. It is possible that there will be a rapid unexpected take up of EVs, which will result in unexpected investment at much higher cost. This highlights the importance of demand management policies to ensure the charging of EVs occurs during off-peak periods and does not impact of peak demand.

5.2.3 Sensitivity to charging behaviour

Peak load and cost outcomes are particularly sensitive to the time of charging and charger power. **Table 34** shows the peak load and cost results for a more extreme charging scenario where all EVs charge during the peak period in the unmanaged scenario. In the unmanaged case this results in a a doubling of the additional peak load and cost imposed by EVs.

Table 34 shows the peak load and costs for a more moderate, yet still realistic, charging scenario where there is 25 percent coincidence between system peak and EV charging in peak demand using a level 1 charger (15 A). In the unmanaged case this results in approximately half the additional peak load and cost imposed by EVs **Figure 57** to **Figure 67** in **Appendix A** provide further analysis.

Table 34: Results with more intensive charging during existing periods of peak demand

		Low			Core			High		
		2015	2020	2030	2015	2020	2030	2015	2020	2030
Change in peak demand (MW)										
SWIS	Smart	1	3	20	2	6	60	3	20	150
	ToU	2	6	30	3	13	120	5	40	290
	Unmanaged	19	100	1,170	23	190	2,420	80	900	3,970
NEM	Smart	7	20	110	12	50	390	20	140	940
	ToU	13	40	220	24	90	790	40	290	1,880
	Unmanaged	150	740	8,100	181	1,400	16,530	620	6,600	27,340
Cost of upgrading capacity ($m)										
SWIS	Smart	4	10	80	10	30	280	10	90	660
	ToU	10	30	160	10	60	560	20	190	1320
	Unmanaged	90	440	5,290	110	850	10,970	360	4,090	17,980
NEM	Smart	30	100	520	60	210	1810	90	660	4,330
	ToU	60	200	1030	110	430	3,630	180	1330	8,660
	Unmanaged	690	3,410	37,160	830	6,430	75,890	2,850	30,260	125,490

Source: AECOM

Table 35: Results with less intensive charging during existing periods of peak demand

		Low			Core			High		
		2015	2020	2030	2015	2020	2030	2015	2020	2030
Change in peak demand (MW)										
SWIS	Smart	-	1	4	-	2	20	1	5	40
	ToU	-	1	9	1	3	30	1	10	70
	Unmanaged	5	20	290	6	50	610	20	230	990
NEM	Smart	2	5	30	3	10	100	5	40	230
	ToU	3	10	60	6	20	200	10	70	470
	Unmanaged	40	190	2,020	45	350	4,130	160	1,650	6,840
Cost of upgrading capacity ($m)										
SWIS	Smart	1	3	20	2	7	70	3	20	170
	ToU	2	6	40	4	10	140	6	50	330
	Unmanaged	20	110	1,320	30	210	2,740	90	1,020	4,500
NEM	Smart	8	20	130	10	50	450	20	170	1,080
	ToU	20	50	260	30	110	910	50	330	2,170
	Unmanaged	170	850	9,290	210	1,610	18,970	710	7,560	31,370

Source: AECOM

5.3 Other costs to the electricity market

Whilst the impact on peak demand and costs associated with increasing capacity are clearly the major costs to the electricity markets of EV, a range of other costs may occur. This section identifies other potential costs, drawing on submissions to the AEMC Approach Paper, but due to limited available information does not attempt to quantify these costs.

5.3.1 Frequency control ancillary services

The frequency of AC (alternating current) power in the NEM changes slightly when an increase or decrease in demand (or generation) is not matched by generation (or demand). The system is allowed some tolerance and is allowed to operate in a band from 49.9 to 50.1 Hz (AEMO, 2010). To keep within these bounds the AEMO operates eight FCAS markets. Six of these are used to raise or lower frequency in response to a contingency—the loss of a generator or a large load—over 6 second, 60 second and 5 minute horizons. The remaining two, known as the regulation raise and lower markets, are used to keep the frequency within the regulated range during normal operation

EV charging could increase the amount of FCAS actions AEMO needs to take in the regulation raise and lower markets, if chargers turn on or off simultaneously. This is possible under managed charging scenarios. For instance, most automated ToU EV chargers would likely switch on at the beginning of off-peak periods. This choice of timing would provide users with more charge earlier, thereby providing greater convenience. Similar problems can easily arise under controlled charging and smart charging scenarios, if chargers collectively respond to the same signals.

Although EV charging could easily increase FCAS actions, this need not happen if the switching on of EV charging is graduated or staggered. There are relatively simple technical solutions to achieve this. Controlled load can be staggered using a multi-channel ripple control system. Similarly, smart charging could be staggered through direct communication with individual chargers. Staggering automated ToU chargers may prove slightly more difficult but may be achieved by introducing shoulder rates, in addition to off-peak rates.

While load staggering is simple to achieve from a technical perspective, it may create policy issues. Users who are allowed to begin charging first essentially receive a priority service and it is unclear how this priority service might be allocated.

5.3.2 Electric Vehicles will have the largest impact at the distribution level

AECOM's analysis and several submissions to the AEMC Approach Paper stress the impact of EVs near the customer end of the electricity supply chain. Ergon Energy notes the impacts at the distribution transformer and zone sub-station level. Energex also emphasises cost at the distribution level and argues that the cost could be even higher on the Low Voltage (LV) parts of a distribution network. Two reasons emerge for this higher cost:

- Higher cost of increasing capacity: as shown in **Section 5.1** the cost of increasing capacity in the distribution network is greater than the combined cost of transmission and generation capacity upgrades. One reason for this is that the quantity of assets (for instance length of line) per customer increases further down the supply chain.
- Diversity is lower at the distribution level: as noted in the Energex submission "The least diversified component of the electricity supply chain is the low voltage distribution network" (Energex, 2011, p.4). Diversity decreases further down the supply chain because assets service fewer customers, raising the possibility simultaneous use of network assets.

Distribution level impacts therefore warrant further consideration and charge management solutions may be most effective if they are responsive to distribution level constraints. The ENA goes even further arguing that "The ability of distribution businesses to control or at least influence the time and rate (in terms of kW) of EV charging will determine the level of impact" (Energy Networks Association, 2011, p.3).

5.3.3 Electric Vehicle clustering and local coordination

Ergon Energy notes that "The uptake of EVs is likely to vary by location reflecting the socio-economic attributes of their customers in geographic areas" (Ergon Energy, 2011, p.4). Broadly, take up is likely to be higher in affluent areas where the population share more environmentally focused values. If charging is unmanaged, this localised take up may create clusters of EV users that require rapid capacity upgrades of their local network and incur costs that are then spread over all customers in served by that DNSP.

Clustering may even create overloading in off-peak periods if several users decide to charge during the same off-peak period. This is most likely under a ToU charging regime, where automated ToU EV chargers would collectively turn on at the beginning of the off-peak or shoulder tariff period.

Upgrading the network may be avoided if EV users and local DNSPs can coordinate charging to ensure local diversity. This is important not only to avoid overloading the network, but also to avoid step changes in load (SP AusNet submission). SP AusNet notes that this can be achieved by staggering controlled load.

Smart charging may offer another solution if the controller has the ability to influence the rate and timing of EV charging in real-time at a neighbourhood or even individual level. However, this fine level of influence will likely lead to greater complexity and cost and this may be acerbated by an incentive, rather than using a command and control, approach.

5.3.4 Rural Electric Vehicle users

Rural drivers tend to cover greater distances, which will initially not be suited to the range of EVs. Rural take up is therefore expected to be low. However, where take up does occur, the impact on network is likely to be greater. There are two main reasons for this. Firstly, the cost of upgrading rural networks is already generally higher. Secondly, as noted by SP AusNet rural single phase substations typically have a very low capacity and so even one or two EV chargers could overload the system.

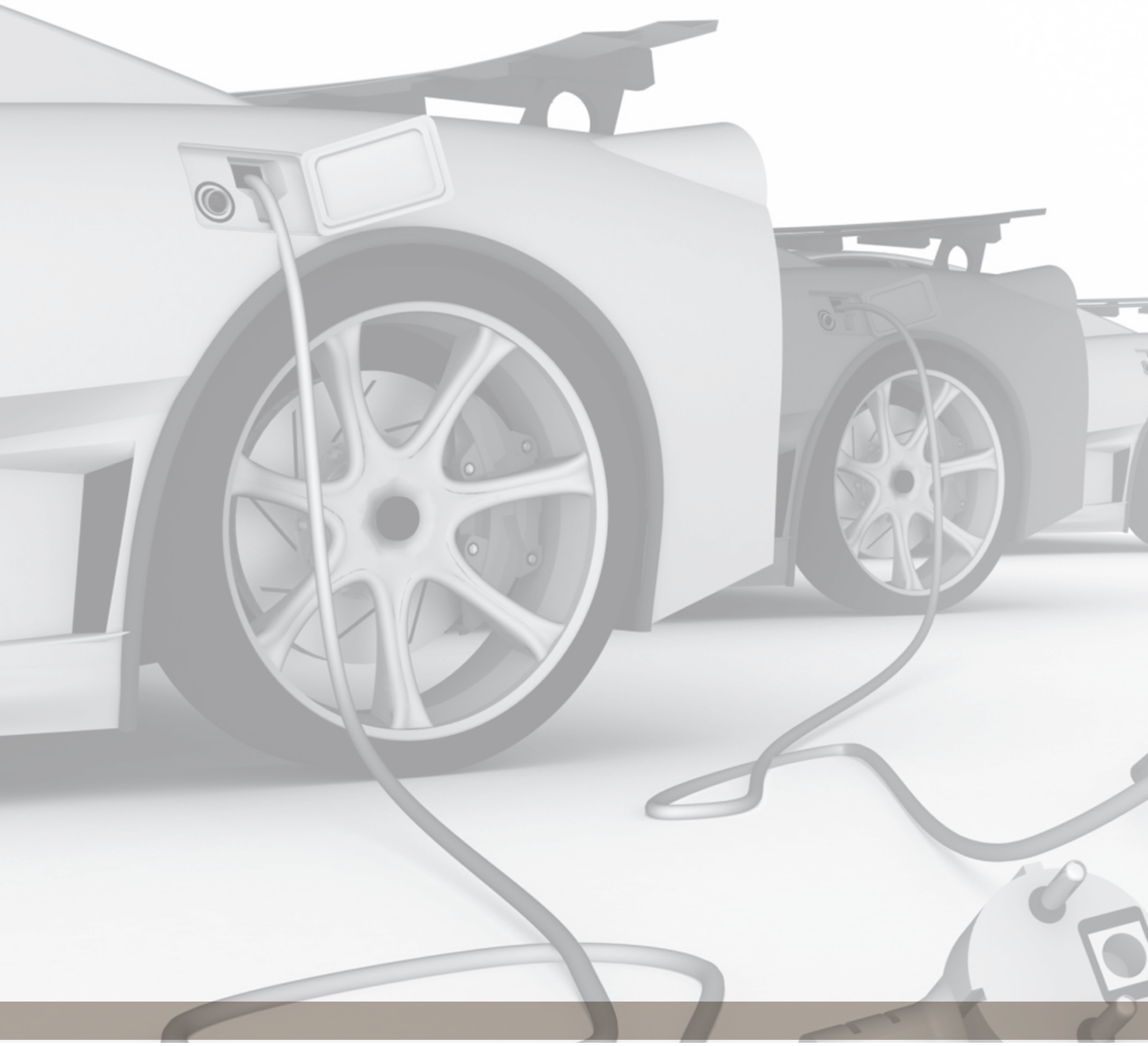
5.3.5 Network protection

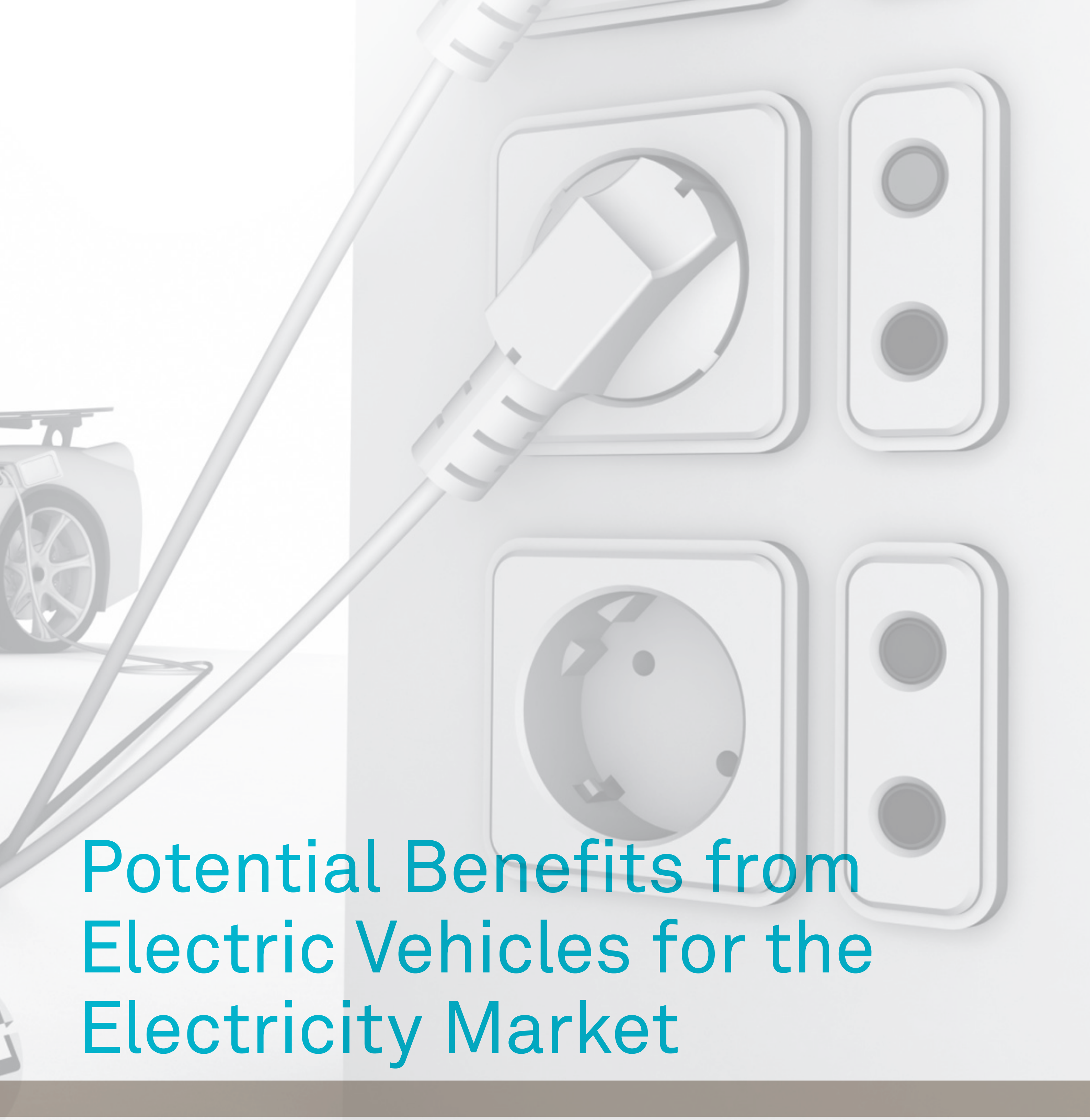
Energex notes that EV charging has the potential to affect network protection arrangements and that these impacts would cost more if take up is rapid. However, Energex also notes that this issue is not unique to EVs and only needs to be considered when particular arrangements to support EVs are being considered.

5.3.6 Metering and Electric Vehicle charge control systems

Our results show that controlled and smart charging have the lowest overall impact on peak load. However, TRUenergy notes that controlled or smart charging may also have their own costs including:

- *Development of new IT and communication systems:* dynamic EV charging systems will take account of current conditions in the network and market. Consequently, DNSPs, EV users and potentially retailers will need to invest IT and communications systems capable of sending, receiving and processing real-time market and network data.
- *Development and operation of tariffs:* DNSPs and retailers will need to develop new tariffs for controllable and smart charging. This leads to higher costs in both cases. However, in the case of smart charging, the tariff is likely to be considerably more complicated, imposing higher costs and risks for the business.
- *Separate metering arrangements:* charge management solutions which apply different tariff arrangements to EVs compared to the rest of the household load will likely require separate meters. The installation of new meters will be costly. However, this cost may be partially reduced if new meters are able to automate functions such as meter reading.





Potential Benefits from Electric Vehicles for the Electricity Market

6.0

Potential Benefits from Electric Vehicles for the Electricity Market

6.1 Improved load factor of network assets

An improved load factor of network assets allows the electricity system to deliver more energy with the same assets. If the market was efficient, customers should benefit from a lower electricity price than they would pay in the absence of EVs. This section estimates how much lower residential electricity prices might be for the delivery of electricity. However, it is important to recognise that this is not a new economic benefit but a financial transfer to non EV electricity consumers.

6.1.1 Assumptions and approach

6.1.1.1 Calculating the percentage decrease in fixed costs

If the absolute cost of the electricity system remains the same but demand increases then the average cost per unit of demand will decrease.

In order to keep costs constant (with the addition of EV charging load) we base our estimate on off-peak demand only, since an increase in peak demand imposes costs (already addressed in **Section 5.0**).

6.1.1.2 Energy assumptions

Transmission level energy assumptions are shown below in **Table 36** and distribution level assumptions are shown in **Table 37**.

Table 36: Transmission level energy demand assumptions (MWh)

State	2015	2020	2030*	Average Growth (%)
QLD	72,924	90,657	159,315	5.8%
NSW + ACT	81,637	88,844	105,157	1.7%
VIC	53,115	60,639	76,122	2.3%
SA	16,401	18,017	22,617	2.3%
TAS	12,499	14,192	17,816	2.3%
WA	35,000	40,000	45,515	1.3%

Source: AEMO (2011a) (for NEM data); CMEWA (2009). *The estimated for 2030 is extrapolated based on average energy growth.

At the distribution level customers can be divided into half hourly metered customers, who are typically large industrial users, and commercial and residential customers. We have based our estimate of the decrease in residential prices, off the existing demand at the distribution level from commercial and residential customers, which is approximated by Net System Load Profiles. However, this is only an approximation and since industrial users do in fact share parts of the distribution network assets, especially at the high voltage and sub-transmission level. Consequently, the estimate of price decreases at the distribution level is likely to be optimistic.

Table 37: Distribution level energy demand assumptions (MWh)

State	2010	2015	2020	2030
QLD	18,562	27,758	34,508	60,642
NSW	18,530	20,197	21,980	26,015
ACT	1,495	1,630	1,774	2,099
VIC	17,611	19,681	22,469	28,206
SA	5,800	6,781	7,449	9,350
TAS	2,711	3,027	3,436	4,314
WA	22,247	23,958	27,381	31,156

Sources: Net System Load Profiles published by AEMO (2011a), Wessex Consult (2010). Notes: 2015, 2020 and 2030 estimates are based on average growth in **Table 36**.

6.1.1.3 Calculating the decrease in residential tariffs

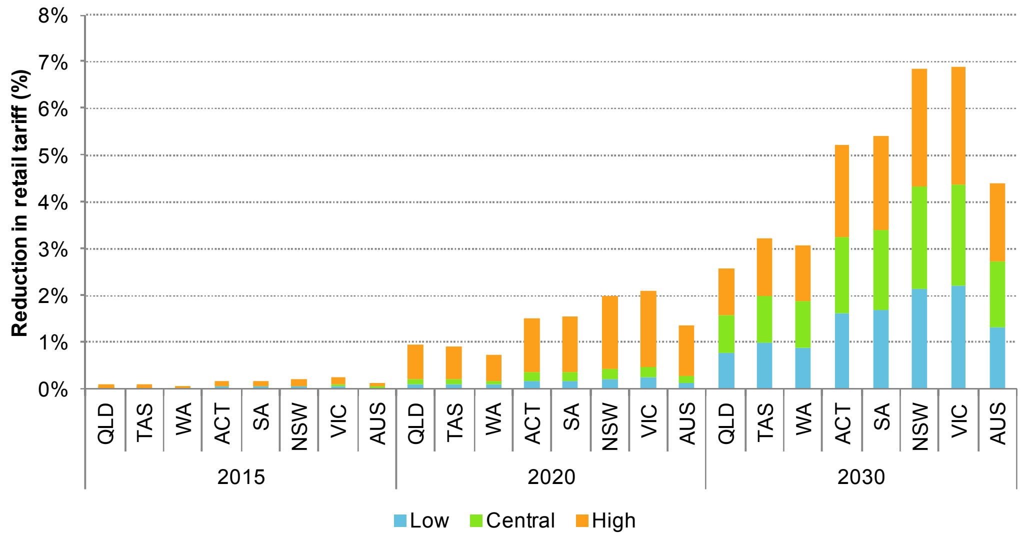
To calculate the percentage change in residential tariffs we add the percent change in cost for transmission to that of distribution, weighted by their contribution to residential tariffs. We assume transmission makes up 11 percent and distribution 44 percent of residential tariffs. These assumptions are consistent with Garnaut (2011, p.8) who states that "About 10 percentage points of the movement costs are for transmission and 40 percent for distribution" and Treasury modelling which shows that network costs will actually make up around 55 percent over the next 20 years (Treasury, 2011).

6.1.2 Results

Figure 36 provides an estimate of the potential reductions in retail tariffs from improved utilisation of network asset assuming controlled charging. Controlled charging ensures 100 percent off-peak charging and as such represents the maximum benefit. The impact of time of use and smart metering depends on its success at shifting charging into off-peak periods. The results highlight the potential reduction in retail tariffs is directly linked to the timing of EV take up, with the larger reductions occurring towards 2030 when take up is higher.

Across the study area, the potential reduction in retail tariff is up to 5 percent in the high take up scenario by 2030 compared to what might happen otherwise. However, the potential savings vary from around 2.6 percent in Queensland to around 7 percent in New South Wales and Victoria. This difference is driven by higher take up rates and the base level of electricity demand. For example, as highlighted in **Table 37**, Queensland currently accounts for around 20 percent of energy demand but by 2030 this is expected to grow to around 40 percent.

Figure 36: Estimated reduction in retail tariff from improved load factor of network assets with off-peak charging (assuming controlled charging)

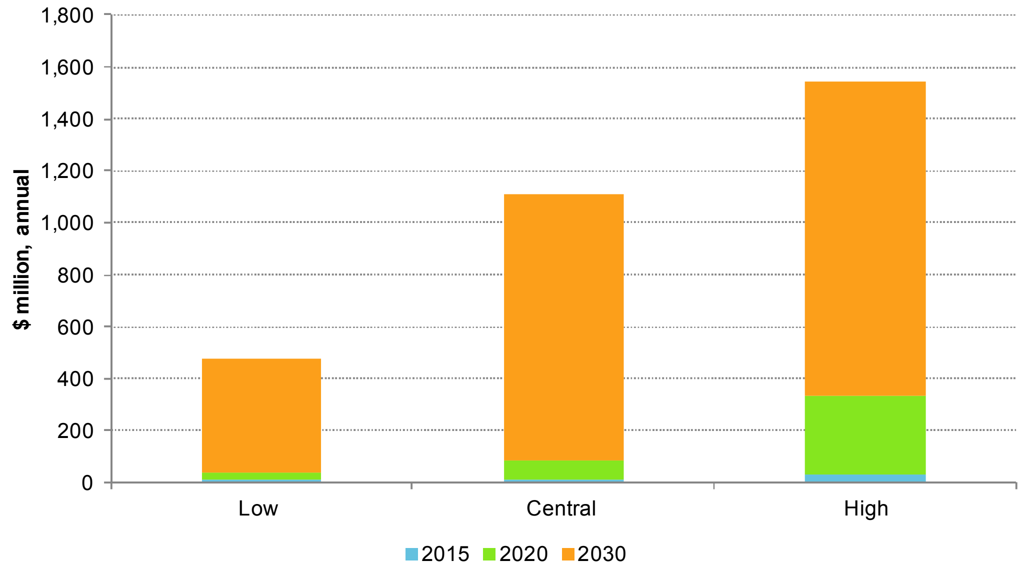


Source: AECOM

Figure 37 shows the estimated value from reduced retail prices in the NEM under controlled charging. Again, the value depends on the take up scenario but could potentially range from around $7 million to $28 million a year in 2015, $35 million to $330 million a year by 2020 and $475 million to $1.5 billion a year by 2030 compared to what might happen otherwise. It is clear, even in the low take up scenario, that as take up increases the potential benefits from improved load factor of network assets are significant.

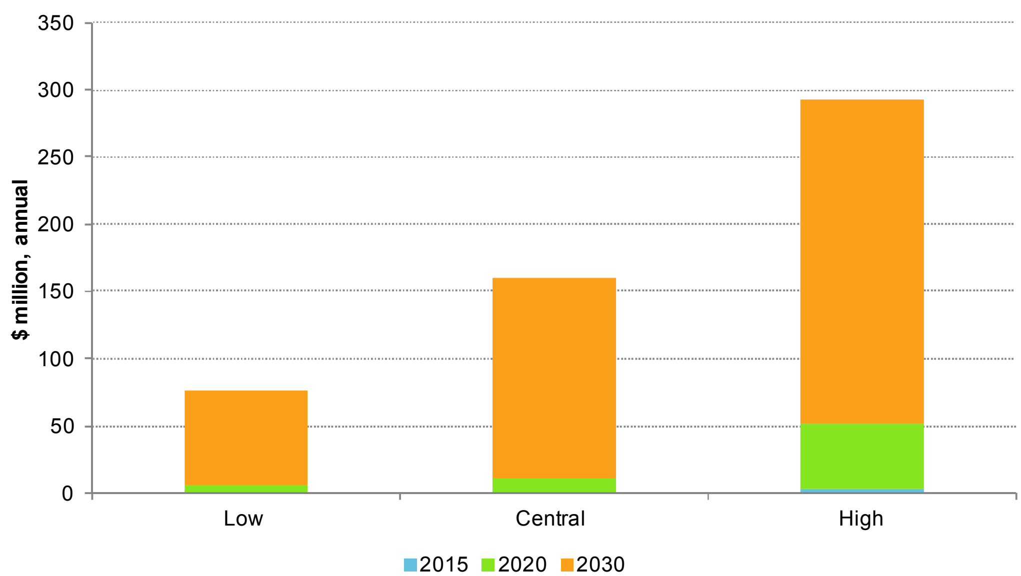
Figure 38 shows the estimated value from reduced retail prices in the SWIS under controlled charging. Depending on the scenario, the value of reduced retail prices could range from $1 to $4 million in 2015, $5 to $45 million by 2020 and $70 to $240 million by 2030.

Figure 37: Estimated value from reduction in retail tariff from improved load factor of network assets with off-peak charging (assuming controlled charging) - NEM



Source: AECOM

Figure 38: Estimated value from reduction in retail tariff from improved asset load factor with off-peak charging (assuming controlled charging)- SWIS



Source: AECOM

6.1.2.1 Discussion

An improved load factor was clearly identified as a major potential benefit in many of the submissions, including Ergon Energy, Energex, Western Power, SP AusNet and the University of South Australia. Both Western Power and the University of South Australia highlight the direct link between improved load factor and pricing, which is also borne out in AECOM's analysis. Ergon concurs that this would lead to downwards price pressure.

6.1.3 Impact of improved load factor on generation

A higher load factor will also benefit generation, by enabling higher profitability. However, these benefits are unlikely to flow on to customers until the generation mix changes and in the short run prices may even be higher as the market adapts. In the short run, off-peak prices will likely rise, increasing the return to capital intensive base load generation. As a result, in the medium to longer term we should expect more base load generation and because this new generation is also available during peak periods, lower peak prices. The result overall should be a decrease in price volatility and average electricity bills. However, average prices over the course of a full day may go up or down.

The West Australian energy market includes a separate market for capacity, the Reserve Capacity Scheme. Consequently, at least part of the capital cost of new generation is recovered through the capacity market leading to less volatility and lower peak prices than would otherwise be the case. This muting affect is likely to reduce the impact of EVs on wholesale prices. There may be a need for the Independent Market Operator (IMO) to review the allocation of reserve capacity credits and reserve capacity requirements as EVs are introduced.

6.1.4 Operating and maintenance costs

Improved load factor of network assets may have other costs in terms of increased operating and maintenance costs and reducing the life of the asset. ChargePoint notes in their submission that "the introduction of mass market EV's will accelerate the need for replacement and upgrading of ageing or inadequate infrastructure" (ChargePoint, 2011, p4). This section substantially addresses the need to upgrade inadequate infrastructure. However, EV charging may also accelerate the deterioration of some assets, transformers in particular, by extending the period of time assets operate at or above rated values. This may be a particular problem where EV charging extends the period of peak demand into the evening. SP AusNet also alludes to this in their submission stating that "consideration will be required of the impact of improved utilisation on the life of assets" (SP AusNet, 2011, p10).

6.2 Potential Flexibility Benefits

The use of smart metering for EV charging which will expose electricity consumers to real time costs of consuming electricity provides flexibility benefits to DNSPs, TNSPs and retailers. Theses flexibility benefits will provide opportunities for increased revenue for retailers and generators. Network businesses will face the biggest cost from EVs (see **Section 5.1.3**). However because they are regulated and their prices are capped, they have limited opportunities to capture the benefits EVs can provide.

This section discusses the additional potential benefits that arise from the flexibility offered by controllable and smart charging, in particular:

- how much flexibility can EVs provide?
- how can EV charging flexibility be used?

Flexibility in the electricity market is the ability to adapt to changing conditions in real time. This flexibility could allow EV users to take advantage of unexpected or local opportunities in the generation, transmission or distribution sectors, or react to unexpected constraints to avoid unnecessary cost. The key to providing flexibility is the ability to react in real time rather than in a planned way. Static schemes for demand management, such as ToU charging and controlled load through a timer cannot provide these benefits.

Flexibility can technically be provided by either controlled or smart charging. However, to be successful appropriate incentives need to be provided. This could include real time price signals from either retailers, distributors or an intermediary such as an aggregator. These options will be explored in more depth in step 4 of this study (See **Table 3** for an overview of the overall study framework). Here we merely identify the potential benefits, and assume that EV users are exposed to incentives commensurate with the real time cost of consuming electricity, currently borne by DNSPs, TNSPs, and retailers.

6.2.1 How much flexibility can Electric Vehicles provide?

How much flexibility is available at any time depends on how much power can be turned on or off at that time. At one extreme, all EVs would be connected and able to be switched on. **Table 38** shows the potential flexible load from EV charging, in the situation where all EVs are connected to the grid. Somewhere near this amount may be available in the late evening or morning, if workplaces have charging facilities. However, most of the time only some EVs will be plugged in and available.

Flexibility is also unlikely to be symmetrical in the sense that same amount of power can be turned on as turned off at one time. The amount of power that can be turned on and off will depend on the time of day because of the charge level. For example, in the early evening when most vehicles are expected to be charging there will be more load to turn off than to turn on. Also, in practice, there is likely to be limited ability to reduce load at peak periods if a ToU charging regime is used, since this would tend to move most load to off-peak periods anyway. One solution to this may be V2G, which is discussed further in **Chapter 7.0**.

Table 38: Potential flexible EV load (with all EVs connected)

Market	Low			Central			High		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
Level 1 charging (15 amps) - MW									
NEM	151	744	8,099	181	1,404	16,533	624	6,602	27,341
SWIS	19	97	1,168	23	188	2,422	81	904	3,969
Level 2 charging (32 amps) - MW									
NEM	322	1,586	17,277	387	2,996	35,270	1,331	14,083	58,328
SWIS	41	206	2,491	50	402	5,167	172	1,928	8,468

Source: AECOM

The availability of widespread charging infrastructure will increase flexibility by allowing users to connect to chargers more often. The sale of flexibility may even provide a small income stream to help fund public and work place charging points.

The rate and timing of charging may also prove important, since fully charged vehicles (unless they have V2G capacity) are unable to offer any flexibility to the network. This suggests that there is value in diverse charging times, even during off-peak periods. This runs counter to the interests of EV owners who, in the absence of incentives, will be keen to charge as soon as possible.

6.2.2 How might Electric Vehicle charging flexibility be used?

Flexible EV load may have several uses, including:

- congestion and network management
- managing price risk
- making use of intermittent generation.

6.2.2.1 Congestion and network management

Transmission can become constrained either during periods of high demand, planned outages or unexpected asset failures. At the transmission level, this can increase the risk of lost load or actually result in lost load. In some cases, the transmission service provider will be able to put in place temporary (but potentially expensive) measures to support the network, in others the network will have to operate at lower level of reliability. Dynamic EV charging can help by reducing charging activity and peak load during these critical periods.

At the distribution level, dynamic flexible EV charging can operate in a similar way, helping DNSPs address high demand, planned outages and asset failures. The distribution benefit is likely to be much higher than transmission benefit, because EV charging will make up a proportionally bigger share of the load. DNSPs will realise these benefits through existing reliability incentive schemes and potentially through reduced costs during planned maintenance. At the margin, networks may also be able to delay some network augmentation.

In the case of controlled charging, ripple control provides a very clear and existing mechanism to allow DNSPs or TNSPs to influence EV charging. However, this comes at the cost of consumer control. Incentivised behaviour through smart charging could offer an alternative.

6.2.2.2 Managing wholesale price risk

Retailers offer residential customers a fixed price but pay the market price. Consequently, retailers carry price risk that is ultimately passed on to customers through higher prices. Smart charging could help manage this risk by allowing EV users to react to the current retail price, buying less when prices are high and more when they are low. Overall, this would lead to lower average prices for EV owners and reduced price risk for retailers. However, it is unclear if this would be passed on directly to EV owners or to customers more generally. In the long term, better management of price risk would likely further impact the generation mix in much the same way as that described in **Section 6.1.3**, increasing the amount of base load generation.

Both AusGrid and Western Power noted the potential value of flexible EV charging in managing wholesale price risk. Western Power noted that, in Western Australia, flexible EV load is likely to have the biggest effect on the half hour ahead market for balancing energy (Western Power, 2011). AusGrid also noted that flexibility in the West Australian market could be valued at $186,000 per MW per annum - the penalty for unmatched demand (AusGrid, 2011).

Smart charging could manage price risk by supplying a real time price signal or some other incentive, either through an aggregator or directly from the retailer. The opportunity to manage price risk through controlled load depends on who is responsible for managing the load. In the past, controlled load has been directly managed by DNSPs and is generally directed at whole areas rather than specific retail customers. Consequently, controlled charging may not be as effective. However, it should be noted that DNSPs will tend to reduce controlled load during periods when prices are high - indirectly managing retail price risk - and DNSPs may also contract to act on behalf of retailers. How and when this happens and the treatment of revenue arising from these actions should be considered in more detail.

6.2.2.3 Integrating intermittent generation

Intermittent generation, such as wind and solar, create price volatility in the electricity market. First, because the market cannot rely on intermittent generation to run, additional dispatchable generation is needed to cope with peak load. Second, wind and solar generation have zero fuel costs and so can, when they are operating, deliver large amounts of energy to the market, at very low prices. The Renewables 2011 *Global Status Report* (Ren21, 2011) notes that the increased share of renewable energy into the grid creates reliability and stability issues and has raised concerns in places like in Germany and Spain with respectively 14and 21 percent of electricity coming from intermittent renewable energy.

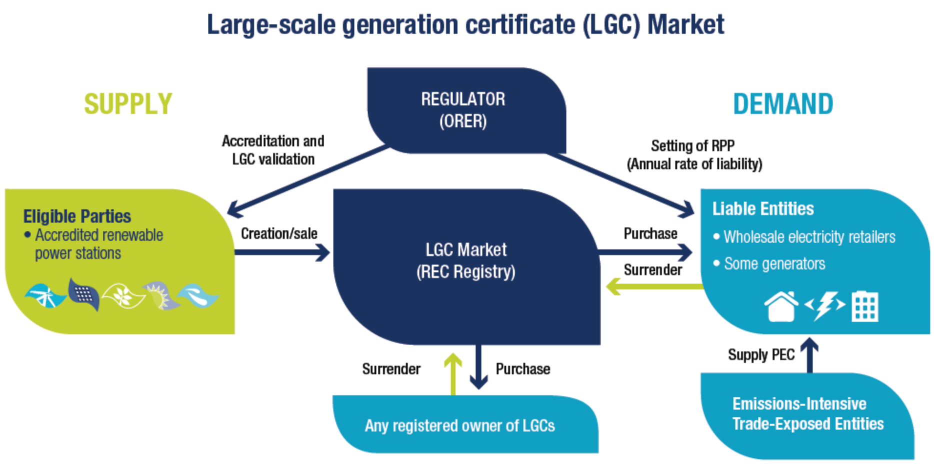
Large amounts of electricity are sometimes generated at night when demand is low. By encouraging EVs to charge at night renewable resources can be managed more effectively. Origin Energy and the University of South Australia both noted that smart charging has the ability to help integrate renewable generation by absorbing fluctuations in generation. Essentially, this would involve EVs taking advantage of low prices (provided by a real time price signal) and charging when intermittent generation is available. Efficiency in the wholesale or ancillary services market could also be improved by aggregators matching uncertain supply, such as renewable generation, with variable load, such as EVs. The existing market design should enable price signalling, for example, higher off-peak demand should increase off-peak prices.

EVs also offer the possibility of distributed storage, if they can feed back into the grid. This is discussed **Chapter 7.0**.

Interaction with the existing renewable incentives

Flexible EV charging has the potential to facilitate intermittent renewable energy. However we need to consider what interaction this will have with the existing incentives, under the LRET. Currently, the LRET sets an overall target for renewable energy in Australia. To meet this target the ORER allocates individual renewable energy targets to liable entities, including wholesale electricity retailers and some generators. To demonstrate compliance, liable entities buy LGC from the LGC market, which are in turn earned and sold by renewable energy generators. This system, which is also known as the market for Renewable Energy Certificates (RECs) is illustrated in **Figure 39**.

Figure 39: The renewable energy certificate market



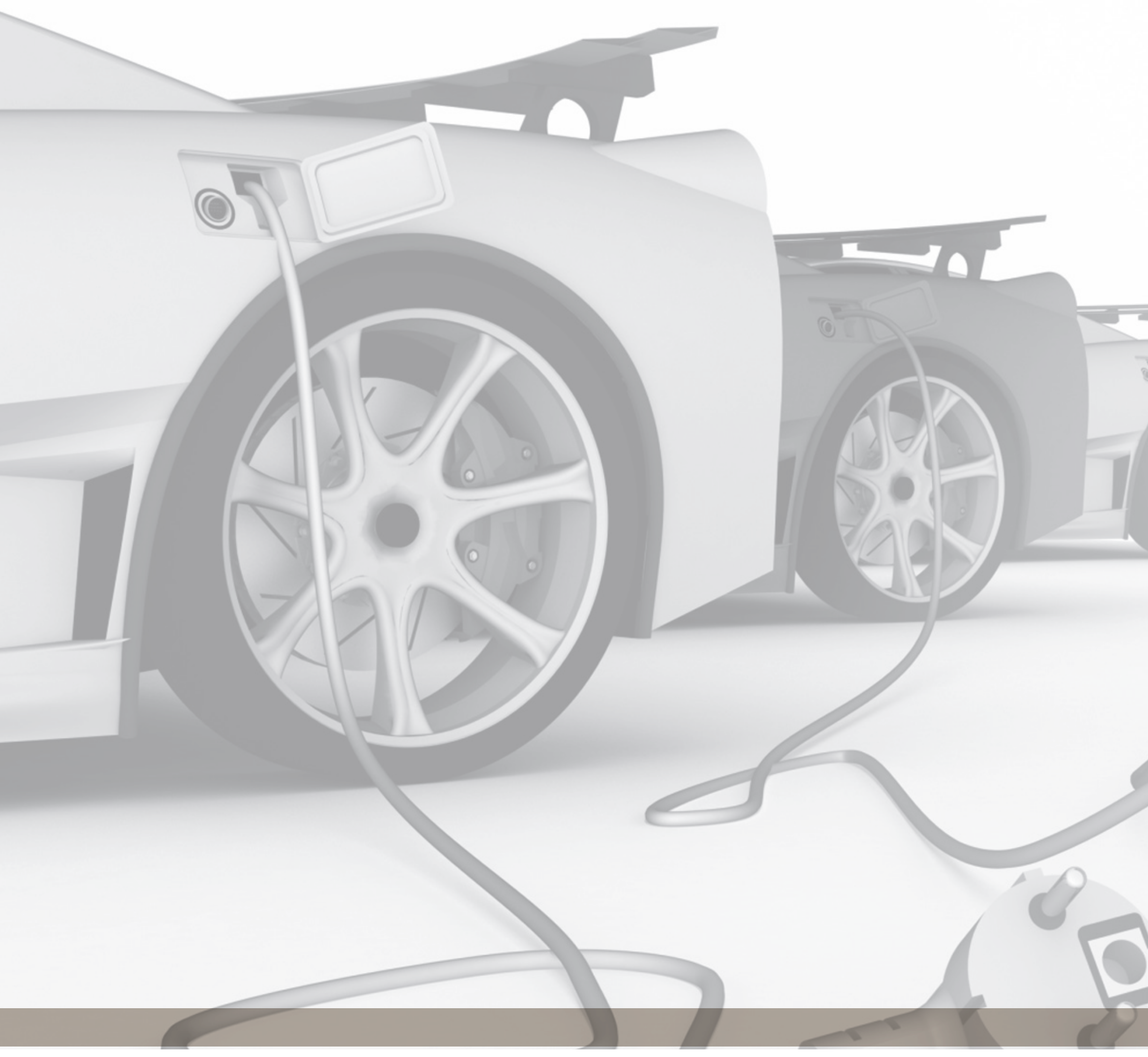
Source: ORER (2011)

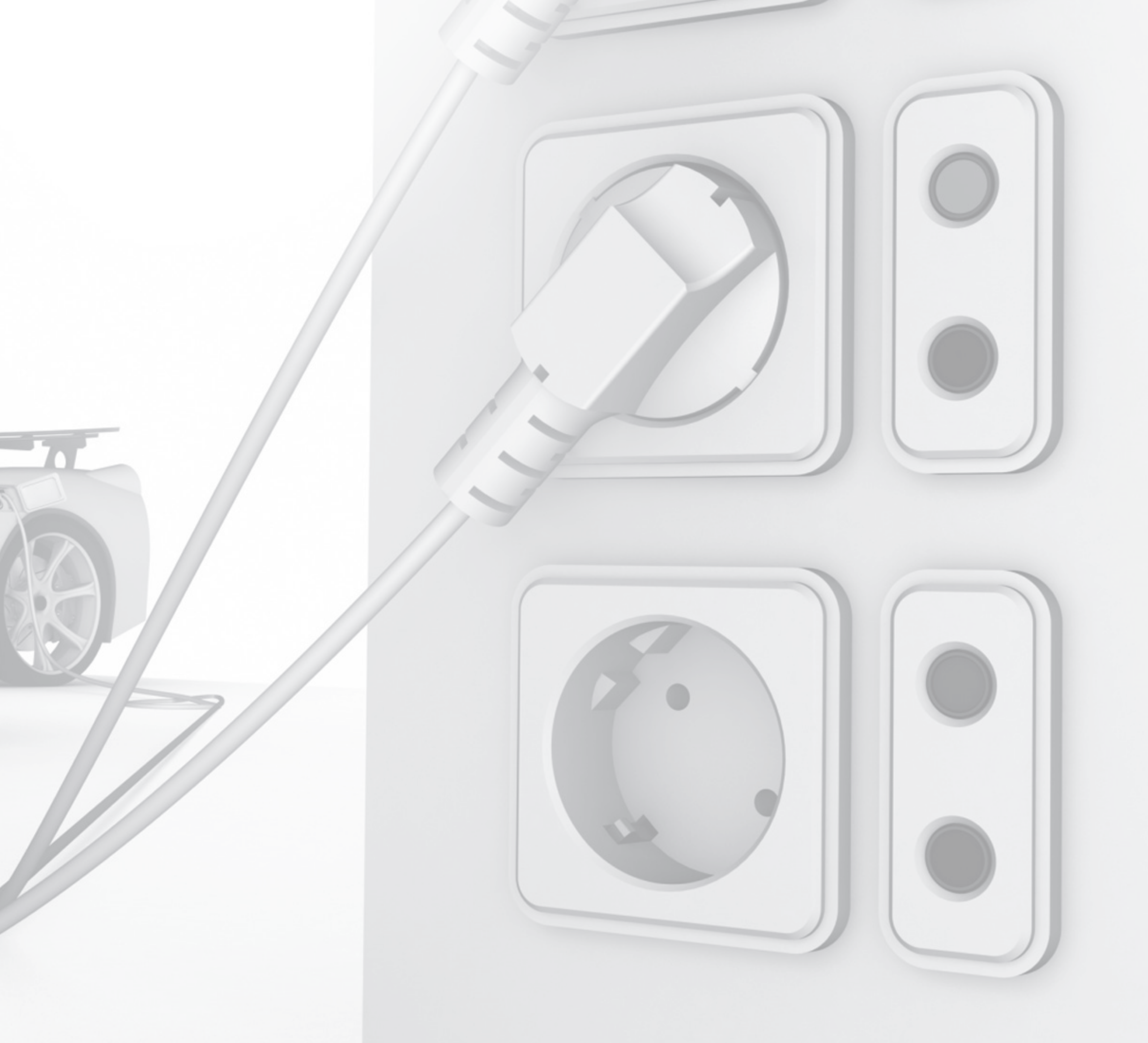
Flexible EV charging, matched to intermittent renewable energy generation, is likely to interact with the REC market. Greater use of intermittent generation by EVs will help maintain higher energy prices and increase the profits of renewable energy generators. In turn, this will encourage the development of more renewable energy and unless the LRET is increased, will result in lower LGC prices, over the medium term. However, this would be offset by increased demand for GreenPower, if enough consumers choose to purchase GreenPower for charging EVs.

However, as discussed in **Section 3.5.1** take up of EVs is not expected to be significant enough by 2020 to impact on the LRET.

6.2.2.4 Facilitating smart network infrastructure

A variety of smart network technologies, such as smart meters, already exist which could be applied across the network and in homes to help manage demand and react to changing conditions on the network. To date these technologies have not been widely adopted. However, a major application like smart EV charging could facilitate this much wider growth. For example, installing a smart charging solution would likely require a smart meter (to record ToU information) and communications equipment to relay real time tariffs. Once installed, the smart meter and real time tariffs could be applied to general household load and facilitate the management of other flexible residential loads, such as refrigeration, washing machines and pool pumping. With higher take up of smart metering, the flexibility benefits discussed above would be increased.





Vehicle-to-grid

7.0

Vehicle-to-grid

V2G technologies use EV batteries to provide energy storage and a flexible energy supply. This results in a greater amount of many of the same kinds of flexibility benefits provided by smart charging, as well as the potential to provide some ancillary services. However, V2G will also require some additional investment and create some new challenges, and overall it is unclear if these costs are justified. A promising alternative (and complement) is V2H, which is briefly explored in **Section 7.4**. Subsequent sections explore V2G by asking three questions:

- What are the benefits of V2G?
- What support will V2G need?
- What does the industry think?

In their submission, the Centre for Energy and Environment Markets (Centre for Energy and Environmental Markets, 2012, p3) suggested that V2G should be incorporated into the analysis on the cost of peak demand. Following discussion with AEMC V2G, which is recognised as a potentially significant arrangement in curbing peak load in the future, was not included in the modelling due to the infancy of their technology and therefore, the large uncertainties entailed with their realisation over the forecast period.

7.1 What are the benefits of vehicle-to-grid?

7.1.1 Flexibility benefits

V2G will provide the same type of flexibility benefits as smart metering (see **Section 6.2**). However, V2G can feed electricity back to the grid so the amount of flexibility and its availability will be greater when it is really needed. For instance, if smart charging is used to encourage off-peak charging, there will be very little scope for decreasing peak load further during high priced events such as maintenance, after an asset failure, or during a critical peak load. V2G on the other hand can begin supplying the grid at this point and effectively reduce peak load.

Table 39: Functions of V2G compared to smart metering

Function	Smart Charging	V2G	Price signal
Turn charging on	✓	✓	Low price
Turn charging off	✓	✓	High price
Power home		✓	Very high price
Feed in to the grid		✓	Very high price

7.1.2 Ancillary services

The following is a list of possible ancillary services that could be performed by EVs, as identified by Kempton & Tomic (2005a, 2005b) and Clement-Nyns et al (2011):

Frequency regulation

Providing power reserves to maintain frequency and voltage to facilitate the efficient handling of imbalances and/or congestion is an important aspect of grid management. Frequency regulation requires direct and real-time control by the grid operator, who continuously monitors the generator to load demand balance; responding within a minute or less by increasing or decreasing the output of the generator.

In Australia's case, regulation services are a subset of what is commonly referred to as Frequency Control Ancillary Services (FCAS). The aim of FCAS is to keep frequency within the operating range of 49.9Hz to 50.1Hz, and the FCAS providers bid their services where they receive payment for availability and for actual delivery of services as they arise (Usher et al, 2011). An aggregator could contract with EV owners to offer FCAS services in the market.

Spinning reserves

Spinning reserves refers to additional generating capacity that can deliver power quickly upon the request from the grid operator; it is paid for by the length of time they are available and ready. Contracts duration is typically short, lasting around 10 minutes but can be much longer depending on the specific case.

There is the potential for V2G to assist with grid support during maintenance. However, DNSPs would need to be certain of availability, so are unlikely to contract V2G for such services until there is more certainty around provision of services (see discussion below on managing vehicle availability).

7.1.3 Better integration of renewable energy

Storage technologies are expected to play an important role in a broad adoption of renewable energy. V2G has the potential to facilitate the penetration of renewable energy, when the fleet is used as distributed storage. Kempton and Dhanju (2005, p.4) analysed the possibility to use EV as distributed storage for large wind in the US and found "the majority of need for storage could be met by small storage that would be called frequently – an ideal application for V2G". However, a study on the impact of V2G on wind power in California highlights that this benefit is only realised when there is more than 20 percent of generation supplied from wind as below this level the system can cope without subsequent electricity storage additions (Bri-Mathias et al, 2010).

7.2 What support will vehicle-to-grid need?

Overall, V2G needs everything smart charging needs, plus a bit extra. Metering and tariff / incentive or control systems need to provide service for outgoing as well as incoming energy; V2G households will need to invest in extra equipment; and DNSPs will need to invest in new IT and communications systems.

7.2.1 Vehicle-to-grid needs smart two-way metering

V2G needs two way metering for billing purposes, in addition smart metering or otherwise coordinated charging is essential, so that the services can be delivered at appropriate, and in timely manners, with the least amount of labour (by way of monitoring changes to the electricity market) burden placed on vehicle owners.

The timing at which EVs discharge energy into the grid must take account of the requirements of the grid operator. One option for achieving this is through smart meters, which allow EV charging to be controlled remotely so that charging can be shifted to off-peak loads to achieve load levelling. Another option is through smart charging, where the EVs self-regulate charge timing. This mechanism generally refers to the ability of EVs to either be centrally controlled, or respond to price or other signals to regulate their charging behaviour (Usher et al, 2011).

If EVs can accurately and meaningfully maintain up-to-date communication with the energy grid and subsequently discharge power when it is required, then V2G may become a viable provider of ancillary services.

7.2.2 Distribution network costs

Technologies which feed-in electricity from the household level into the distribution network—such as solar feed-in— have the potential to reverse power flows in distribution substations. This can create new technical problems for distribution networks requiring additional investment in capacitor banks and static variable compensators (SVC). However with V2G, this is unlikely to be a problem because, unlike solar panels—which feed-in whenever the sun shines—V2G would only feed-in during periods of high demand (or high wholesale prices if contracted to a retailer).

There may be some operational issues with V2G that may require standards and possibly regulation. Feed-in technologies must provide supply that meets prescribed standards to avoid network issues. For existing solar feed-in generation, this quality of supply is accredited by the Clean Energy Council. It is unclear who would bear this responsibility for a V2G scheme.

A further cost to the controller is likely to come when they try to use V2G to actively manage their network. To do this will need investment in compatible IT and communication equipment as well as development of appropriate incentive schemes. If this capability is developed after EVs are widely adopted, they may run the risk of incompatibility issues. Step 4 may consider whether this should be regulated or unregulated activities.

7.2.3 Investment from vehicle-to-grid owners

In addition to the contribution that V2G can make to energy demand management, there is also potential for V2G-capable vehicles to produce a revenue stream. This may accrue to DNSPs, retailers or owners. Such revenue needs to justify extra investment, given potential impact on lifetime ownership cost of EVs. The economic benefit associated with EV ownership depends on a number of factors, some of which are presented in the **Table 40**.

Table 40: Revenue and costs associated with V2G-capable EVs

Revenue factors	Cost factors
Market rate of electricity ($/kWh)	Cost per energy unit produced
Amount of power dispatched (kW)	Electric energy dispatched over a given year
Total time of power dispatched (hours)	Purchased energy cost
	Equipment degradation cost as a result of V2G

Source: Factors mentioned in Kempton & Tomic (2005)

Costs

Projected costs entailed with V2G system technologies vary. Turton & Moura (2008) identifies wiring, metering, communication to the grid manager and safety systems as components of V2G system infrastructure. An indicative cost for V2G infrastructure is US$400 for a capacity of 6.6kW for a basic system, and an additional US$1,500 for an upgrade to 15kW. This cost would likely be incurred as an additional upfront cost to the infrastructure costs set out in **Section 3.3.1**.

In the case of equipment degradation cost, a crucial element that must be considered is the rate at which battery performance degrades through the repeated charge and discharge made through V2G. Battery life is typically expressed in cycles measured at a specific depth-of-discharge (DoD), with shallow cycling having less impact on battery life than deep cycling.[16] The economic benefit accrued to EV owners may not exceed the battery degradation cost, and research is still in progress to determine the impact that V2G charge and discharge behaviour has on battery life cycle. If the degradation costs are too high relative to the price at which electricity is purchased and resold for V2G purposes, then EV owners will not participate.

Revenue

Economic benefits for V2G investors depend on the assumptions employed on these and other revenue and cost factors. In one calculation conducted by Kempton & Tomic (2005a), a net profit of US$2,554 a year is observed for V2G-capable EV owners when, as a component of the cost factor, US$650 for wiring for V2G is assumed. The net profit falls to US$1,731 if V2G wiring is assumed to cost US$1,500.

Moreover, the tariff at which electricity discharged from the electric vehicle is sold back into the grid plays a significant role in determining the revenue stream for vehicle owners. In Usher et al (2011), the net benefit for participants to V2G arrangements is less than A$50 in one scenario where battery packs have assumed capacity of 10kWh, electricity is purchased at $0.10 kWh, resold at $0.24kWh and battery degradation cost is assumed to be $0.10 per kWh per cycle. When the assumptions are changed such that the battery pack storage is set at 20kWh and electricity resale price at $0.60 per kWh, the annual net revenue becomes closer to $1530.

It is clear that the case for V2G capabilities is largely influenced by various revenue and cost factors, and contractual arrangements. As such, the idea that V2G can contribute to the return on investment for electric vehicle consumers must be considered with some level of caution. Going forward, as battery prices fall and cost of electricity rises, the viability of V2G will improve. However, further work needs to be undertaken on the impact of V2G on battery life and opportunities to provide a tariff that incentivises customers to use V2G and allows them to capture a share of the benefits that the electricity market will gain from V2G.

Feed-in tariff rates and consumer understanding of the return on investment of V2G will likely play a significant role in the success of V2G, since, without a simple-to-understand, coherent and predictable set of policies governing the present and future trajectory of feed-in tariff rates and other revenue and cost factors, consumers will be exposed to too much risk associated with investing in V2G.

7.2.4 A mechanism for managing vehicle availability

Quinn et al (2010) note that one of the potential quality issues that may arise under V2G is the availability profile of ancillary services under this system. The presence and availability of ancillary service resources is dependent on the “probabilistic (and uncontrolled) presence of vehicles at charging stations, and the location of the charging stations” (ibid, p.1502). The degree to which ancillary services can be provided is dependent on numerous variables related to driving and charging behaviour of EV owners, as well as the geographical distribution of EV ownership.

Furthermore, reliability issues for V2G are dependent on the architecture under which it is rolled out. There are two approaches (as shown in **Figure 40**):

Deterministic architecture whereby there exists a direct line of communication between the grid system operator and the vehicle so that each vehicle can be treated as a deterministic resource to be commanded by the grid system operator

Aggregative architecture whereby an intermediary is inserted between the vehicles performing ancillary services and the grid system operator.

[16] Kempton & Tomic (2005) cite the example of a 3000-cycle lifetime at 100% discharge, and a 1,000,000-cycle lifetime for cycling at 3% discharge. Usher et al (2010) cites several studies on battery life; in one instance, 3,000 cycles were observed at 80% DoD; and in another, 7,000 cycles at 100% DoD.

Figure 40: Dispersed architecture of V2G versus aggregative architecture of V2G

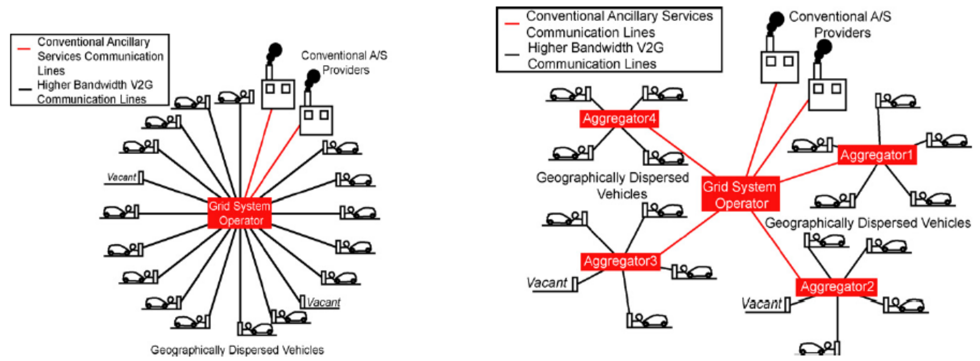


Fig. 1. Example plug-in vehicle-to-grid network showing geographically dispersed communications connections under the direct, deterministic architecture.

Fig. 2. Example plug-in vehicle-to-grid network showing geographically dispersed communications connections under the aggregative architecture.

Source: Quinn et al (2010)

Quinn et al (2010) show that including an aggregating entity in the command and contracting architecture can improve the scale and reliability of V2G ancillary services, thereby making V2G ancillary services more compatible with the current ancillary services market. However, the aggregative architecture has the adverse effect of reducing the revenue accrued by plug-in vehicle owners relative to the default architectures. Over time, as take up of EVs increases and more charging infrastructure becomes available, the risks of V2G are reduced and the management of V2G should become easier.

7.3 What does the industry think?

The cost for establishing V2G capabilities is still largely unknown mainly due to the lack of industry standards and agreement over what kind of capital is required to perform the various potential V2G ancillary services. A quick review of the latest AEMC submission papers reveals the various perspectives on V2G held by different industry stakeholders.

Recognising AEMC's statement that V2G is indeed "currently at a nascent stage," Energex (2011) raises the issue on additional aspects of embedded generation in the form of 'microgrids' within the energy network that needs to be assessed. This is because EVs may discharge under V2G settings but may only do so at a less than 100 percent capacity of its energy storage, and at different levels to the distribution network.

The timing of V2G as a realistic demand management solution is uncertain (Jarvinen et al, 2011). They raise the point that state Governments would need to fully deregulate retail pricing to facilitate the widespread adoption of V2G technology, and a critical mass of EVs would need to be on the road before they meaningfully contribute to the alleviation of peak demand.

Energex (2011) argues that the requirement to install two-way inverters to achieve V2G ignores the notion that some or all of the technology needed to accommodate this benefit could be 'on board' the EV (along with metering and other systems). This would negate the requirement for DNSPs to implement new infrastructure specifically for EVs.

Unless existing meters in homes can distinguish between EVs and other household appliances, there will be a requirement to install a separate meter (Usher et al,2011).

Charge Point (2011, p.5) notes the need for recharging devices to include "an embedded revenue grade meter and the appropriate communications device." It is also argued that the separation of EV energy consumption requiring separate metering, and administration will increase overhead and operational burdens on the current regulatory climate. This position is also taken by Origin Energy – that the introduction of a separate national metering Indicator would increase cost and complexity for consumers and the industry.

Usher et al (2011) reports that the additional cost to vehicle owners to implement V2G – compatible technology should not be prohibitively expensive, especially if the existing onboard electronics from the motor, motor inverter and charger are used. Separate grid-tie inverters, on the other hand, come at a much higher cost.

7.4 Vehicle-to-home supply

V2H is another method for utilising EV energy storage capabilities. Instead of feeding electricity back to the grid as in the case of V2G, the power is used in household appliances so that the demand on the electricity from the grid is temporarily substituted by the EV. V2H could be set up either stand-alone or in conjunction with a V2G system. When set-up with V2G, the V2H system would first meet the home supply and then feed-in to the grid.

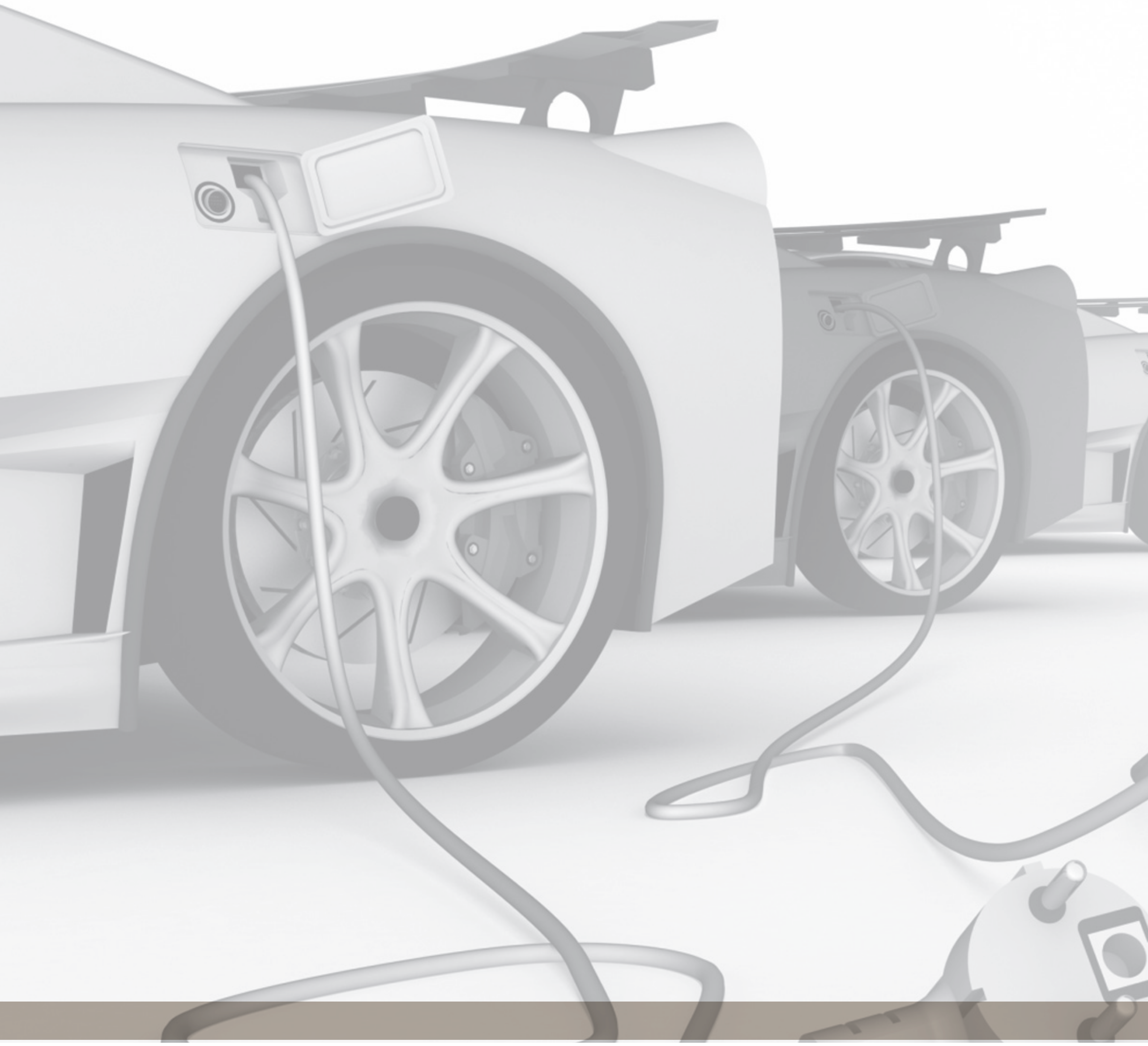
Energex (2011, p.4) notes that the V2H system will have "nearly all the benefits and none of the problems associated with vehicle-to-grid systems present to the distribution network."

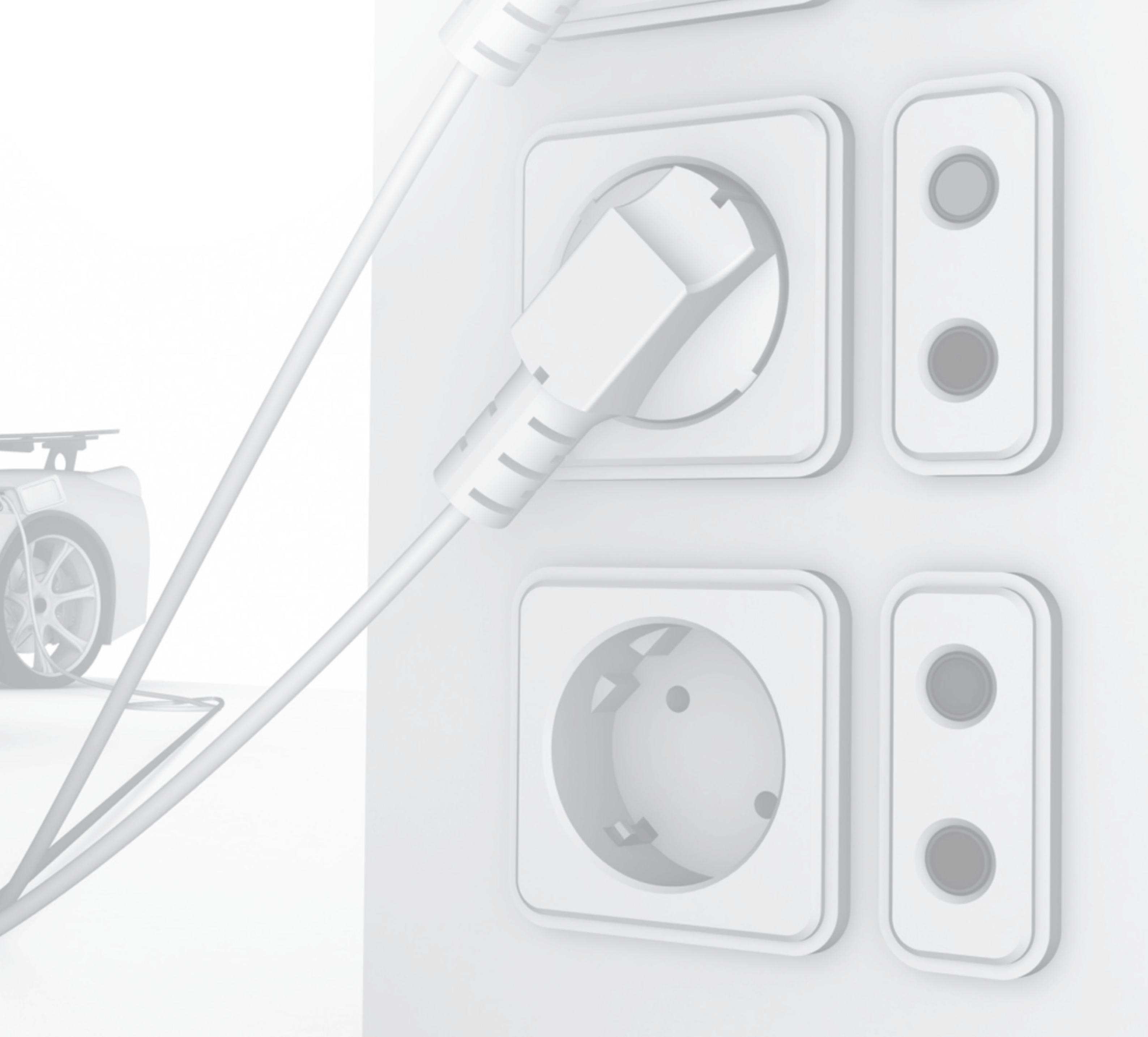
V2H would have the benefit of slightly lower losses from internal usage rather than drawing from the grid. However, it is unlikely that V2H would be completely cost and problem free. V2H arrangements would require infrastructure investment on the house. A switchboard mechanism would still be required for the household to source its energy from its EV, either to prevent flows back into the grid or, at least, isolate the EV when the grid is de-energised.

7.5 Conclusions

EVs provide an opportunity to act as energy storage devices and feedback electricity to the grid or to the house. This facility could be used to reduce strain on the grid during periods of peak demand, provide ancillary services or power a home. The benefits of V2G could be large; however the success of V2G depends on a number of factors including:

- if V2G is to be a viable provider of ancillary services, smart two way meters will be required to ensure the timing at which EVs discharge electricity back to the grid is responsive to the needs of the grid operator
- DNSPs will need to invest in compatible IT and communication equipment as well as develop appropriate incentive schemes. Some of the technology needed to accommodate this benefit could be 'on board' the EV
- V2G households will need to be convinced to participate. V2G households will require investment in extra equipment and need to overcome concerns about battery life and coming back to a vehicle that is discharged. As yet the full consequences for battery life are unknown and many manufacturers are concerned about warranty of the battery. Further, drivers may be wary about coming back to a vehicle that is discharged. These concerns will ease over time as more information is available about charging behaviour, more charging infrastructure becomes available and technology becomes smarter so that it can ensure a minimum battery charge
- the success of V2G is dependent on a critical mass of EVs. As shown above, significant levels of take up are not expected in the short term, with high take up starting to occur in 10 to 15 years.





Natural Gas Vehicles

8.0

Natural Gas Vehicles

8.1 Overview

NGVs use either CNG or LNG as fuel, both of which are compressed forms of methane (CH_4), commonly known as natural gas. In Australia, CNG-fuelled and LNG-fuelled vehicles exist predominantly in the heavy vehicle market such as bus fleets, garbage trucks and long distance freight trucks (DRET, 2011a).

LNG-fuelled vehicles are a recent development in Australia; largely due to technological improvements in storage vessels and gas dispensers that have led to improved safety and performances of LNG vehicles. They have ranges and refuelling times that are similar to diesel-fuelled vehicles with little or no power-to-weight disadvantages. In order to be in its liquefied state, LNG must be stored at less than -162˚C; the latest LNG cylinders allows for the fuel to be kept in liquid form for two weeks or more (IANGV, 2011).

CNG as a transport fuel, on the other hand, has traditionally faced a number of barriers. For instance, CNG-fuelled vehicles have comparably shorter ranges than diesel or petrol fuelled vehicles, because CNG is only stored under pressure, which means vehicles must carry large CNG storage tanks at the expense of space (Envestra, 2011). There has also been a limited availability of specialised refuelling stations which has served as an impediment to its widespread diffusion. Home refuelling is feasible, however requires a compressor due to the low pressure of gas supplied into the home, making it relatively expensive.

According to the International Association of Natural Gas Vehicles (IANGV), the total number of NGVs across the world grew by 11.6 percent between 2009 and 2010, totalling 12.7 million units. Market penetration of NGVs is predominantly in developing countries, with the top five countries being Pakistan, Iran, Argentina, Brazil and India. These countries collectively held approximately 9.3 million NGVs in 2010, which is equivalent to 73 percent of the world NGV population. In Pakistan's case, NGVs represent approximately 60 percent of their national fleet.

The NGV market in Australia is very small by comparison. Abmarc reports that there are fewer than 3000 NGVs domestically; which is equivalent to approximately 0.02 percent of the national fleet (GoAuto.com.au, 2011). Whilst CNG and LNG have been exempt from fuel excise, this exemption ended on 1 December 2011, with excise rates to be phased in over four years, with a final rate of 26.13 cents per kilogram from 1 July 2015 (ATO, 2011).

8.2 Passenger vehicles

AECOM's vehicle choice model, as described in **Section 3.0,** was used to estimate the take up of passenger NGVs. For the purposes of the model this includes light commercial vehicles and passenger fleet. AECOM's modelling assumes that people make their decisions to purchase a new vehicle based on a number of factors including vehicle price, fuel costs, available infrastructure, vehicle range and preference for greener vehicles. They also tend to make decisions based on an average ownership of four to five years. AECOM's vehicle choice model includes these factors into the analysis.

8.2.1 Assumptions

The majority of assumptions discussed in **Section 3.0** for ICE and electric passenger vehicles also apply for gas passenger vehicles. Specific NGV assumptions are summarised in **Table 41** and discussed below.

Vehicle price: there are currently no natural gas vehicles available for purchase directly from manufacturers in Australia. Internationally, there are a small number of CNG variants of certain models, such as the Honda Civic GX NGV which are sold in the US. The price premium for the Civic GX NGV over the standard Civic DX is approximately US$10,000. In comparison, conversion costs for an existing ICE vehicle range from around $3000 (Australian estimate of direct cost) to over $10,000

(NGVAmerica, 2011). Impco have recently launched a refilling system called Phill that allows motorists to refuel their car using the natural gas supplied to their home. The cost to install Phill and convert a vehicle is estimated to be around $8,500 (Rob Mercer, Managing Director Impco). For simplicity, a price premium of $10,000 has been adopted in this study.

Natural gas consumption: fuel efficiencies of gas vehicles and conventional ICE vehicles are broadly comparable when converted into equivalent units. Gas consumption of about 23.3 litres per 100km has been assumed based on a tank with a 70 litre capacity and range of 300km. This is equivalent to 0.21 GJ per 100km; in comparison, petrol consumption of 8 litres per 100km is equivalent to 0.276 GJ per 100km.

Gas prices: this study has adopted an observed retail CNG price of $1.06 per kg from ActewAGL's Fyshwick station which is equivalent to $22 per GJ. This gas price is indexed to changes in wholesale gas prices adopted from modelling in *Strong growth, low pollution* (Treasury, 2011). The price of gas is anticipated to increase significantly over the next five to ten years in Australia due to development of LNG facilities on the east coast of Australia, which will increase prices in line with the export gas market, and a higher use of gas in electricity generation. There is much uncertainty around future gas prices in Australia, so a low and high price scenario was modelled.

Availability of refuelling infrastructure: whilst residential charging of NGVs is technically feasible, the gas pressure delivered to residential dwellings is relatively low and requires a specialised refuelling unit. Impco have recently launched a residential refuelling unit in Australia. Technological development in commercial refuelling stations is likely to occur but be restricted to mostly metropolitan regions where the reticulated gas network already exists ((compared to the electricity network which is widespread).

Table 41: Passenger NGV assumptions

Parameter	Unit	Value
Price premium over comparable ICE vehicle	$	10,000
Consumption Assumes range of 300km for 70L tank of CNG; density 0.185 kg / L at 20MPa; energy content 48 MJ / kg.	L / 100km GJ / 100km	23.3 0.21
Gas price – current	$ / kg $ / GJ	1.06 22
Gas price – escalation - Central price series - Low price series - High price series	 Index based on Treasury (2011) 20% lower than central series 20% higher than central series	

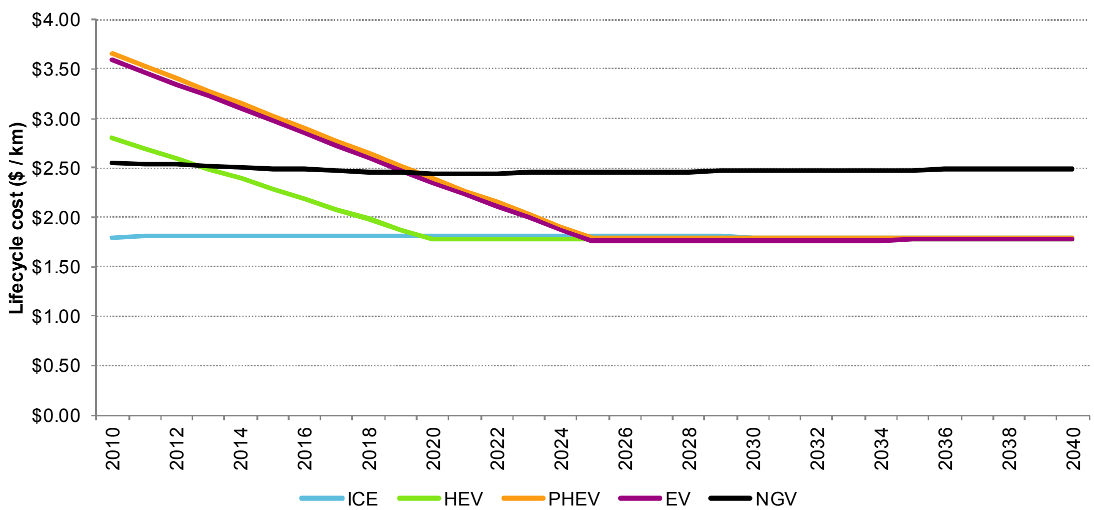
Sources: AECOM; ActewAGL (2011); Treasury (2011)

8.2.2 Results

Analysis of the lifecycle cost of passenger NGVs shows that only vehicles that travel large distances are competitive against other ICE vehicles and EVs over the medium to long term. **Figure 41** and **Figure 42** illustrate the range of lifecycle costs ($ / km) for different engine types of a medium sized car with low and high vehicle kilometres travelled respectively. The figures show that for vehicles travelling short distances, NGVs are uncompetitive with ICE for all years, and only competitive with EVs in the short to medium term. After 2020, when the upfront cost of EVs has fallen, NGVs have the highest lifecycle cost. For a vehicle that travels longer distances, NGVs are again only competitive against all technologies in the short to medium term and are only marginally better than ICE vehicles in the short term. Similar results are observed for small and large vehicles.

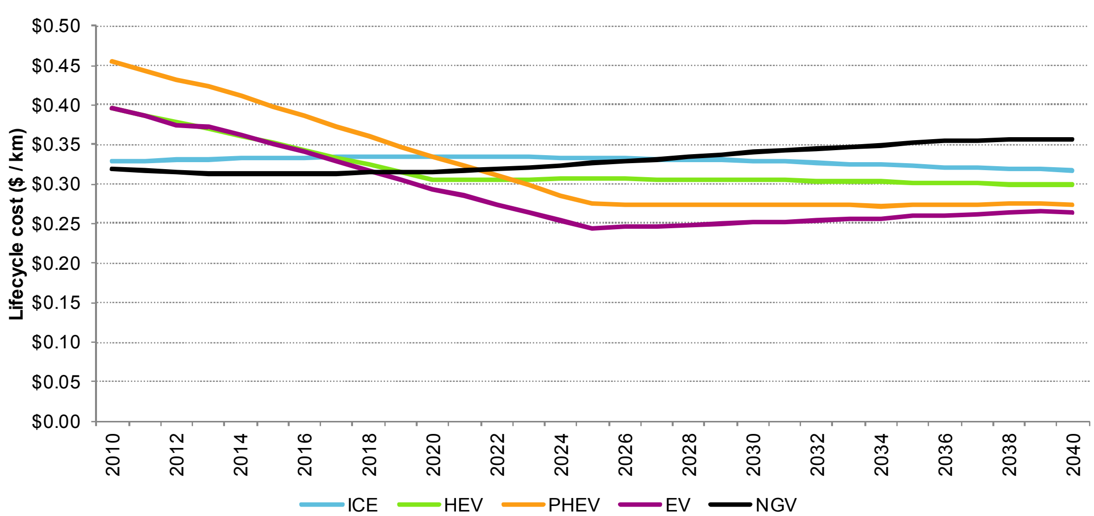
Therefore demand for NGVs is likely to be minimal in all segments of the passenger market except for those that travel large distances. This is consistent with the observed take up of LPG, which is predominantly seen in the taxi market where vehicles are travelling large distances so benefit more from the cheaper fuel. Furthermore, this demand may be concentrated in the short to medium term due to a combination of stable gas prices (in the short run) and relatively expensive EVs. From around 2020, as EV supply constraints are removed, and continued purchase price reductions and efficiency improvements occur, the relative competitiveness of NGVs is eroded.

Figure 41: Lifecycle cost – medium car, low vehicle kilometres travelled



Source: AECOM

Figure 42: Lifecycle cost – medium car, high VKT



Source: AECOM

The vehicle demand model predicts that the take up of NGVs is very low under each scenario with sales highest in the early years of the analysis and then gradually tapering off from 2015 onwards. This occurs for three main reasons:

- first: the availability of refuelling infrastructure is very limited when compared to conventional transport fuels and electricity which is available in every property

- second: EVs become more competitive because supply becomes unconstrained (HEVs in 2015 and PHEVs / BEVs in 2020), purchase prices of EVs ultimately reach parity with an ICE vehicle, and range / battery improvements continue to occur
- third: gas prices are stable up to 2015 (zero or modest real growth) after which more rapid annual increases in the order of 3.5 to 4.5 percent are assumed to occur (as a result of LNG exports from eastern Australia).

The combination of these factors serves to reduce the competitiveness of NGVs against other engine types. However, it is important to recognise that there are uncertainties in both the EV and NGV markets, as well as future fuel prices, and these conclusions may change over time as both markets develop.

8.3 Buses and trucks

As discussed above, people make their vehicle purchase decisions based on a number of factors. However, the purchase of a bus or truck is principally a commercial decision. As such, the estimation of take up of natural gas buses and trucks uses an alternate methodology and only considers the financial costs over the operating life of the vehicle.[17]

8.3.1 Assumptions

There is a moderate amount of uncertainty surrounding the characteristics of CNG buses and LNG trucks primarily due to commercial confidentiality. As such, this study has made a number of assumptions in order to conduct the analysis.

Table 42 summarises the assumptions applied in the financial analysis with each of these assumptions discussed in more detail below. The assumptions were developed based on AECOM's research and industry consultation.

Table 42: Truck and bus assumptions

Parameter	Bus			Truck	
	Diesel	CNG	Electric	Diesel	LNG
Price	$450,000	$650,000	$750,000	$350,000	$510,000
Consumption	30 L / 100km	2.5 GJ / 100km	120 kWh /100km	56 L / 100km	2.2 GJ / 100km
Vehicle life	7.5 years	7.5 years	7.5 years	7.5 years	7.5 years
Annual distance travelled (VKT)	45,000	45,000	45,000	90,000	90,000
Maintenance	$0.35 / km	$0.51 / km	$0.25 / km	$0.18 / km	$0.26 / km

Sources: AECOM; ABS; NSW state Transit; Adelaide City Council / Dr Andrew Simpson

Purchase prices

Diesel bus purchase prices were obtained from a manufacturer, which also stated that an equivalent CNG bus is approximately 45 percent more expensive. For a truck, the prime mover purchase price is based on AECOM experience. To obtain an equivalent LNG truck (prime mover) price, a premium of 45 percent has been applied based on the bus premium. The cost of an electric bus is estimated from the Tindo electric bus trial being conducted in Adelaide (Adelaide City Council, 2011).

[17] For this analysis "trucks" are assumed to be the prime mover only and excludes trailers.

Consumption

Diesel consumption data from the ABS Survey of Motor Vehicles was adopted for bus and truck fuel consumption, while consumption for a CNG bus was based on Cockroft & Owen (2007). Data from truck trials based on RARE Consulting (2010) was used to estimate LNG consumption which in energy terms is essentially equal to that implied by the ABS diesel consumption data. The Tindo electric bus trial has available energy of 235 kWh for a range of approximately 200km (no air-conditioning) which yields a consumption rate of around 120 kWh / 100km.

Vehicle life

The life of both buses and trucks has been assumed equal to the effective tax life as determined by the ATO of 7.5 years.

Annual distance travelled

The annual average distance travelled per bus as implied by New South Wales state Transit performance statistics shows that buses travel approximately 42,000 km per year (state Transit, 2010). For simplicity this study has assumed 45,000 km.

An assumption of 90,000 km travelled annually for trucks has been made based on ABS data for articulated trucks. However industry sources indicate that only high VKT trucks (approximately 150,000km) are likely to find gas a viable option.[18]

Maintenance costs

Maintenance costs for diesel vehicles were adopted from the *Guide to Project Evaluation* (Austroads, 2008). Information provided by a CNG bus manufacturer suggest that maintenance costs for a CNG bus is approximately 45 percent higher than for an equivalent diesel bus. This relativity has also been adopted for LNG trucks in the absence of more specific information. A review of the Tindo electric bus indicates that maintenance costs are in the order of 9 c/km however the report emphasises that detailed records of maintenance were difficult to extract and interpret. In light of this uncertainty, this study has assume that maintenance costs for an electric bus are approximately 30 percent lower than for an equivalent diesel bus, analogous to the assumptions made for passenger EVs.

Vehicle sales

Vehicle sales have been estimated from the stock of buses and trucks (ABS, 2010a) and the assumed vehicle life of 7.5 years as discussed above. **Table 43** summarises the current volume of sales and assumed annual growth under each take up scenario.

Table 43: Bus and truck sales

State	2010 Sales		Annual sales growth		
	Bus	Truck	Low	Central	High
VIC	740	3350	1%	1.5%	2%
NSW	910	2480	1%	1.5%	2%
ACT	40	20	1%	1.5%	2%
QLD	780	2520	1%	1.5%	2%
TAS	100	220	1%	1.5%	2%
SA	200	1040	1%	1.5%	2%
WA	540	1680	1%	1.5%	2%

Source: AECOM; ABS

[18] http://www.fullyloaded.com.au/industry-news/articleid/40793.aspx

Fuel prices

As with passenger vehicles, electricity prices have been adopted from Treasury modelling and diesel prices estimated using the methodology from Gargetts (2011). (See **Section 3.3.1.6** for more detail)

CNG prices in the NEM states and Western Australia are based on Treasury modelling for wholesale gas prices in the NEM and non-NEM regions.

LNG prices in Western Australia are based on prices in *Inquiry into domestic gas prices* report by the Western Australian Economics and Industry Standing Committee. LNG prices in eastern states are assumed to be lower than in Western Australia, though are expected to rise following the commencement of LNG exports from the East Coast around 2015.

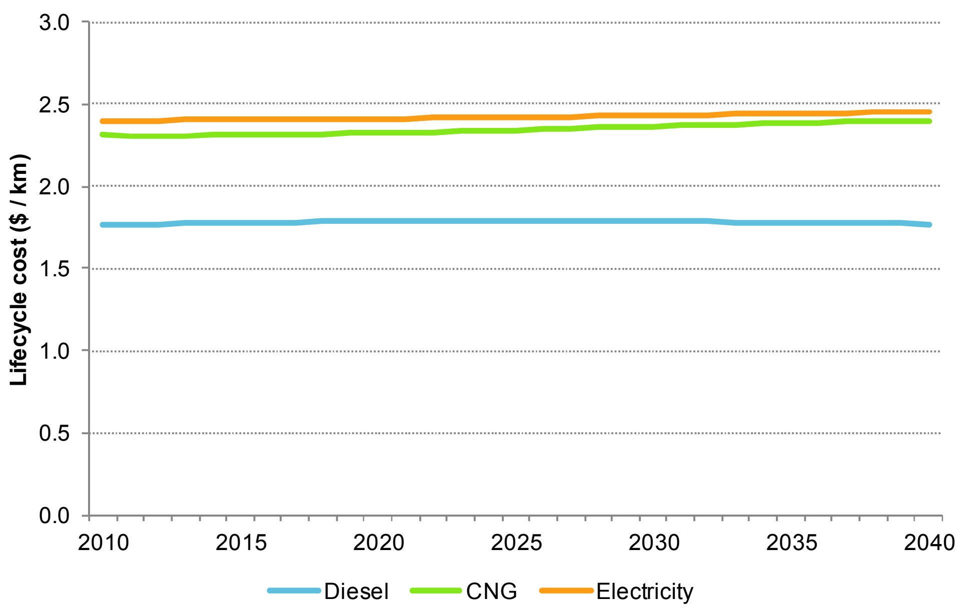
The Commonwealth Government seeks to establish an effective carbon price for heavy on-road liquid fuel use (including heavy trucks and buses) from 1 July 2014. This will improve the relative fuel costs for gas vehicles.

8.3.2 Results

Financial analysis

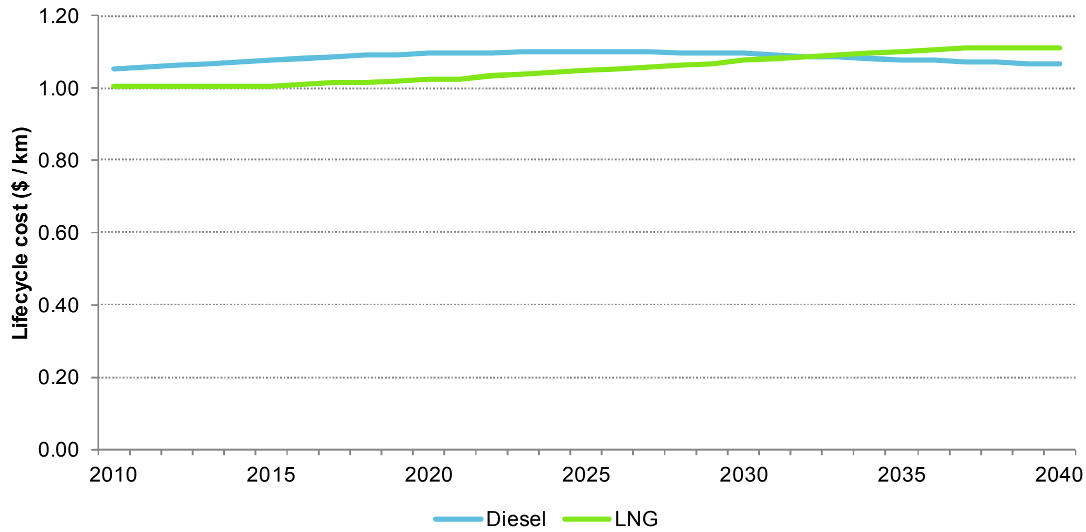
Figure 43 highlights that CNG buses are less financially attractive to purchase and operate compared with diesel buses. In comparison, the financial viability of LNG trucks is marginal (see **Figure 44**). It should be noted that the financial analysis does not include consideration of a residual resale value. Resale values of diesel buses and prime movers are likely to be higher than for CNG buses and LNG trucks given the scarcity of refuelling gas infrastructure. Inclusion of a resale value is therefore likely to worsen the viability of CNG buses and LNG trucks relative to their diesel equivalents.

Figure 43: Lifecycle cost of buses



Source: AECOM

Figure 44: Lifecycle cost of trucks



Source: AECOM

On a purely financial decision, demand for CNG buses is likely to be low. However, a number of CNG buses are already in operation around Australia in metropolitan transit fleets. Most buses are operated by government who will face increasing pressure to reduce their greenhouse gas emissions. Given transport typically accounts for a large proportion of greenhouse gas emissions it is possible that there will be increased take up of natural gas buses, despite not being financially viable, to assist in meeting greenhouse gas reduction targets.

For trucks, the financial analysis showed that the decision to purchase an LNG truck was marginal and depends on a few key assumptions – principally annual VKT. A number of businesses are currently operating some LNG trucks for a variety of activities, primarily long haul freight. Wesfarmers (Gas Today Australia, 2009) notes that LNG vehicles can closely match their diesel equivalent, and can be fitted with sufficient LNG fuel tanks to suit journeys of up to 1,200 km.

As discussed above, on purely financial grounds, take up of CNG buses and LNG trucks is expected to be low. However, there are other factors such as greenhouse gas emissions reductions that mean take up may be higher than otherwise expected. Therefore, for the purposes of considering the impact of NGVs on the gas market, three take up scenarios (see **Table 44**) have been considered.

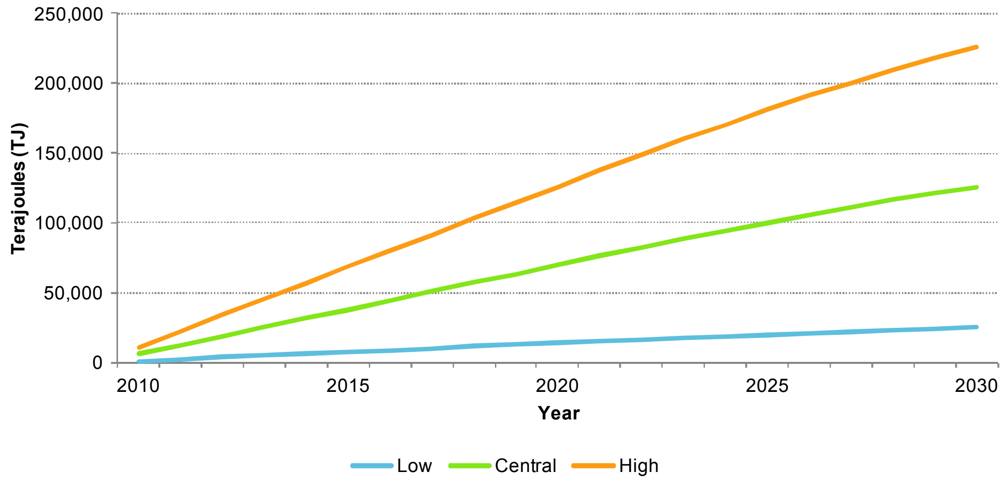
Table 44: Proportion of sales in each scenario

Scenario	Bus – CNG sales (%)	Truck – LNG sales (%)
Low	10%	10%
Central	50%	20%^
High	90%	40%

Source: AECOM. ^ Based on Westport submission (Westport, 2011)

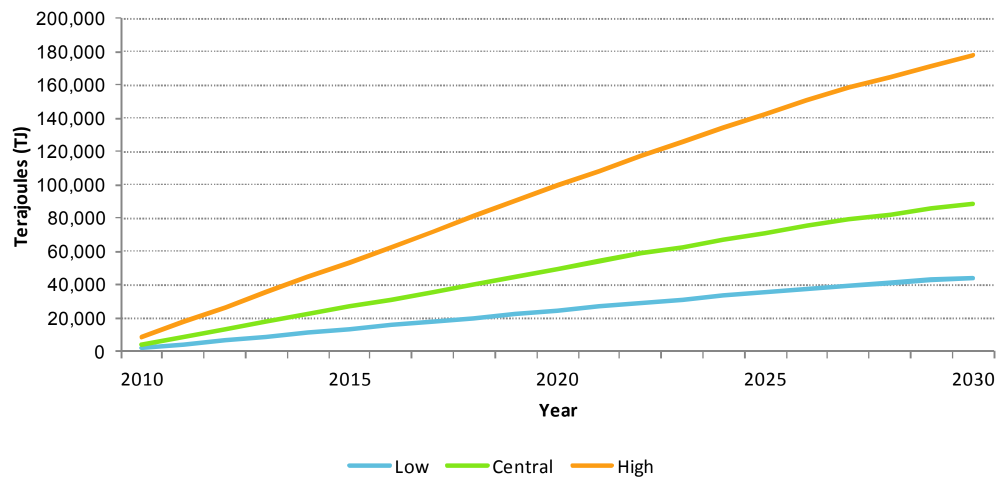
Figure 45 and **Figure 46** summarise the consumption of gas for buses and trucks respectively. The high take up scenario could see around 120,000 TJ of gas by 2015, rising to around 225,000 TJ of gas by 2020 and around 400,000 TJ of gas by 2030.

Figure 45: CNG bus gas consumption



Source: AECOM

Figure 46: LNG truck gas consumption



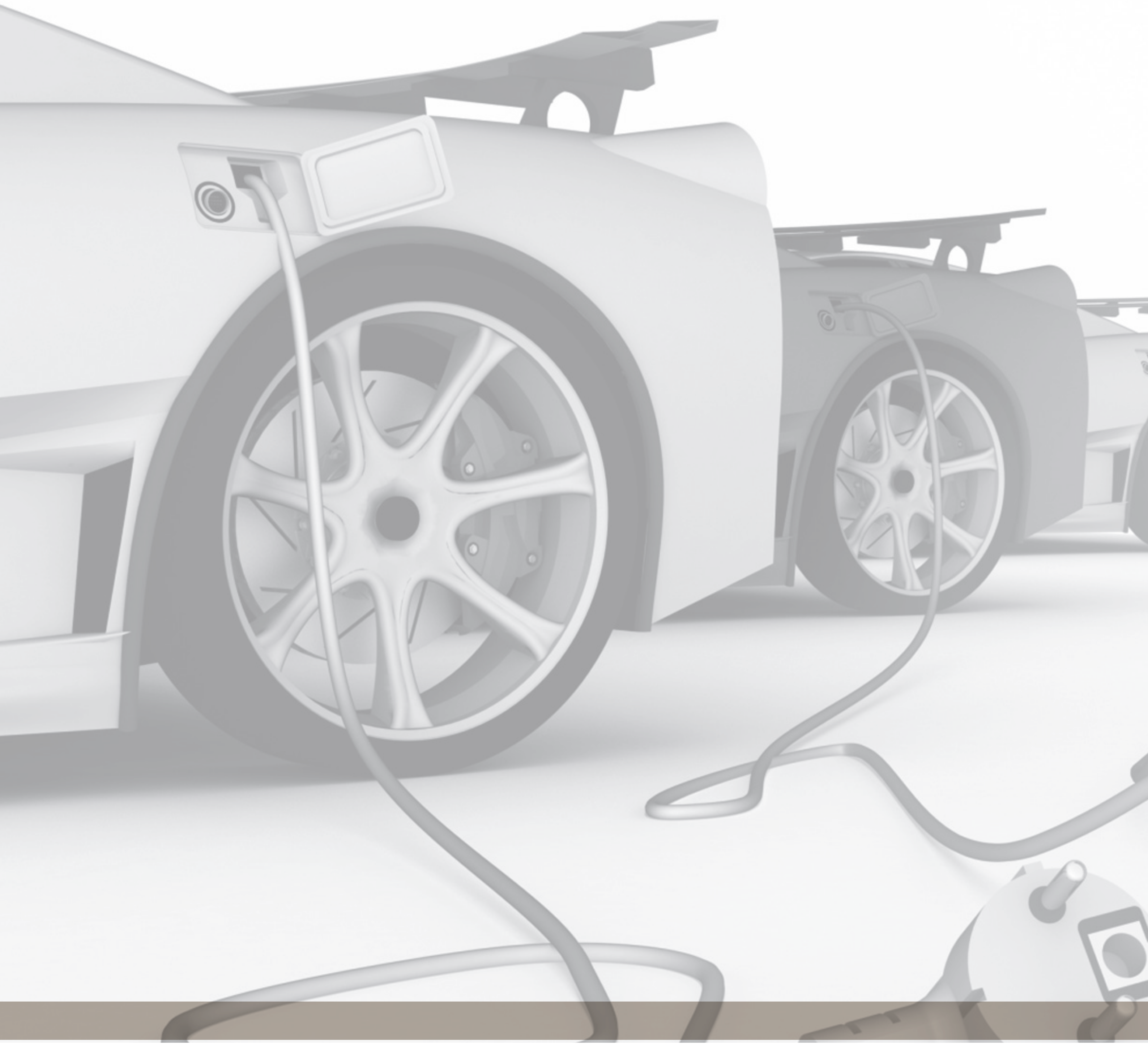
Source: AECOM

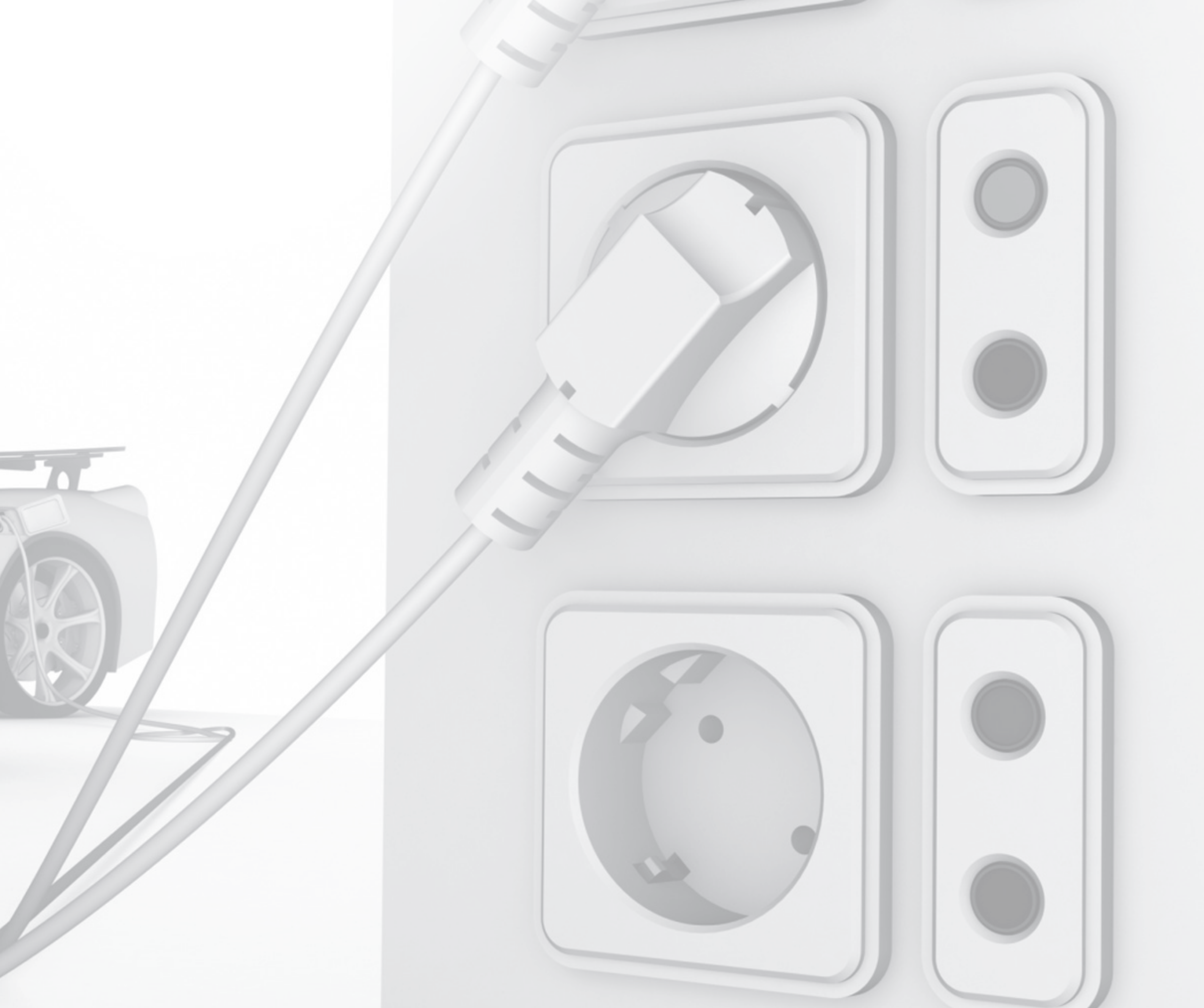
8.3.3 Submissions

A number of submissions were made to both the Issues Paper and the Approach Paper on the take up of NGVs. The comments generally highlight that there are a number of benefits from gas vehicles including reduced costs compared with traditional fuels and environmental benefits including GHG emission reductions. However, many submissions highlighted that there are still perceived barriers to NGVs including availability of charging infrastructure, safety (perceived), higher upfront costs and lack of information. It is generally recognised that this is an evolving market and there is still a lot of uncertainty around its future and that of its competitors such as EVs. Most of the submissions generally agree with the level of take up and agree that take up in the passenger market is likely to be low but there is greater potential for take up in heavy vehicles.

The following summarises the comments raised in relation to the take up of NGVs the submissions to both the Issues Paper and the Approach Paper:

- The Australian Automobile Association (AAA) submission to the Issues Paper highlighted the following key factors affecting the take up of NGVs: fuel price; relative price fuel price of petrol and diesel; availability of refuelling infrastructure; reliability and safety; government incentives; emergence of other fuels and technology. The AAA also commented that gas vehicles will be most easily exploited by vehicle fleet operators using depots with refuelling capability (Australian Automobile Association, 2011, p4). If vehicles are refuelled at home, there may be a need to modify the domestic gas supply infrastructure and as such commercial refuelling may be preferable.
- Westport Innovations (Australia) commented that LNG refuelling capacity can reach 20% of the on-road heavy duty transport sector and 40% of the off-road mining and locomotive in 10 years. This would represents 6% of domestic gas use (Westport Innovations, 2011, p2) NGVS include a number of benefits and risks. Benefits include: diversifies the energy mix, reduces carbon emissions and is cost-effective compared with oil based fuels (Westport Innovations, 2011, p3). Some of the challenges include: operating risks associated with technology performance; high upfront vehicle costs; lack of widespread infrastructure; insufficient information on current technology (Westport Innovations, 2011, p3).
- TRUenergy highlights that a key factor affecting the uptake of NGVs is the excise on public refuelling for gas vehicles (TRUenergy, 2011, p2) and recommends the level of rebates/subsidies affecting NGVs is reviewed (TRUenergy, 2011, p2).
- SP AusNet highlight that Australia currently has fewer than 3000 NGV vehicles (less than 0.02% of the national vehicle fleet) (SP AusNet, 2011, p19). Whilst recognising that NGVs produce lower particulate emissions and generally more fuel efficient (SP AusNet, 2011, p21), they believe that the residential market is unlikely to develop significantly due to competing export markets, gas peaker generators and safety concerns of NGVs (p16). Further, residential charging has draw backs due to safety, noise pollution, relatively high cost and range anxiety. CNG and LNG vehicles will predominantly be used in the heavy vehicle market in specialist applications such as metropolitan bus fleets, garbage trucks and line haulage (p20). CNG as a transport fuel has practical impediments (ie. Storage tanks, requires more frequent refilling) (SP AusNet, 2011p 21).
- The Government of South Australia recognises that NGVs can offer significant emissions reductions but augmenting infrastructure and distribution systems to enable refuelling maybe a challenge (Government of South Australia, 2011, p2).
- Energy Networks Australia (ENA) highlight that NGVs are expected to deliver benefits in terms of energy security, greenhouse gas reduction, and may lead to benefits to gas networks through increased through put leading to lower gas network tariffs/prices (Energy Networks Australia, 2011, p7). In their response to the Issues Paper ENA comment that the modelling of uptake of CNG buses and LNG trucks appears reasonable (Energy Networks Australia, 2012, p1).
- Ausgrid highlight that the widespread uptake of NGVs can impact electricity markets by changing uptake of EVs as a competing transport mode; changing the demand for and costs of gas supplies; and adding new electricity load for gas transport and refuelling, depending on how it is managed. (Ausgrid, 2011, p10).
- BOC suggest the analysis in the 2011 Alternative Fuels Strategic Issues Group report is more reflective of the long term prospects of LNG vehicles (BOC, 2012, p1).
- Envesta highlight that given the uncertainties in the technology, it is premature to conclude that EV technology will be the dominant emerging technology and that NGVs will not have great market reach (Envesta, 2012, p2). They also note the DRET Paper on 'Strategic framework for alternative transport fuels' is less conclusive/predictive of potential EV/NGV outcomes (Envesta, 2012, p3)
- iGas Energy agree that there is a high capital cost of fitting a gas engine/fuel system relative to diesel but this can be offset by lower gas price compared to diesel. They believe that 10,000 trucks could be running on CNG by 2020.





Impact of Natural Gas Vehicles on the Gas Market

9.0

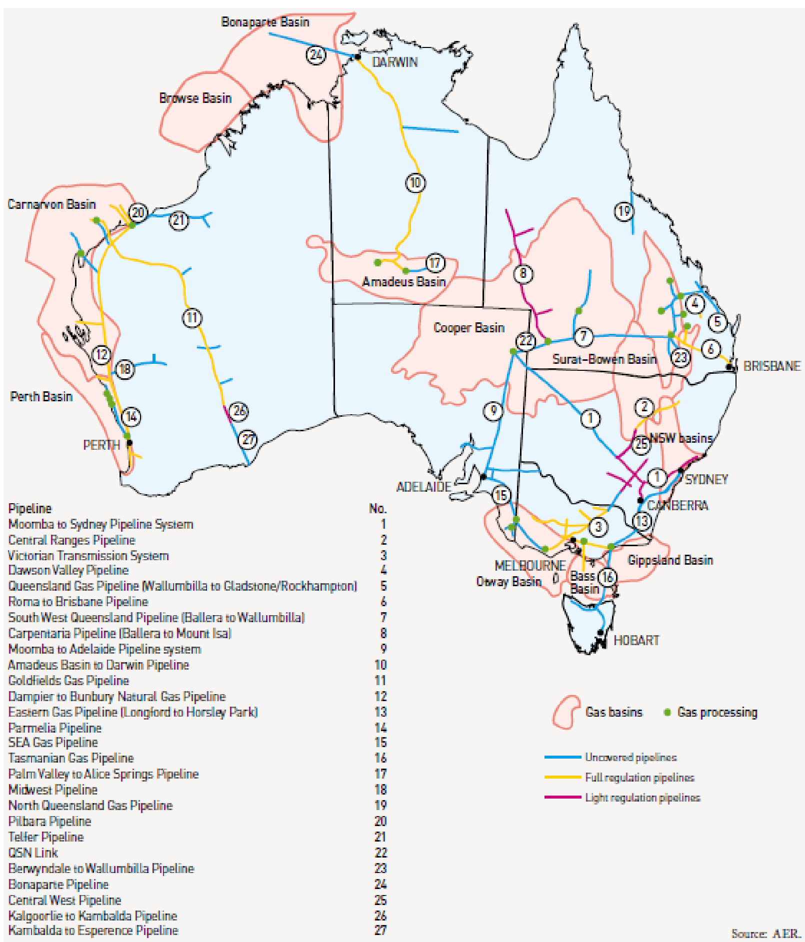
Impact of Natural Gas Vehicles on the Gas Market

9.1 Description of current gas market

9.1.1 General

Gas producers sell natural gas in wholesale (contract and spot) markets to major industrial, mining and power generation customers, and to energy retailers which on-sell it to business and residential customers. Gas is carried from fields through a network of transmission pipelines, as shown in **Figure 47** below. In cities, gas is delivered through networks of distribution pipelines.

Figure 47: Australian gas basins and transmission pipelines



Source: AER (2011)

9.1.2 Gas market developments

Natural gas is expected to play a key transitional role in meeting Australia's energy needs in the move towards a carbon constrained economy. With associated growth in the use of natural gas for electricity generation, there are also growing links and interdependencies between the gas and electricity markets.

The DRET[19] drives Commonwealth gas market policy in the energy market reform program being implemented by the Standing Council on Energy and Resources (SCER). Key streams of this program include the development of a national regulatory regime for gas pipelines and retail markets, and further market development to improve transparency, competition and trading opportunities. The SCER has also established the GMLG, a collection of key representatives from all sectors of the gas supply and demand chain, to further reform the operation of gas markets around the country. The GMLG:

- developed a gas market Bulletin Board, a website which provides daily information about gas infrastructure and gas supply and demand, and provides market participants with opportunities for trading gas
- designed a new gas wholesale trading market, implemented in Sydney and Adelaide initially, with Brisbane operations commencing in December 2011
- developed the annual Gas Statement of Opportunities, published by the AEMO. This document provides a source of information to assist industry participants and other interested parties in their planning and identification of potential investment opportunities and is also an information tool for policy makers examining the projected short and long-term reliability of the nation's gas supply.

9.1.3 Production

Table 45 below shows gas production in 2011, by state and by end market (AER, 2011). Most of the production is delivered to customers, after allowing for energy used in compressing gas for transmission and some losses from leaks. The Western Australian domestic market used 348 PJ in the year 2010-11. The eastern Australian market used 713 PJ, of which 482 PJ comprised conventional gas and 231 PJ coal seam gas.

Table 45: Natural gas production and reserves (2011)

Gas Basin	Production (Year to June 2011)		Proved and Probable Reserves (30 June 2011)	
	Petajoules	Percentage of Domestic Sales	Petajoules	Percentage of Australian Reserves
Western Australia				
Carnarvon	344	31.8%	68,856	59.6%
Perth	4	0.3%	42	0.0%
Northern Territory				
Amadeus	2	0.1%	141	0.1%
Bonaparte	20	1.8%	1,184	1.0%
Eastern Australia				
Cooper (South Australia – Queensland)	96	8.9%	1,373	1.2%
Gippsland (Victoria)	252	23.3%	4,571	4.0%

[19] http://www.ret.gov.au/energy/energy_markets/gas_market_development/Pages/GasMarketDevelopment.aspx

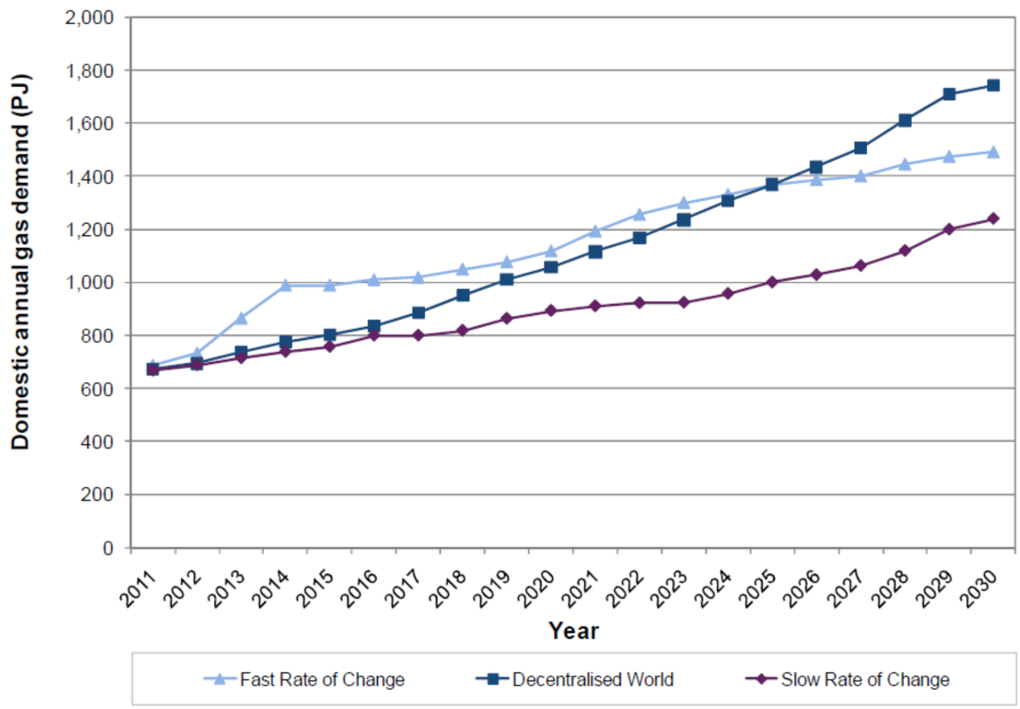
Gas Basin	Production (Year to June 2011)		Proved and Probable Reserves (30 June 2011)	
	Petajoules	Percentage of Domestic Sales	Petajoules	Percentage of Australian Reserves
Otway (Victoria)	106	9.8%	939	0.8%
Bass (Victoria)	18	1.6%	268	0.2%
Surat-Bowen (Queensland)	10	1.0%	183	0.2%
Total conventional natural gas	851	78.6%	77,557	67.2%
Coal Seam Gas				
Surat-Bowen (Queensland)	225	20.8%	34,986	30.3%
New South Wales basins	6	0.6%	2,910	2.5%
Total coal seam gas	231	21.4%	37,896	32.8%
Australian Totals	1082	100.0%	115,453	100.0%
Liquefied Natural Gas (Exports)				
Carnarvon (Western Australia)	933			
Bonaparte (Northern Territory)	14			
Total liquefied natural gas	948			
Total Production	2030			

Source: AER (2011)

1. Conventional Natural Gas reserves include LNG and ethane
2. Proved Reserves are those for which geological and engineering analysis suggests at least a 90 percent probability of commercial recovery. Probable reserves are those for which geological and engineering analysis suggests at least a 50 percent probability of commercial recovery

Figure 48 shows forecast aggregate annual gas demand in the eastern Australian domestic market (excluding LNG exports) under three scenarios that are described in the *2011 Gas Statement of Opportunities*. Domestic gas demand is currently around 700 PJ a year but this is expected to rise by 2030 to between around 1,250 PJ and 1,750 PJ a year.

Figure 48: Forecast aggregate annual gas demand in the eastern Australian domestic market



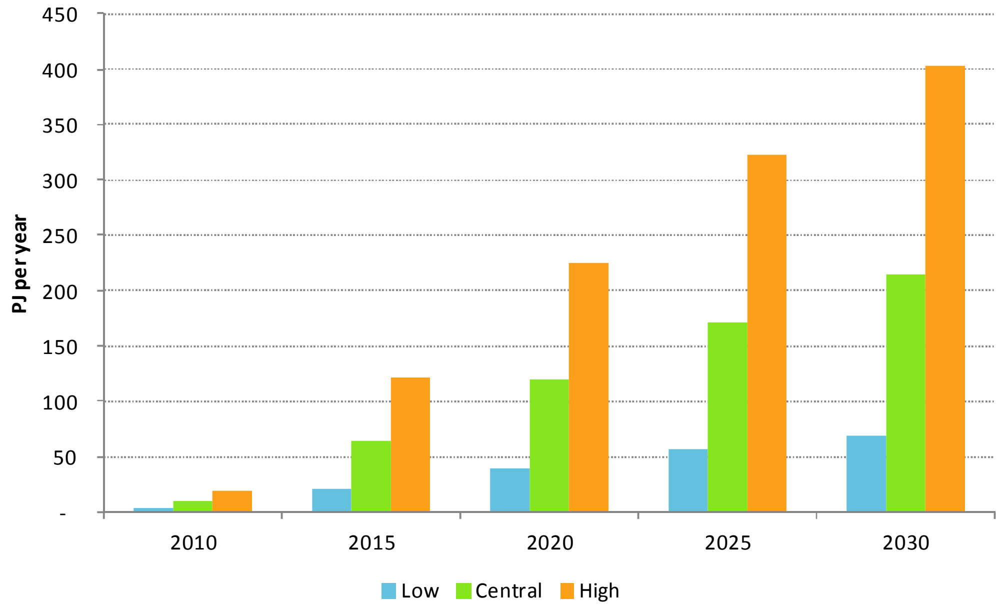
Source: AEMO (2011b)

9.2 Possible impacts on gas wholesale and retail markets

9.2.1 AECOM's analysis

As discussed in **Section 8.0**, if the take up of NGV buses and trucks is 50 and 20 percent respectively under the central scenario, the total gas required would be around 65 PJ (65,000 TJ) of gas by 2015, rising to around 120 PJ of gas by 2020 and around 215 PJ of gas by 2030 in the central case. In the high case where 90 percent of buses are CNG and 40 percent of trucks are LNG, volumes could be 120 PJ of gas by 2015, rising to around 225 PJ of gas by 2020 and around 400 PJ of gas by 2030.

Figure 49: Scenarios of gas volume for NGVs



Source: AECOM

In 2015, AECOM's central estimate of gas demand for NGVs is 65 PJ, which is less than 5 percent of projected annual demand nationally. Gas demand for NGVs is estimated to grow by 4 percent per year, which is the same rate as domestic demand shown in **Figure 48**. AECOM's central estimate of aggregate demand across all years until 2040 is 4,600 PJ, which is less than 5 percent of current proven and probable reserves (shown in **Figure 47**). The volumes of gas for NGVs can therefore be supplied in the market, although there may be marginal price impacts.

In Australia, wholesale gas is sold mostly under confidential, long term contracts. The trend in recent years has been towards shorter term supply, but most contracts still run for at least five years. Foundation contracts underpinning new production projects are often struck for up to 20 years. Such long term contracts are commonly argued as being essential to the financing of new projects because they provide reasonable security of gas supply, as well as a degree of cost and revenue stability.

Large gas customers (say more than 1 PJ per year) are likely to enter into medium term, wholesale contracts. The following section presents market-based evidence that such contracts have been available at commercially viable prices. Smaller gas customers, such as individual drivers, will purchase gas either from a retailer or reseller (such as Wesfarmers). AECOM's analysis shows that the viability of NGVs is very sensitive to gas prices, and that NGVs are not attractive to customers paying retail prices for gas.

Future gas price movements in the eastern Australian market will depend on availability of LNG export terminals (and then global LNG market) and supply of coal seam gas. Gas price movements in Western Australia are already linked to the global LNG market. Steps 4 and 5 of the AEMC study will test whether there is any need for special gas market regulation to cater for NGVs.

9.2.2 Other evidence

In recent years there have been significant developments in LNG infrastructure for truck refuelling across Australia, demonstrating a growing trend for heavy vehicles to use LNG instead of diesel or fuel.

In 2009, Wesfarmers Energy opened an LNG plant in Kwinana, Western Australia which is capable of supplying 175 tonnes per day (9.7 TJ per day or 3.5 PJ per year) for power stations and 130 heavy vehicles. (Gas Today 2009, http://gastoday.com.au/news/wesfarmers_opens_kwinana_lng_plant/001437/)

In 2011 German gas company BOC opened its Westbury Micro-LNG plant in Tasmania to supply LNG to over 120 heavy vehicles in the region. The plant has the capacity to produce 50 tonnes of LNG per day, the equivalent of 70,000 litres of conventional diesel. BOC signed an agreement in 2010 that will deliver 100 tonnes of LNG per day (5.5TJ per day or 2 PJ per year) to heavy vehicle refuelling stations along Australia's east coast. Under the agreement, Australian coal seam gas explorer and producer QGC will supply 30 PJ (1 PJ is equal to 20 000 tonnes of gas) of coal seam gas to BOC over 15 years from July 2011, with an option for a further 15 years. (Minister for Resources Energy and Tourism, http://minister.ret.gov.au/MediaCentre/MediaReleases/Pages/MicroLNGPlant.aspx, http://minister.ret.gov.au/MediaCentre/MediaReleases/Pages/BOC-APADealGetsLNGintotheTransportFuelMarket.aspx)

9.3 Potential impacts on gas networks

9.3.1 AECOM's analysis

Timing is less important for gas vehicles refuelling than for electric vehicles, because gas networks can generally balance on a daily basis rather than instantaneously. Unlike electric vehicles, there is little need to analyse timing of refuelling, namely unmanaged, time of use, managed or smart charging.

Commercial CNG or LNG vehicles will need specialised refuelling stations, which are likely to be connected either at transmission or sub-transmission level if large quantities of gas are required. Network impacts from commercial refuelling are likely to be small, for the following reasons:

LNG facilities are likely to require high capacity connections to transmission or sub-transmission pipelines, in order to supply sufficient quantities there are already clear price signals for withdrawals through high capacity connections. These signals recognise the need for gas balancing and the scope for line-pack within high capacity gas networks facilities will need to provide storage for CNG or LNG prior to distribution to refuelling stations, so should be able to manage their withdrawals to reduce network impacts and costs.

Passenger NGVs can be refuelled from the gas distribution network. For example, a company called OES CNG claims to have developed a new compressed natural gas (CNG) refuelling system that can be installed outside domestic garages. 'CNG@HOME' works by drawing gas from the domestic natural gas supply and compressing it into the vehicle's CNG cylinder. It takes approximately three hours to fill a standard passenger car, which will give it a range of 200–250 km. It proposes bringing to market two domestic models and two commercial units. The domestic units will have a capacity of 6 cubic metres per hour (m3/h) – equivalent to 6.6 litres of petrol – with one unit to be a standard slow-fill unit and the other to have some internal storage capacity to provide a partial boost (rapid) fill. The light commercial units will have compression capacities of 10 and 13 m3/h respectively and will both have internal storage capacity.

Any distribution connected equipment will need to be approved by the relevant network service provider. For example, ACTEW-AGL's *Gas Connection & Supply Standard Customer Contract* (http://www.actewagl.com.au/~/media/ActewAGL/ActewAGL-Files/About-us/Natural-gas-network/Natural-gas-network-prices/Gas-connection-and-supply-contract.ashx) allows customers to draw up to 6 cubic metres per hour. OES CNG's domestic units meet this requirement.

Some gas distribution networks operate at low pressure, to reduce losses from leaks in older pipes. It is possible that older gas networks might need upgrading to cater for large amounts of distribution connected refuelling of NGVs.

Low take-up of passenger NGVs should mean that potential impacts on distribution networks are likely to be low. Light commercial vehicles are likely to use commercial refuelling stations which are likely to be connected at transmission or sub-transmission level as discussed above. Potential impacts on transmission networks could be greater but presumably will be customer funded.

9.3.2 Submissions

A number of submissions were made to both the Issues Paper and the Approach Paper on the impact of NGVS on the gas market. The submissions generally agree with the conclusions of this study that there is enough gas supply to meet requirements from NGVs and the impacts on the gas markets are likely to be small. The following summarises the comments raised in relation to the take up of NGVs the submissions to both the Issues Paper and the Approach Paper:

- SP AusNet's submission agrees that network impacts are likely to be small (SP AusNet 2011, p.22):

  "*Presently peak durations are of relatively short durations and hence the impact of NGV charging in residential areas is likely to only impact extended networks.*

  The growth in the NGV market will probably be concentrated in fleet vehicles rather than the residential market. These types of customers (eg Toll, Wesfarmers) are likely to install large charging facilities, with associated storage, requiring a reasonable capital allocation and hence any gas network augmentation requirements will need to be funded by the customer. This will ensure that residential customer tariffs are not impacted."

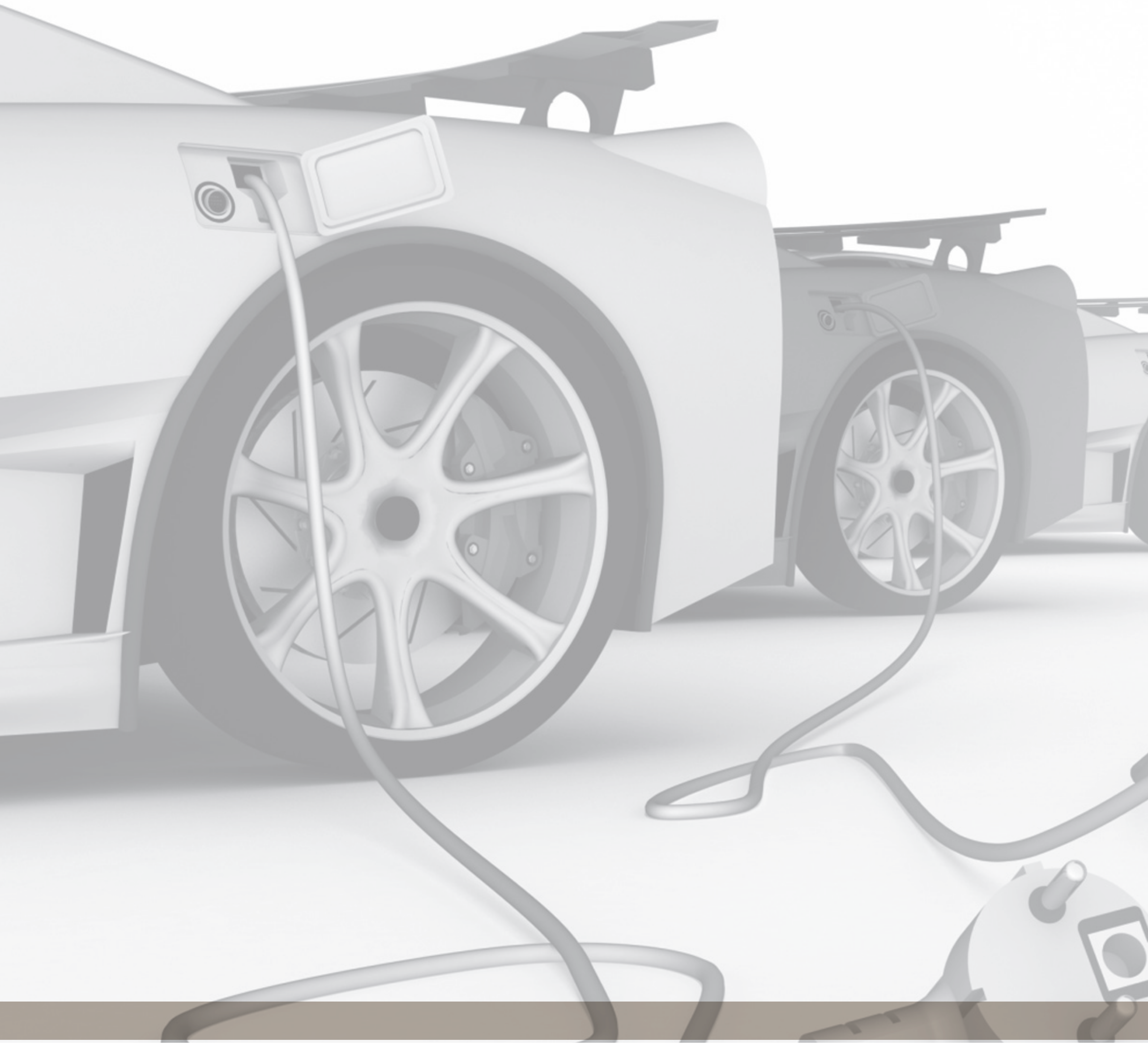
- The Government of South Australia believes the nation's gas reserve should meet this challenge of NGV take up ((Government of South Australia, 2011, p2).
- iGas Energy highlight that CNG trucks fitted with iGas systems will be refuelled directly adjacent to high pressure transmission pipelines. There will be issues related to off-pipeline storage, use of line pack and load factor considerations, but these should be able to be managed through gas haulage and supply contracts. (iGas Energy, 2012, p4)

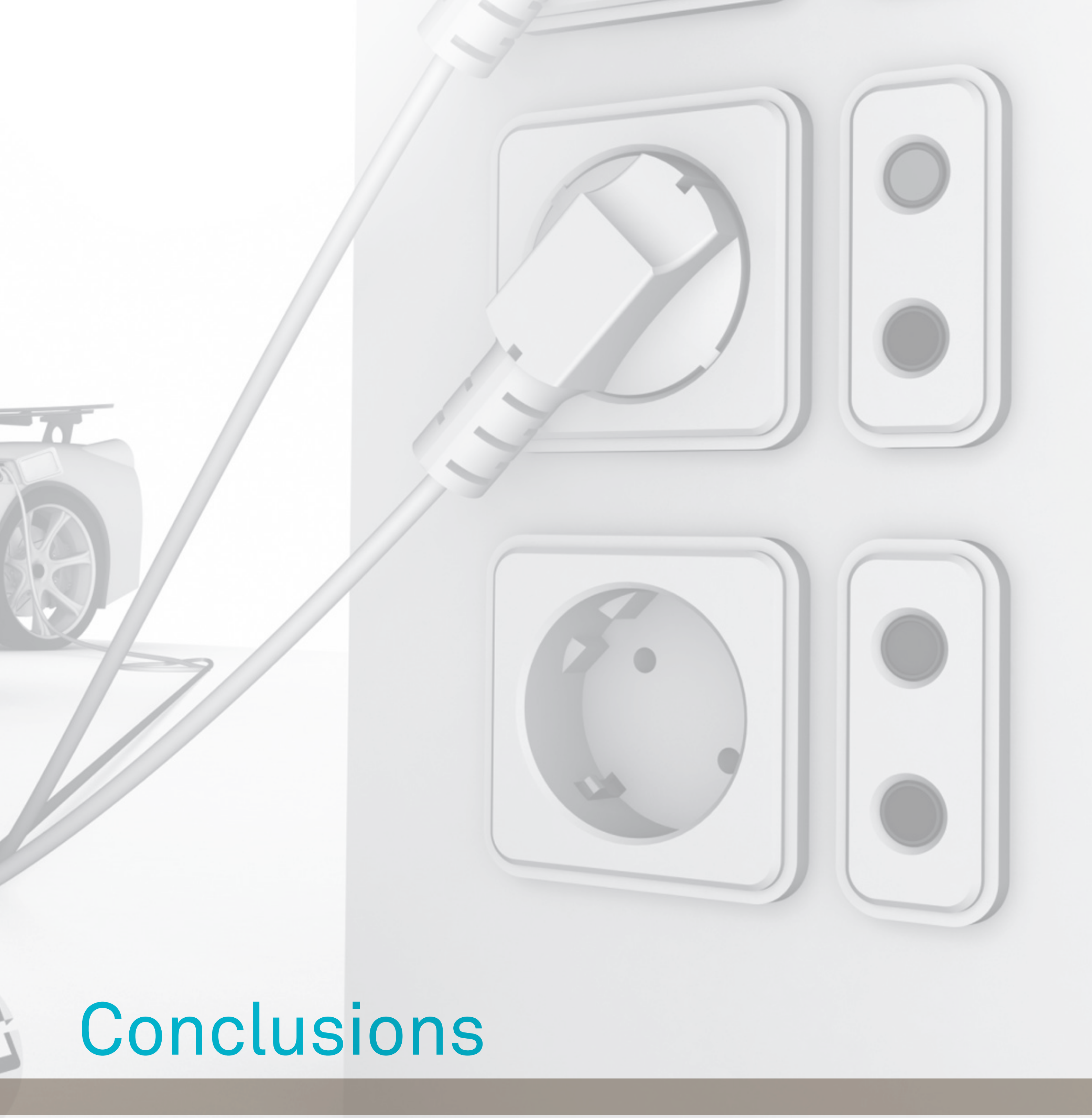
9.3.3 Conclusions

Refuelling of commercial LNG or CNG vehicles will require large charging facilities with their own connection and supply agreements. These can be accommodated in existing market arrangements.

Similarly, refuelling of passenger vehicles fleets will require facilities with special agreements.

Refuelling of passenger vehicles at home can be accommodated within standard supply agreements, provided that the gas distribution network is operating at high pressure. Some older areas are operating are lower pressure to reduce leaks, but over time will be upgraded to enable high pressures.





Conclusions

10.0

Conclusions

This study aimed to assess the potential uptake of EVs and NGVs and identify their respective costs and benefits on the energy markets. Key conclusions from this study include:

Electric Vehicles are likely to play an important role in the future of motor vehicles in Australia…

AECOM's analysis suggests that within 10 to 15 years EVs could have a significant presence in the Australian market. While vehicle sales are expected to be slow initially, accounting for around 1 to 2 percent until 2015, once vehicle prices fall, global supply constraints ease and infrastructure availability increases, EV sales are expected to be around 20 percent of sales by 2020 rising to around 45 percent of sales by 2030. Take up could be slower if EV prices take longer to reach price parity and supply constraints remain in the Australian market. However, it is also possible that take up could be much quicker if for example, battery prices fall much quicker than currently anticipated, Australia is seen as a key electric vehicle market with supply constraints easing quicker and the emergence of leasing arrangements that reduce the upfront purchase cost. In early years, the take-up of PHEVs is projected to be stronger than that of BEVs due to superior range and the ability to use both electricity and petrol as fuel. However, over time there will be a shift towards BEVs as purchase prices converge to parity with ICE, battery improvements result in increased vehicle range, the provision of more charging infrastructure, and higher fuel prices have the potential to make BEVs more competitive.

The impact of EVs on the electricity market depends on the ability to incentivise drivers to charge in off-peak periods…

The impact that EVs will have on the electricity markets is largely dependent on the amount of energy used and the timing of charging. Overall, energy consumption remains relatively low as a proportion of total energy demand even in the high take up scenario for both the NEM and SWIS. However, the biggest potential issue is the impact on peak load. In the worst case scenario where EV charging is unmanaged and occurs during existing load peaks, peak load will increase. As a result, distribution and transmission systems will need to be strengthened and more generation built. Conversely, if charging happens in off-peak periods, then it is not expected to increase peak load, even in high take up scenarios. Unlike many other high energy consumer goods, such as air conditioning, use of electric vehicle charging has more flexibility. If electric vehicle drivers can be encouraged to charge their vehicles in off-peak periods, either through incentivising customers to charge at off-peak times through time of use charging or smart metering, or enforcing off-peak charging through ripple control or regulation, the impacts fall significantly.

EVs offer significant opportunities for improving the efficiency of the electricity market…

If EVs can be managed to ensure the majority of charging occurs in non-peak periods, they present significant opportunities for improving the efficiency of the electricity market, including:

- *Improved load factor:* the cost of meeting peak demand is generation and network capacity that is used infrequently. Most networks operate at less than 50 percent load factor for a large proportion of the day. Going forward, this load factor is expected to deteriorate with peak demand forecast to grow faster than average energy use in the NEM. By flattening the load curve, the fixed costs of the network can be spread across a larger base, resulting in improved load factor.
- *Flexibility benefits:* provided there is some form of dynamic pricing with the charging of EVs, there are further benefits from EVs including managing transmission and distribution networks, managing wholesale price risk and more efficient use of intermittent generation.
- *Vehicle-to-Grid:* EVs also provide an opportunity to act as energy storage devices and feedback electricity to the grid (known as Vehicle-to-Grid (V2G)) or to the house (known as Vehicle-to-House (V2H)). This opportunity could be used to reduce strain on the grid during periods of peak demand, provide ancillary services or power a house. The benefits of V2G could be large;

- however, the success of V2G depends on a number of factors including the impact on battery life, driver concerns, tariff arrangements and the take up of EVS.

The take up of NGVs is uncertain but, even if it was large, is not anticipated to create any major impacts on the gas markets…

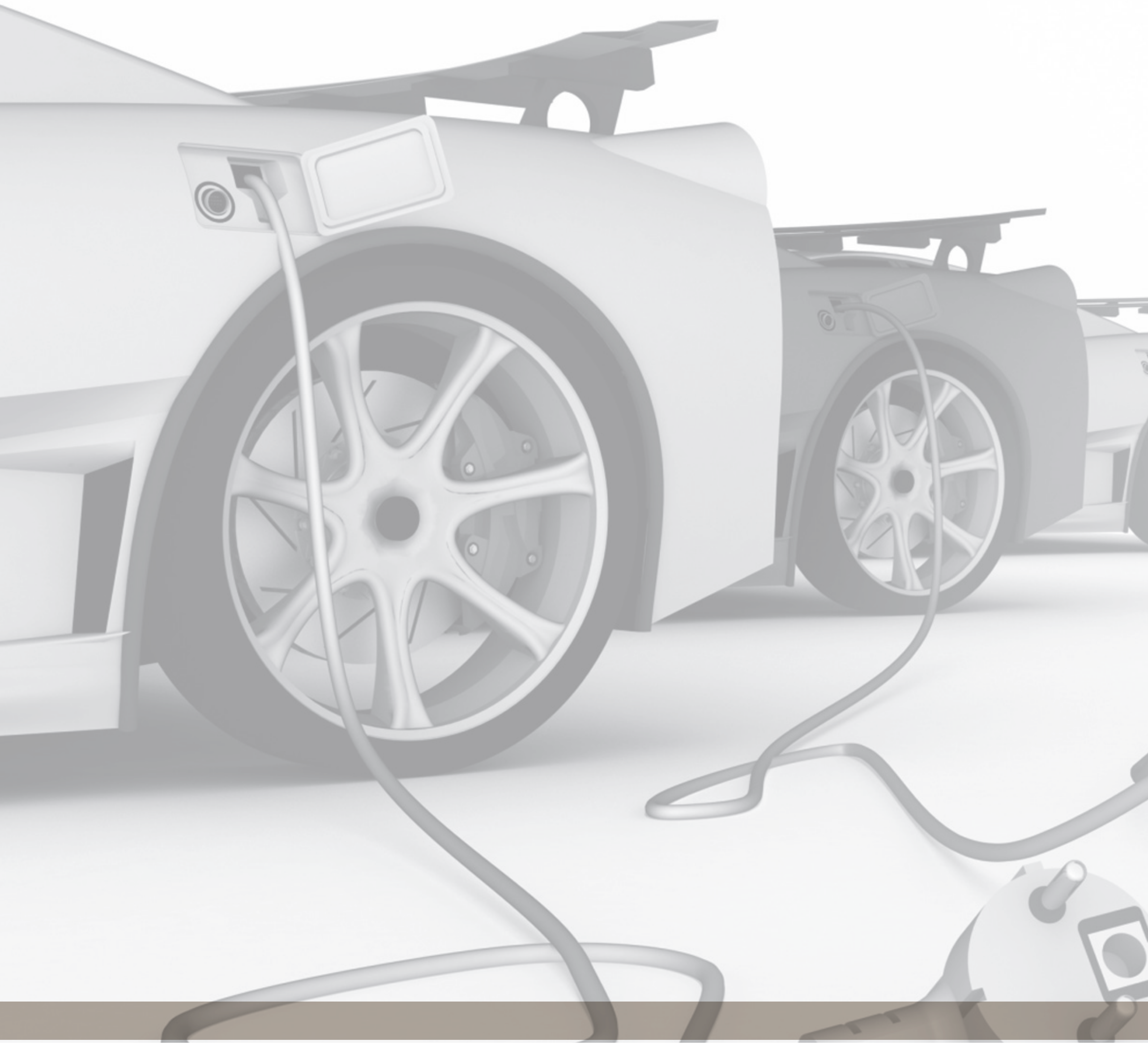
Like EVs, NGVs offer a lower emissions alternative to the traditional vehicles powered by petrol and diesel. NGVs currently have some advantages over EVs. In particular, they are more cost effective for drivers who travel large distances and offer a superior range. Our research suggests that this advantage may diminish over time as the upfront cost of EVs falls, EV vehicle range improves, and gas prices increase relatively more than electricity prices. In addition, NGVs require substantial investment in refuelling infrastructure. In contrast, there is an existing electricity network which will allow recharging of EVs even at home relatively easily. Take up of NGVs is more likely in buses, where governments will be targeting reduced greenhouse gas emissions, and trucks, which typically travel longer distances so benefit more from the reduced operating costs and refuel at a central base or specific locations, making it a viable option to install the refuelling infrastructure. However, both natural gas vehicles and electric vehicles are emerging technologies and there is uncertainty about how both markets will evolve.

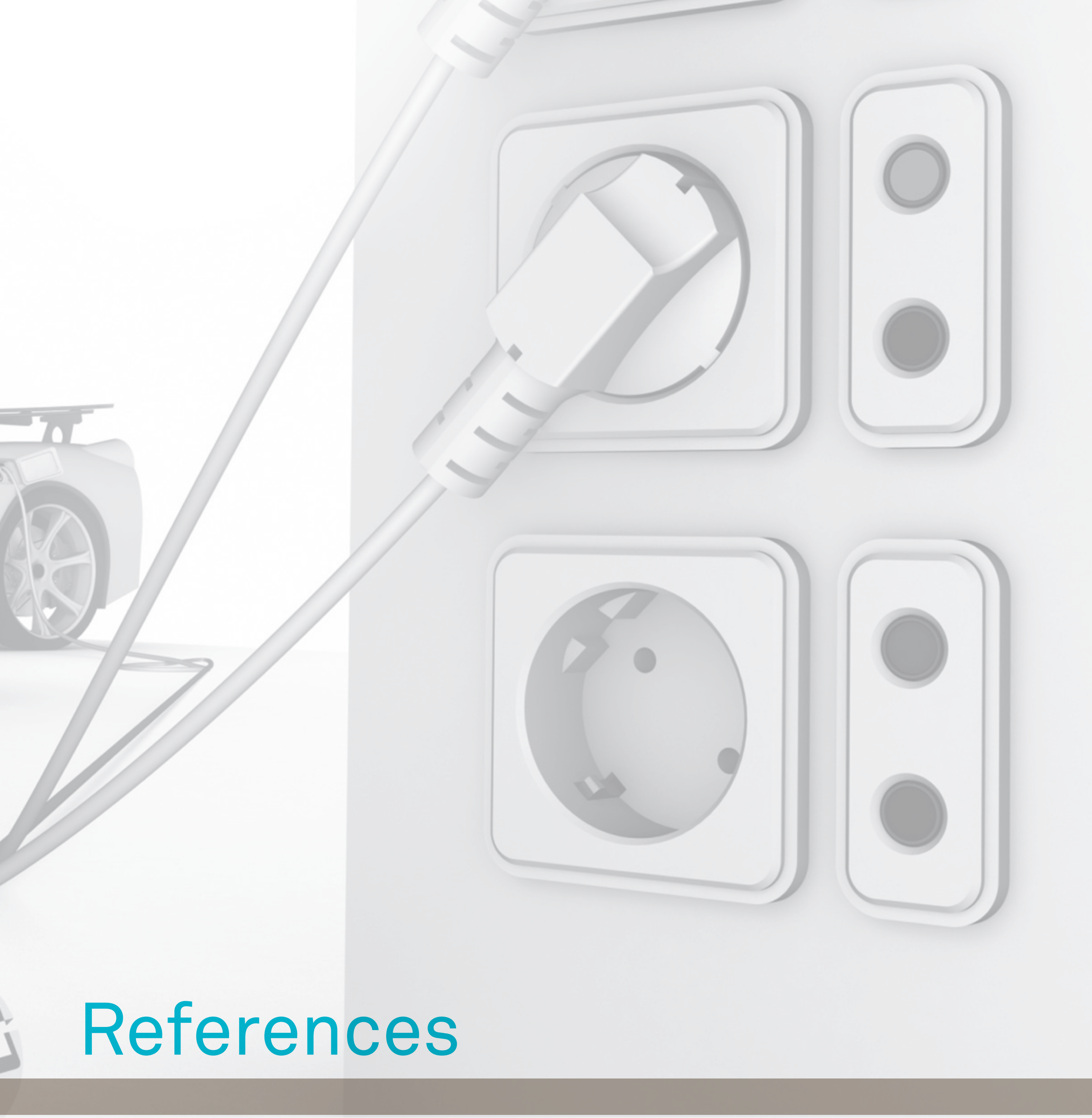
The take up of NGVs is not expected to cause significant issues with eastern or western Australian gas markets because gas networks can generally balance on a daily basis rather than instantaneously, so the timing of charging is not a major issue, and any additional load is likely to be relatively predictable on a daily basis.

Commercial CNG or LNG vehicles will need specialised refuelling stations, which are likely to be connected either at transmission or sub-transmission level if large quantities of gas are required. Network impacts from commercial refuelling are likely to be small, and presumably customer funded, for the following reasons:

- LNG facilities are likely to require high capacity connections to transmission or sub-transmission pipelines, in order to supply sufficient quantities
- there are already clear price signals for withdrawals through high capacity connections. These signals recognise the need for gas balancing and the scope for line-pack within high capacity gas networks
- facilities will need to provide storage for CNG or LNG prior to distribution to refuelling stations, so should be able to manage their withdrawals to reduce network impacts and costs.

The take up of passenger NGVs refuelled at home can be accommodated where gas distribution networks operate at high pressure, which over time will encompass all gas distribution areas.





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Submissions

Submissions in response to the AEMC Approach Paper were made by the organisations listed below. These are available at: http://www.aemc.gov.au/Market-Reviews/Open/Energy-Market-Barriers-for-Electric-and-Natural-Gas-Vehicles.html

Australian Automobile Association

Better Place

ChargePoint

Energex

Energy Networks Association

Energy Retailers Association of Australia

GE Energy

Origin Energy

SP AusNet

TRUenergy

University of South Australia

Westport Innovations (Australia) Pty Ltd

Late submissions:

ACT Government

AGL Energy

Alternative Technology Association

Ausgrid

Blade Electric Vehicles

Ergon Energy

Government of South Australia

Western Power

Submissions in response to the AEMC Issues Paper were made by the organisations listed below. These are available at: http://www.aemc.gov.au/Market-Reviews/Open/Energy-Market-Barriers-for-Electric-and-Natural-Gas-Vehicles.html

APA Group

Aurora Energy

Australian Electric Vehicle Association

Better Place

BOC

ChargePoint

Citipower and Powercor Australia

Commonwealth Dept. of Climate Change and Energy Efficiency

Energy Networks Association

Energy Retailers Association of Australia

Envesta

Horizon Power

iGas Energy

Origin Energy

Saturn Corporate Resources

Late submissions:

ActewAGL

Energy Supply Association of Australia

AGL

Alternative Technology Association

ENERGEX

SP AusNet

Tasmanian Department of Infrastructure, Energy and Resources

Australian Energy Regulator

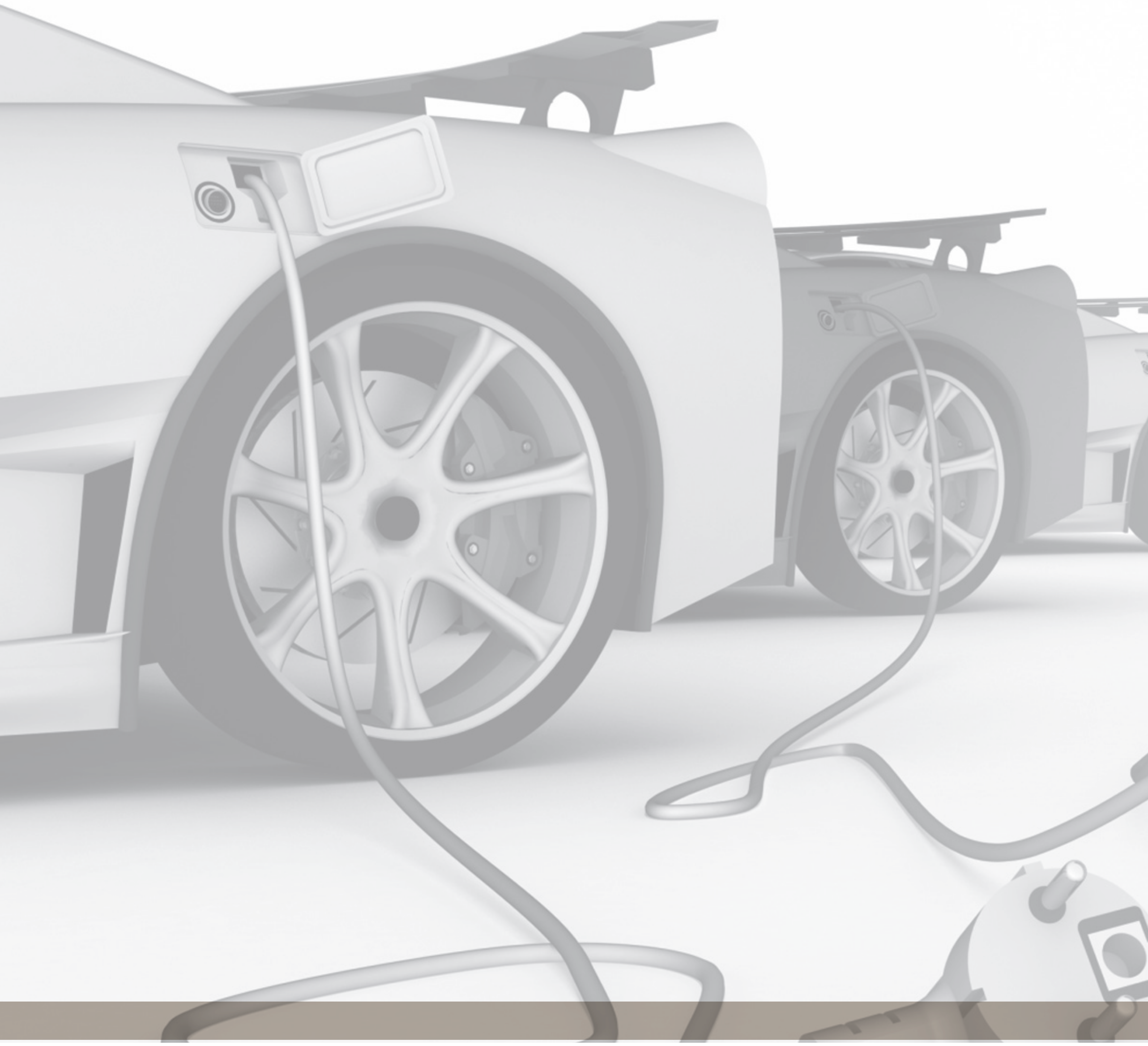
Government of South Australia

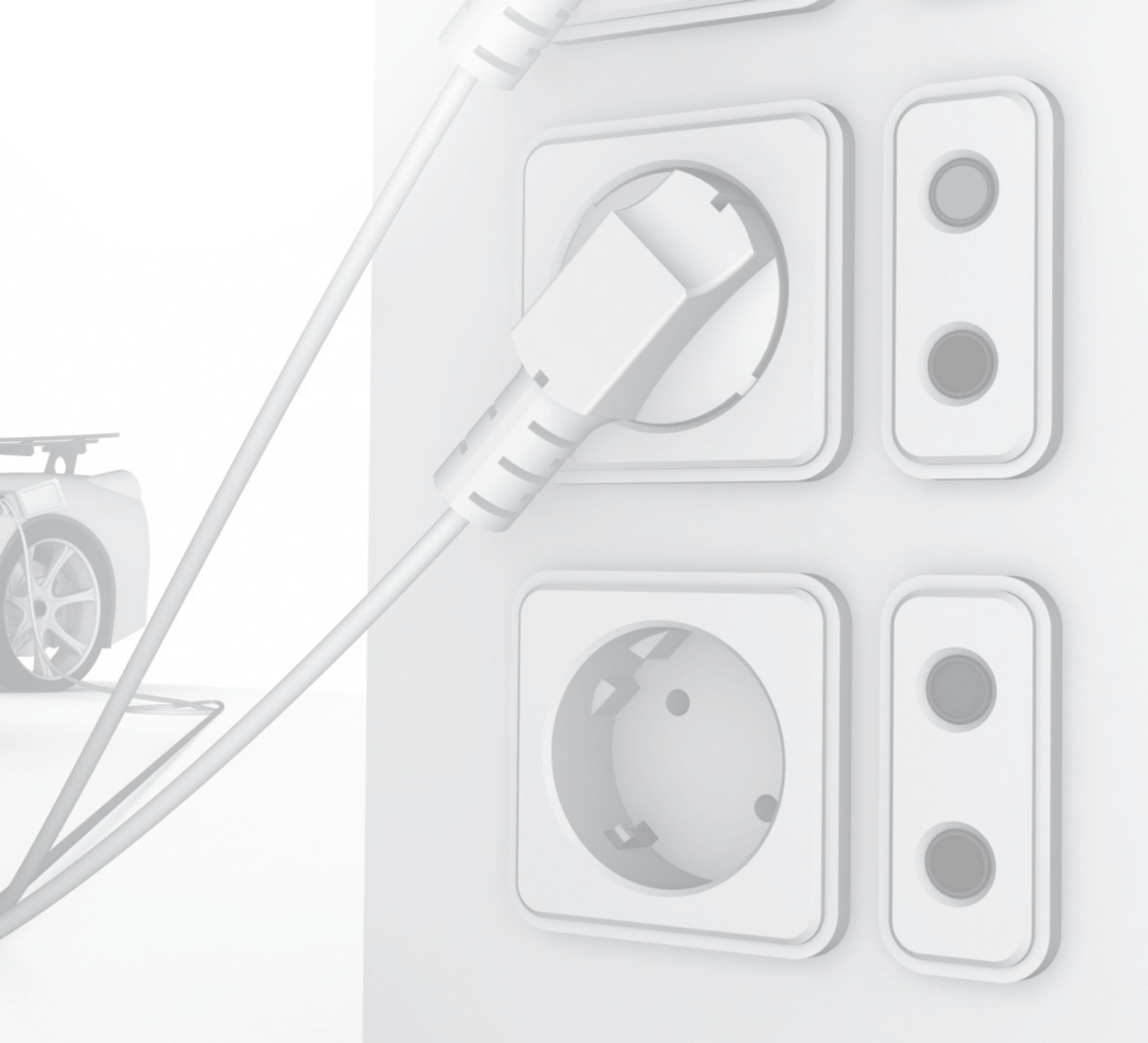
Ergon Energy

University of NSW

Ausgrid

Verdant Vision (submission and letter dated 14 June 2012)





Detailed Results

A

Detailed Results

Vehicle sales results

Table A 1: PHEV and BEV sales by state – central scenario

	PHEV			BEV			Total BEV and PHEV		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
VIC	3,800	59,700	134,500	1,900	4,300	25,000	5,700	64,100	159,500
NSW	4,200	63,100	142,000	2,100	5,400	32,000	6,300	68,500	174,100
ACT	200	3,400	7,200	100	200	1,300	300	3,700	8,500
QLD	2,800	45,000	117,600	1,400	3,900	26,400	4,200	48,900	144,000
TAS	300	3,900	9,100	100	300	1,700	400	4,200	10,800
SA	900	14,300	34,200	400	1,000	6,300	1,300	15,300	40,500
Total NEM	12,200	189,400	444,600	6,000	15,100	92,700	18,200	204,700	537,400
WA	1,600	25,800	67,000	800	2,200	15,100	2,400	28,000	82,100

Source: AECOM. Values are rounded to the nearest 100 vehicles.

Table A 2: PHEV and BEV sales by state – low scenario

	PHEV			BEV			Total BEV and PHEV		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
VIC	3,800	14,000	105,200	1,000	1,800	7,900	4,800	15,800	113,100
NSW	4,200	15,700	112,400	1,000	2,100	10,100	5,300	17,800	122,500
ACT	200	800	5,600	100	100	400	300	900	6,000
QLD	2,800	10,300	93,200	700	1,500	8,300	3,500	11,800	101,500
TAS	300	1,000	7,100	100	100	500	300	1,100	7,700
SA	900	3,300	26,800	200	400	2,000	1,100	3,700	28,800
Total NEM	12,200	45,100	350,300	3,100	6,000	29,200	15,300	51,100	379,600
WA	1,600	5,800	53,100	400	900	4,700	2,000	6,700	57,800

Source: AECOM. Values are rounded to the nearest 100 vehicles.

Table A 3: PHEV and BEV sales by state – high scenario

	PHEV			BEV			Total BEV and PHEV		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
VIC	39,500	132,700	155,400	3,700	17,400	55,600	43,200	150,100	211,000
NSW	41,600	146,400	159,200	4,400	22,900	70,300	46,000	169,300	229,500
ACT	2,300	7,500	8,300	200	1,000	3,000	2,500	8,400	11,300
QLD	27,400	105,900	131,500	2,900	16,500	57,900	30,300	122,400	189,500
TAS	2,500	8,900	10,500	200	1,200	3,700	2,800	10,100	14,200
SA	9,200	32,200	39,400	900	4,200	14,100	10,000	36,400	53,500
Total NEM	122,500	433,600	504,300	12,300	63,200	204,600	134,800	496,700	709,000
WA	15,700	60,400	74,900	1,700	9,400	33,100	17,400	69,800	108,000

Source: AECOM. Values are rounded to the nearest 100 vehicles.

Energy usage results

Table A 4: Energy consumption from EVs (MWh) – central take up scenario

	PHEV			BEV			Total		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
VIC	13,900	159,400	2,299,200	17,000	62,400	499,200	30,800	221,800	2,798,400
NSW	13,000	144,400	2,096,500	15,200	60,500	529,400	28,100	204,900	2,626,000
ACT	800	9,100	124,800	1,000	3,600	27,300	1,800	12,700	152,000
QLD	8,500	100,500	1,653,400	9,800	41,400	415,000	18,300	141,900	2,068,400
TAS	1,000	10,700	157,600	1,100	4,000	33,800	2,000	14,700	191,400
SA	3,300	38,100	576,100	3,900	14,700	124,500	7,200	52,800	700,600
Total NEM	40,400	462,200	6,907,600	48,000	186,600	1,629,100	88,300	648,800	8,536,700
WA	4,800	57,100	937,600	5,600	23,700	236,200	10,400	80,900	1,173,800

Source: AECOM. Values are rounded to the nearest 100 MWh.

Table A 5: Energy consumption from EVs (MWh) – low take up scenario

	PHEV			BEV			Total		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
VIC	13,800	82,300	1,199,300	9,500	29,200	141,800	23,300	111,500	1,341,200
NSW	12,900	77,200	1,093,100	8,100	26,200	144,300	21,000	103,400	1,237,400
ACT	800	4,800	65,500	600	1,700	7,800	1,400	6,500	73,400
QLD	8,500	50,900	849,800	5,200	17,800	112,200	13,700	68,600	961,900
TAS	900	5,700	82,100	600	1,900	9,400	1,600	7,500	91,500
SA	3,300	19,500	298,900	2,200	6,800	35,100	5,400	26,300	333,900
Total NEM	40,100	240,200	3,588,700	26,300	83,500	450,700	66,400	323,700	4,039,300
WA	4,800	28,700	481,800	3,000	10,200	64,000	7,800	38,900	545,800

Source: AECOM. Values are rounded to the nearest 100 MWh.

Table A 6: Energy consumption from EVs (MWh) – high take up scenario

	PHEV			BEV			Total		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
VIC	67,600	821,800	3,466,600	28,000	195,400	1,199,400	95,600	1,017,200	4,666,000
NSW	59,600	758,600	3,145,100	26,700	206,100	1,281,800	86,300	964,700	4,426,900
ACT	4,000	46,600	189,500	1,600	11,100	65,500	5,600	57,800	255,000
QLD	39,500	538,400	2,434,100	17,600	144,900	998,900	57,100	683,400	3,432,900
TAS	4,400	55,000	237,000	1,900	13,000	81,600	6,300	68,000	318,600
SA	15,800	197,600	862,700	6,600	46,900	299,100	22,300	244,500	1,161,900
Total NEM	190,700	2,418,100	10,335,100	82,400	617,400	3,926,200	273,100	3,035,400	14,261,400
WA	22,600	306,400	1,380,500	10,000	82,600	568,100	32,600	389,000	1,948,700

Source: AECOM. Values are rounded to the nearest 100 MWh.

Table A 7: Energy consumption from EVs as a proportion of total energy consumption – central take up scenario

	PHEV			BEV			Total		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
VIC	0.0%	0.3%	3.0%	0.0%	0.1%	0.7%	0.1%	0.4%	3.7%
NSW and ACT	0.0%	0.2%	2.1%	0.0%	0.1%	0.5%	0.0%	0.2%	2.6%
QLD	0.0%	0.1%	1.0%	0.0%	0.0%	0.3%	0.0%	0.2%	1.3%
TAS	0.0%	0.1%	0.9%	0.0%	0.0%	0.2%	0.0%	0.1%	1.1%
SA	0.0%	0.2%	2.5%	0.0%	0.1%	0.6%	0.0%	0.3%	3.1%
Total NEM	0.0%	0.2%	1.8%	0.0%	0.1%	0.4%	0.0%	0.2%	2.2%
WA	0.0%	0.1%	2.1%	0.0%	0.1%	0.5%	0.0%	0.2%	2.6%

Table A 8: Energy consumption from EVs as a proportion of total energy consumption – low take up scenario

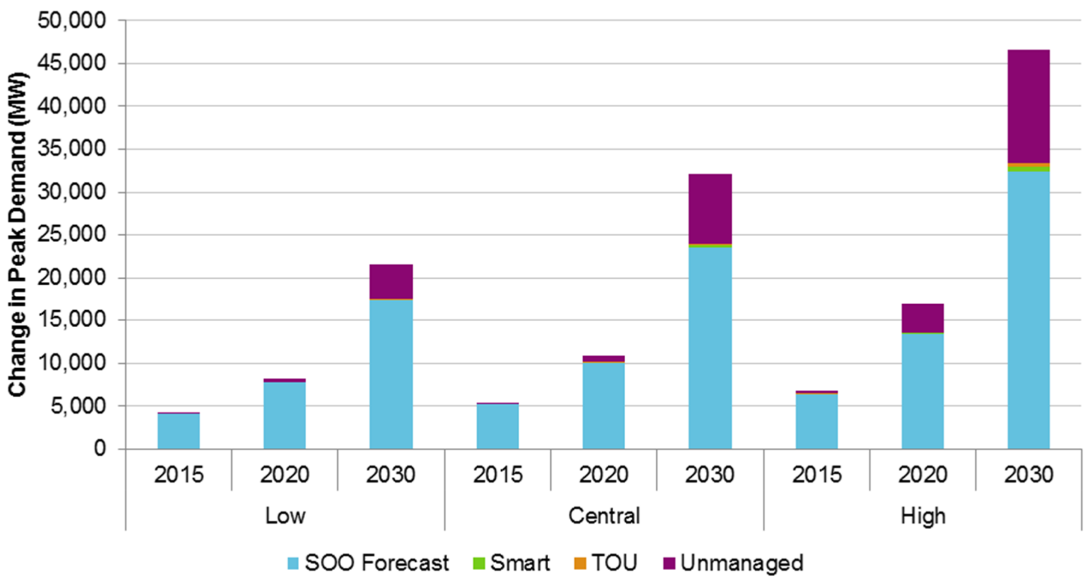
	PHEV			BEV			Total		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
VIC	0.0%	0.1%	1.6%	0.0%	0.0%	0.2%	0.0%	0.2%	1.8%
NSW and ACT	0.0%	0.1%	1.1%	0.0%	0.0%	0.1%	0.0%	0.1%	1.2%
QLD	0.0%	0.1%	0.5%	0.0%	0.0%	0.1%	0.0%	0.1%	0.6%
TAS	0.0%	0.0%	0.5%	0.0%	0.0%	0.1%	0.0%	0.1%	0.5%
SA	0.0%	0.1%	1.3%	0.0%	0.0%	0.2%	0.0%	0.1%	1.5%
Total NEM	0.0%	0.1%	0.9%	0.0%	0.0%	0.1%	0.0%	0.1%	1.1%
WA	0.0%	0.1%	1.1%	0.0%	0.0%	0.1%	0.0%	0.1%	1.2%

Table A 9: Energy consumption from EVs as a proportion of total energy consumption – high take up scenario

	PHEV			BEV			Total		
	2015	2020	2030	2015	2020	2030	2015	2020	2030
VIC	0.1%	1.4%	4.6%	0.1%	0.3%	1.6%	0.2%	1.7%	6.1%
NSW and ACT	0.1%	0.9%	3.2%	0.0%	0.2%	1.3%	0.1%	1.2%	4.5%
QLD	0.1%	0.6%	1.5%	0.0%	0.2%	0.6%	0.1%	0.8%	2.2%
TAS	0.0%	0.4%	1.3%	0.0%	0.1%	0.5%	0.1%	0.5%	1.8%
SA	0.1%	1.1%	3.8%	0.0%	0.3%	1.3%	0.1%	1.4%	5.1%
Total NEM	0.1%	0.9%	2.7%	0.0%	0.2%	1.0%	0.1%	1.1%	3.7%
WA	0.1%	0.8%	3.0%	0.0%	0.2%	1.2%	0.1%	1.0%	4.3%

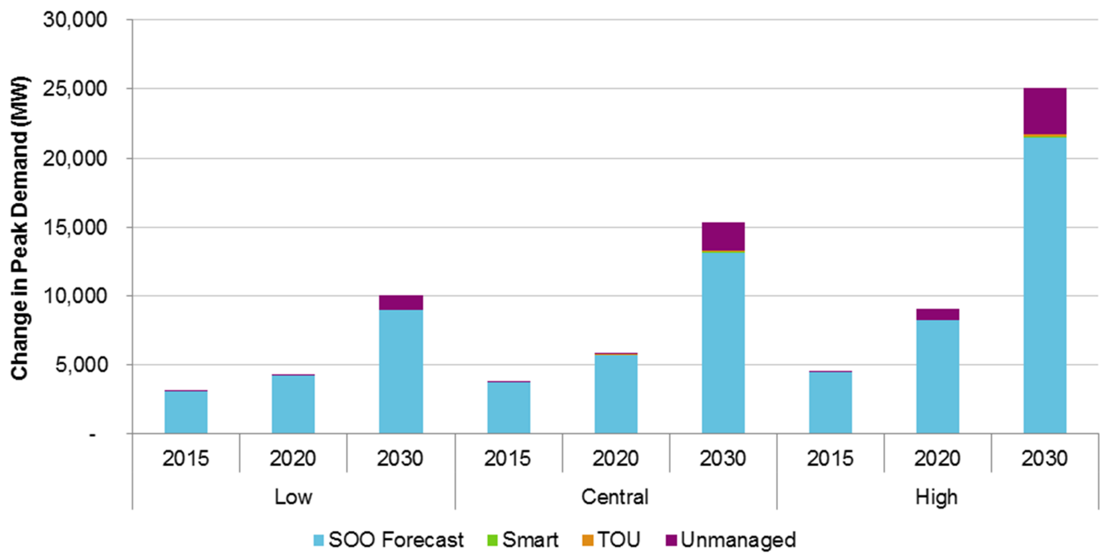
Impact of EVs on peak demand compared to the increase in peak demand required without EVs – state analysis

Figure 50: Forecast change in peak demand for the NEM (Since 2010-2011)



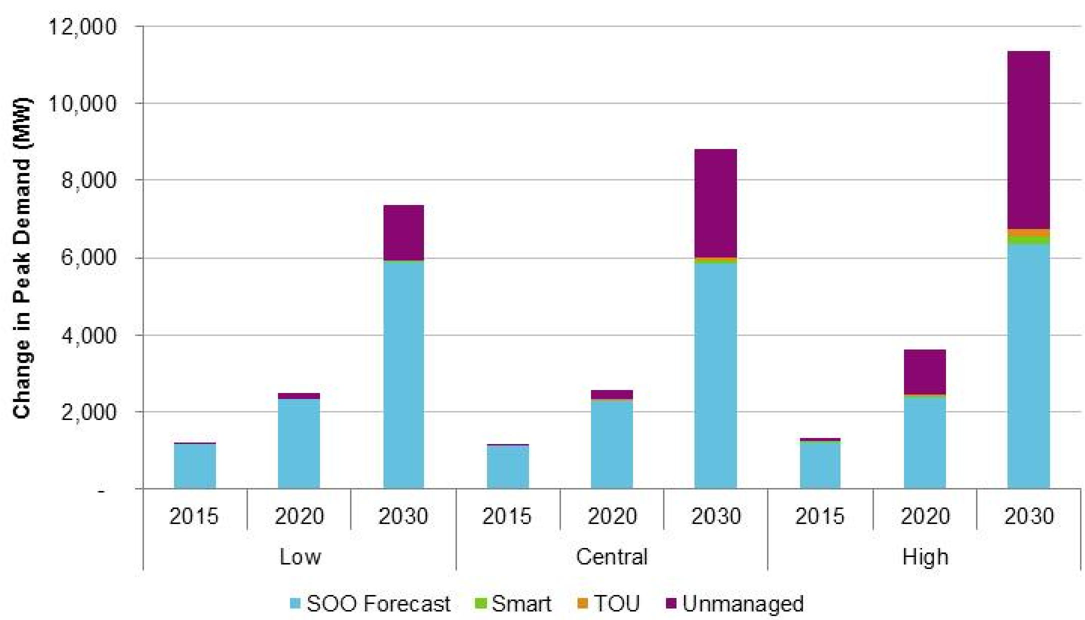
Source: AECOM

Figure 51: Forecast change in peak demand for the Queensland (Since 2010-2011)



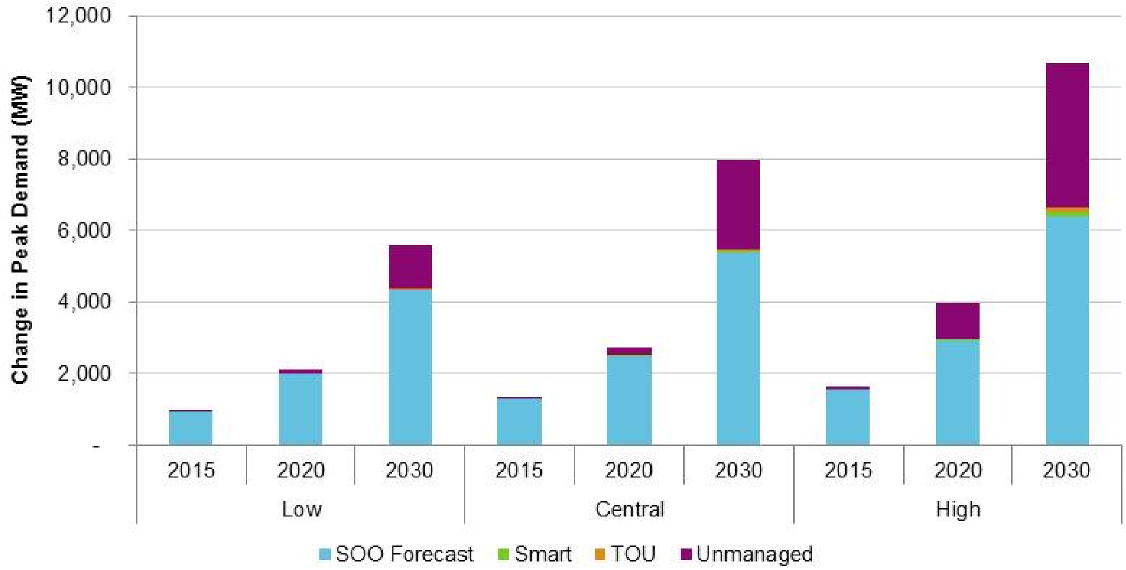
Source: AECOM

Figure 52: Forecast change in peak demand for the NSW and ACT (Since 2010-2011)



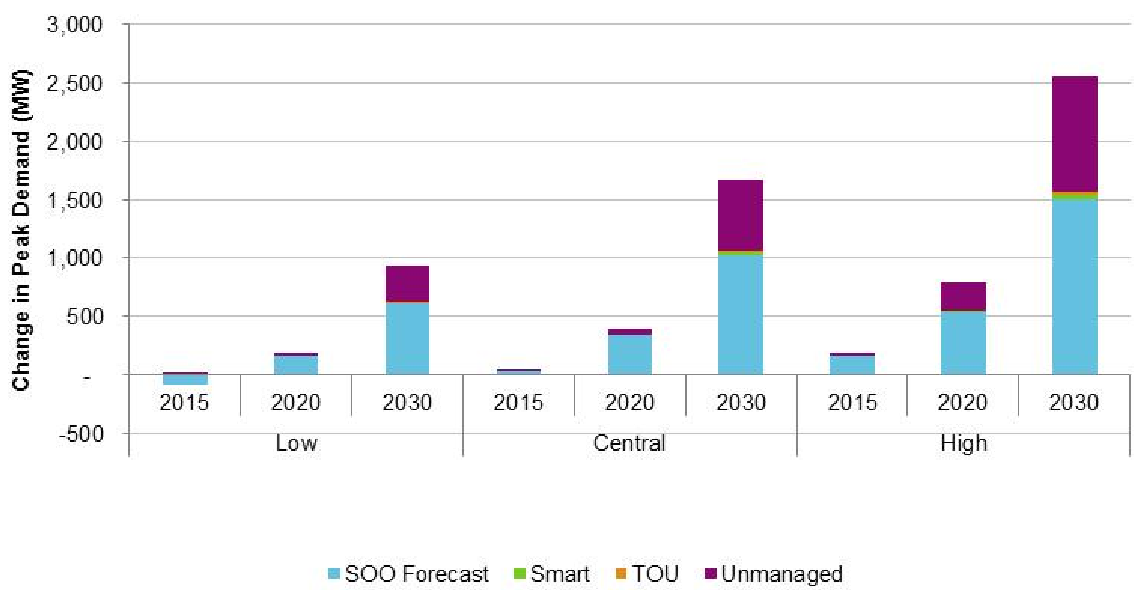
Source: AECOM

Figure 53: Forecast change in peak demand for the Victoria (Since 2010-2011)



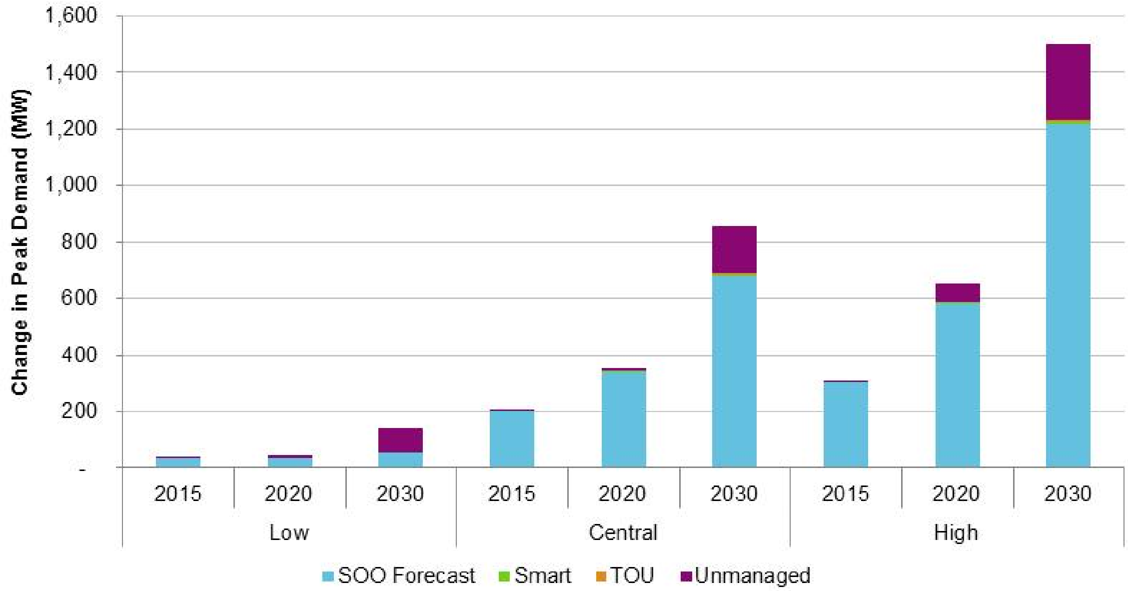
Source: AECOM

Figure 54: Forecast change in peak demand for the South Australia (Since 2010-2011)



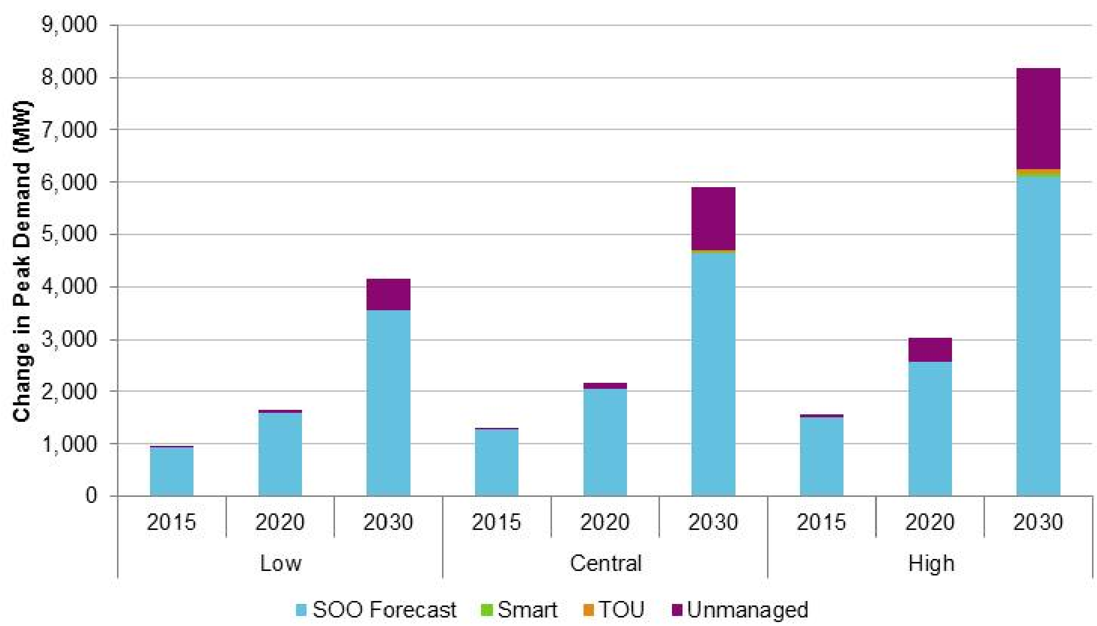
Source: AECOM

Figure 55: Forecast change in peak demand for the Tasmania (Since 2010-2011)



Source: AECOM

Figure 56: Forecast change in peak demand for the Western Australia (Since 2010-2011)



Source: AECOM

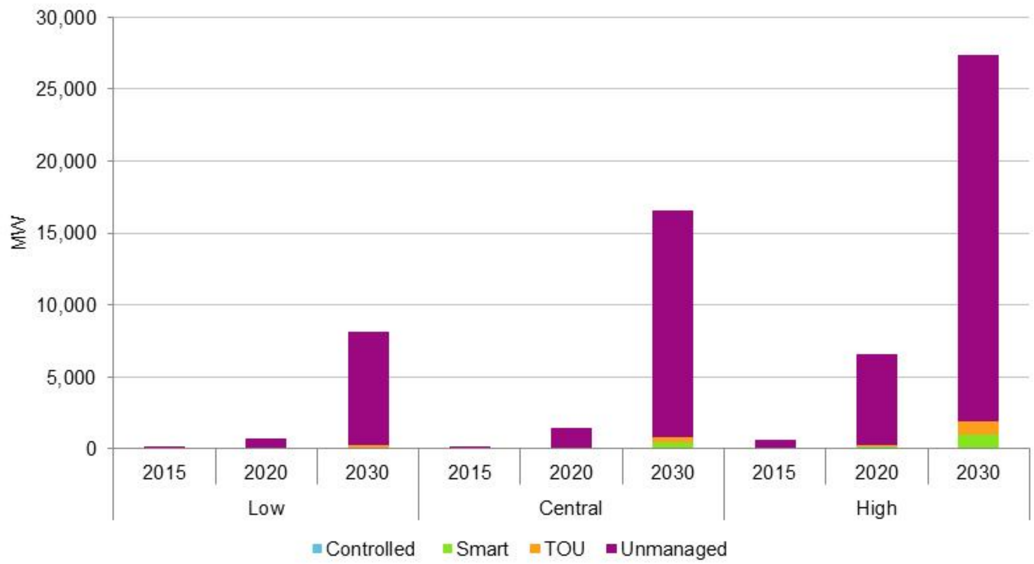
Sensitivity Analysis of Peak Load Impacts

This analysis repeats the analysis in **Section** 5.2 under both slightly more extreme and moderate assumptions.

Extreme assumptions:

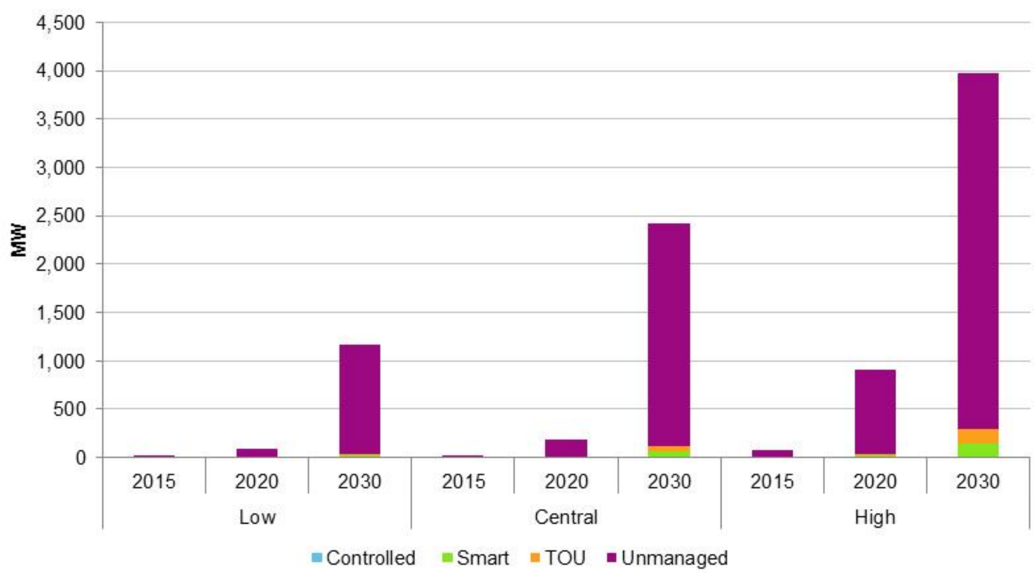
We assume that 100 percent of electric vehicles are charging during the peak period and that all chargers are level 1 15 Amp chargers.

Figure 57: Estimated additional peak demand in NEM (MW)



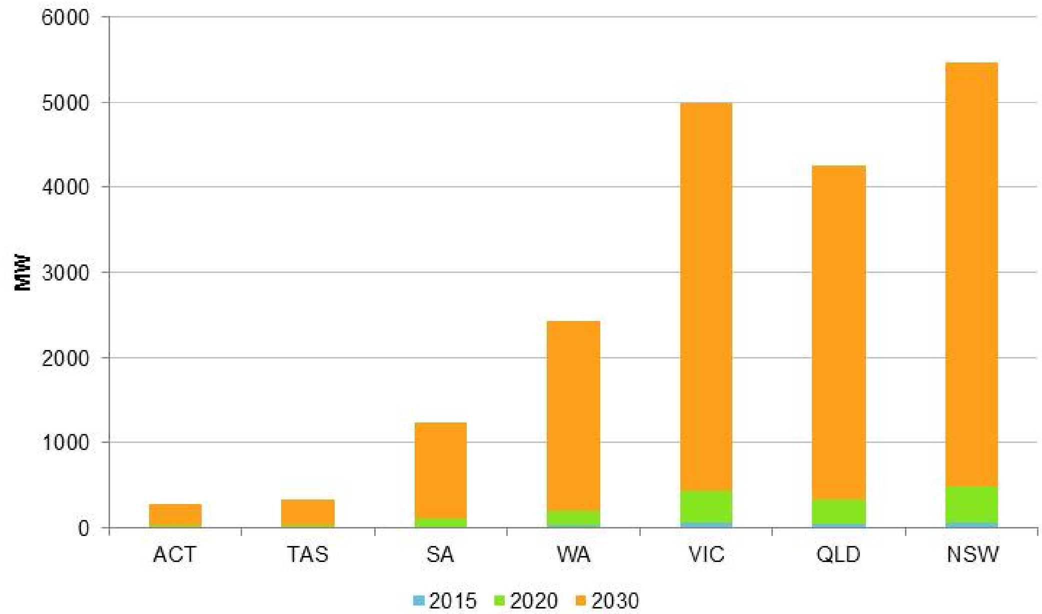
Source: AECOM

Figure 58: Estimated additional peak demand in SWIS (MW)



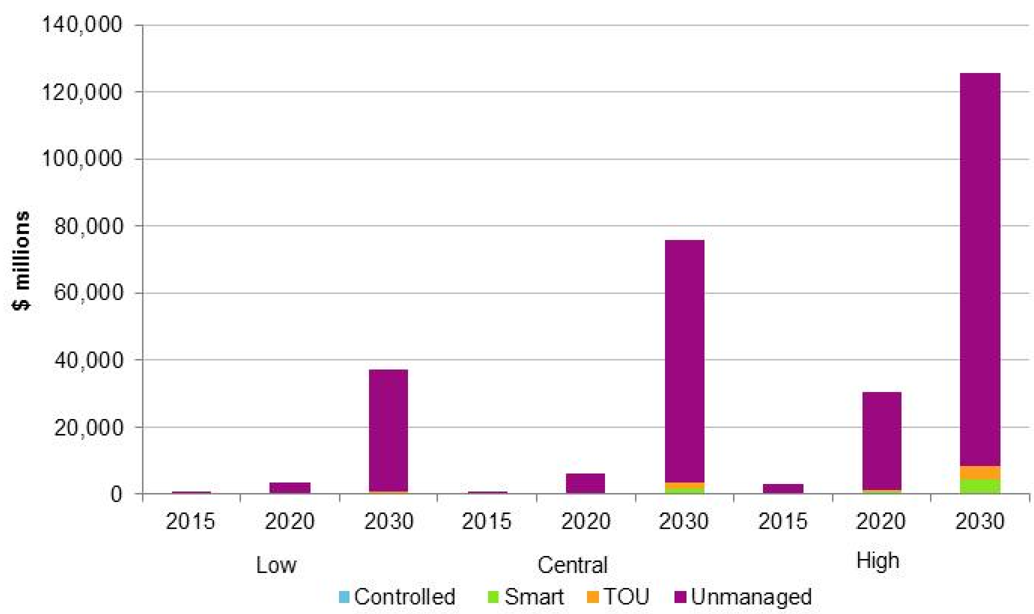
Source: AECOM

Figure 59: Additional peak demand in central take up scenario if charging is unmanaged



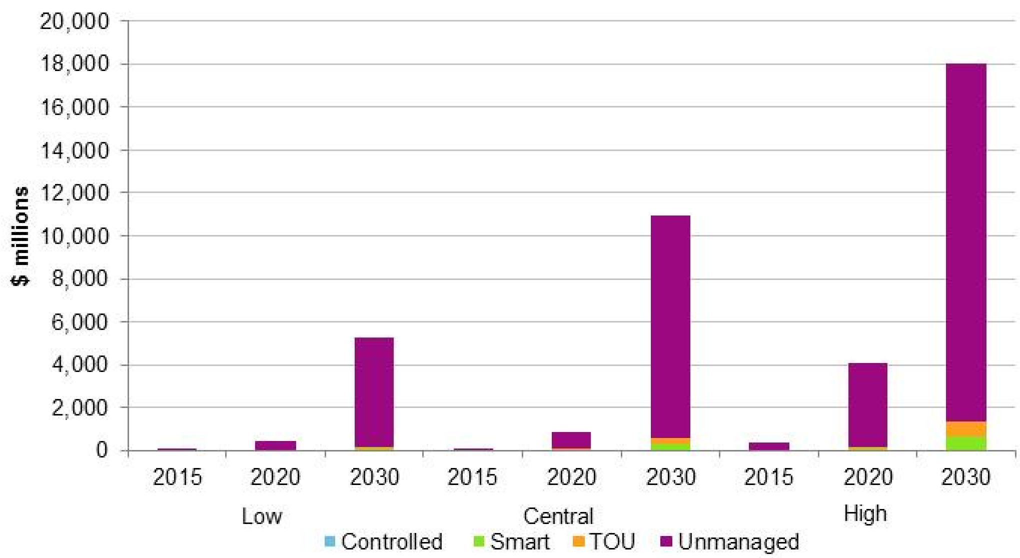
Source: AECOM

Figure 60: Estimated cost (for both generation and network upgrades) of additional peak demand in NEM ($ millions undiscounted)



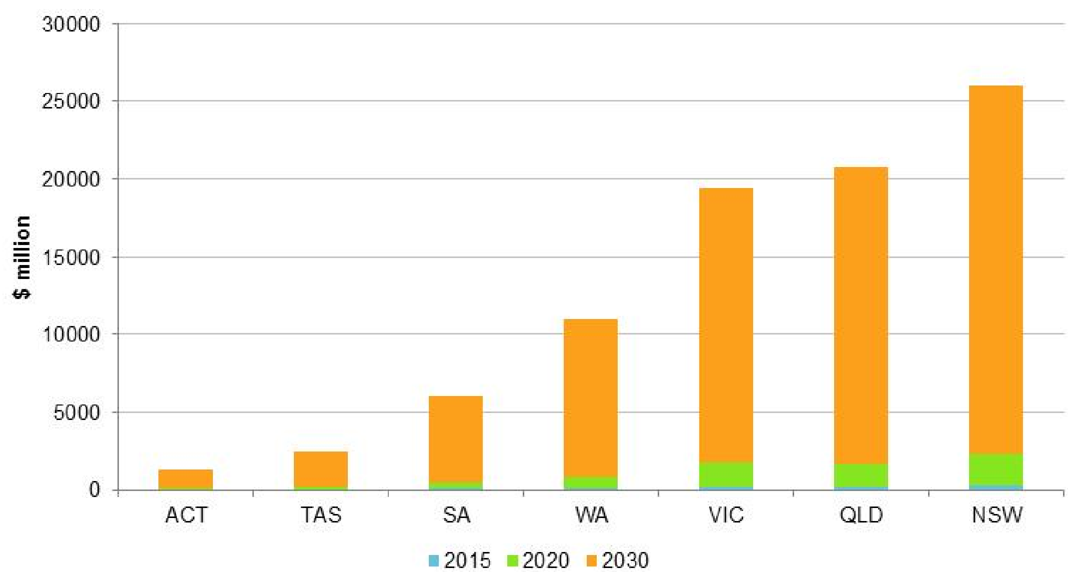
Source: AECOM

Figure 61 :Estimated cost (for both generation and network upgrades) of additional peak demand in SWIS ($ millions undiscounted)



Source: AECOM

Figure 62 Costs of additional peak demand in central take up scenario if charging is unmanaged ($million undiscounted)

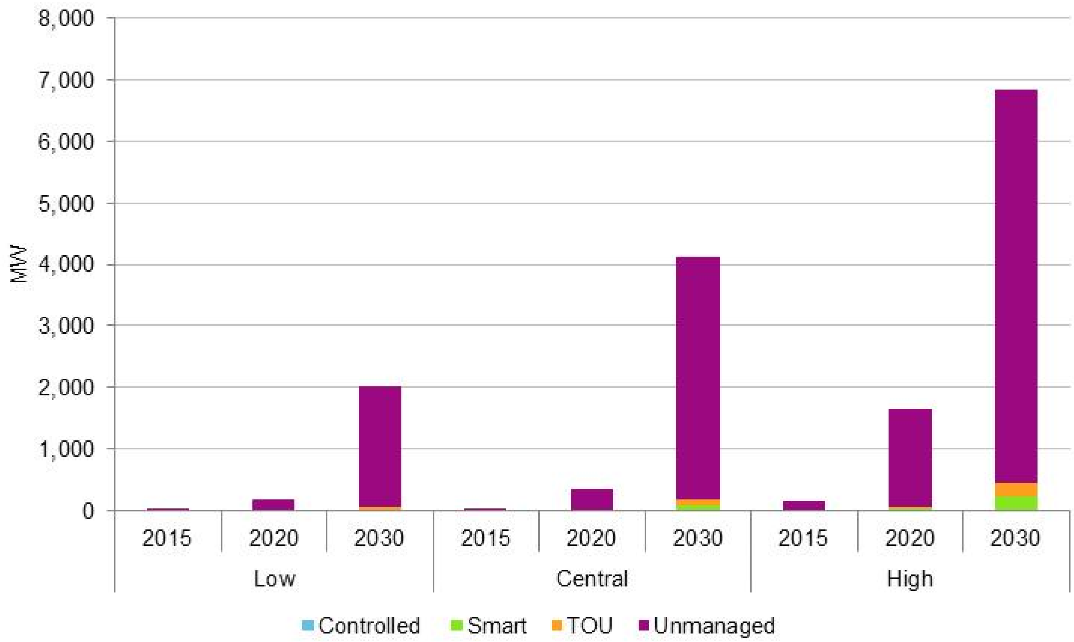


Source: AECOM

Moderate (yet realistic) assumptions:

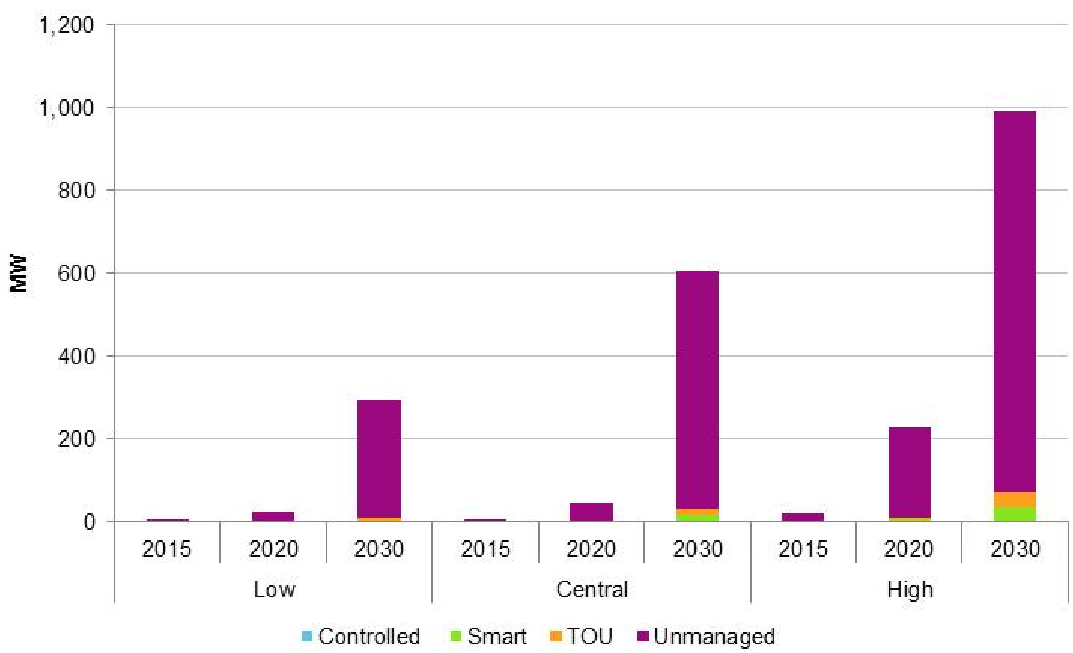
We assume that there is 25 percent coincident demand between system peak and electric vehicles charging using chargers that are level 1 15 Amp chargers.

Figure 63: Estimated additional peak demand in NEM (MW)



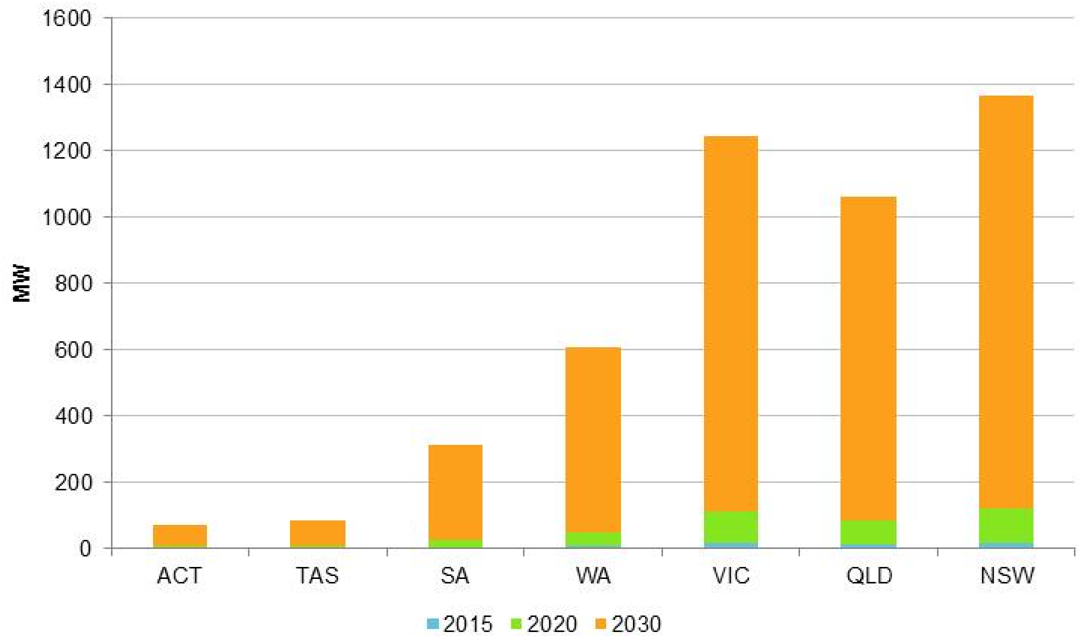
Source: AECOM

Figure 64: Estimated additional peak demand in SWIS (MW)



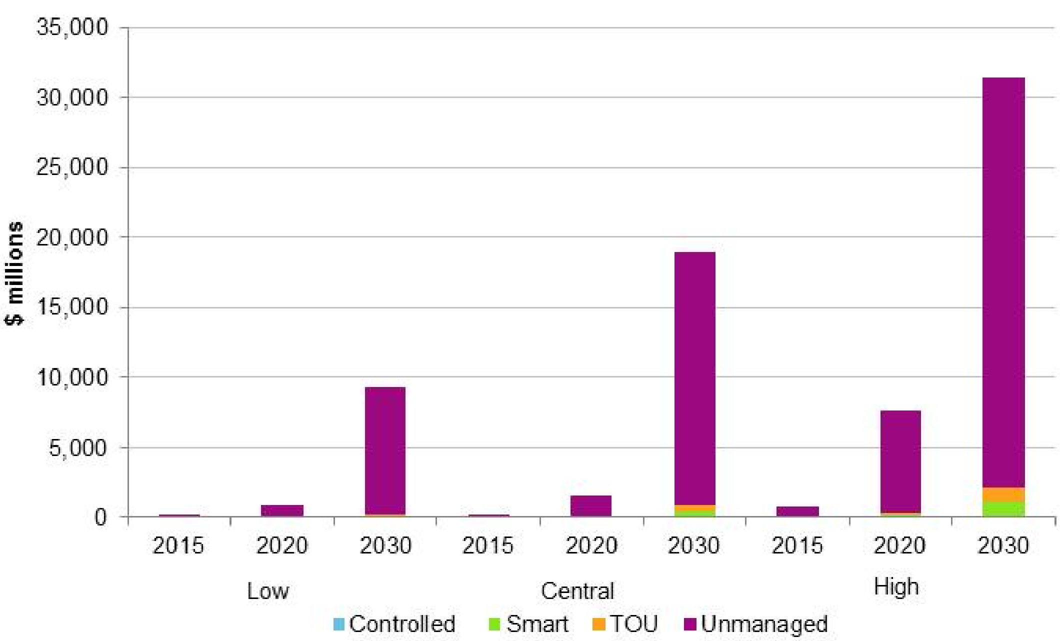
Source: AECOM

Figure 65: Additional peak demand in central take up scenario if charging is unmanaged



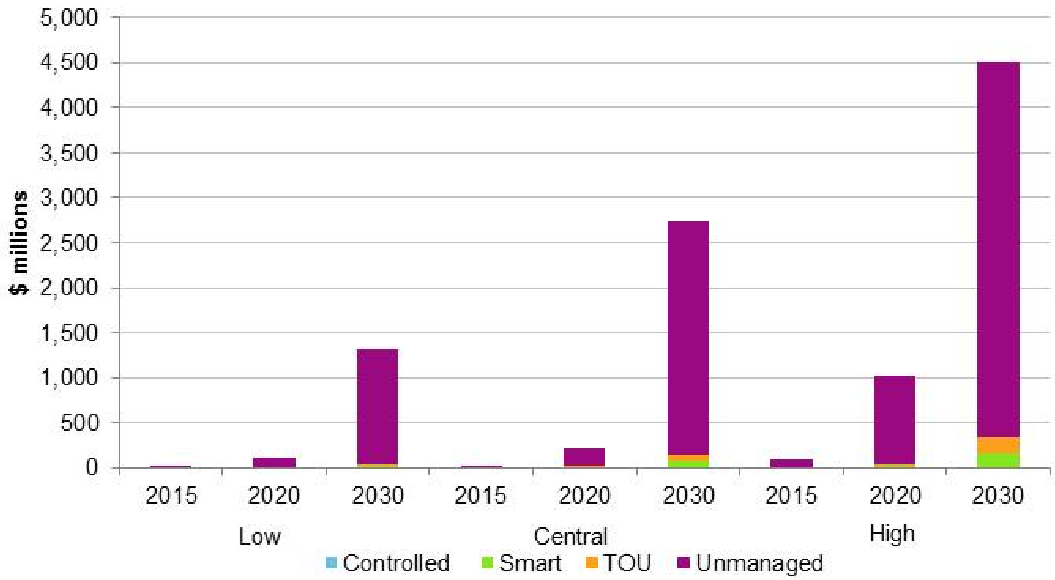
Source: AECOM

Figure 66: Estimated cost (for both generation and network upgrades) of additional peak demand in NEM ($ millions undiscounted)



Source: AECOM

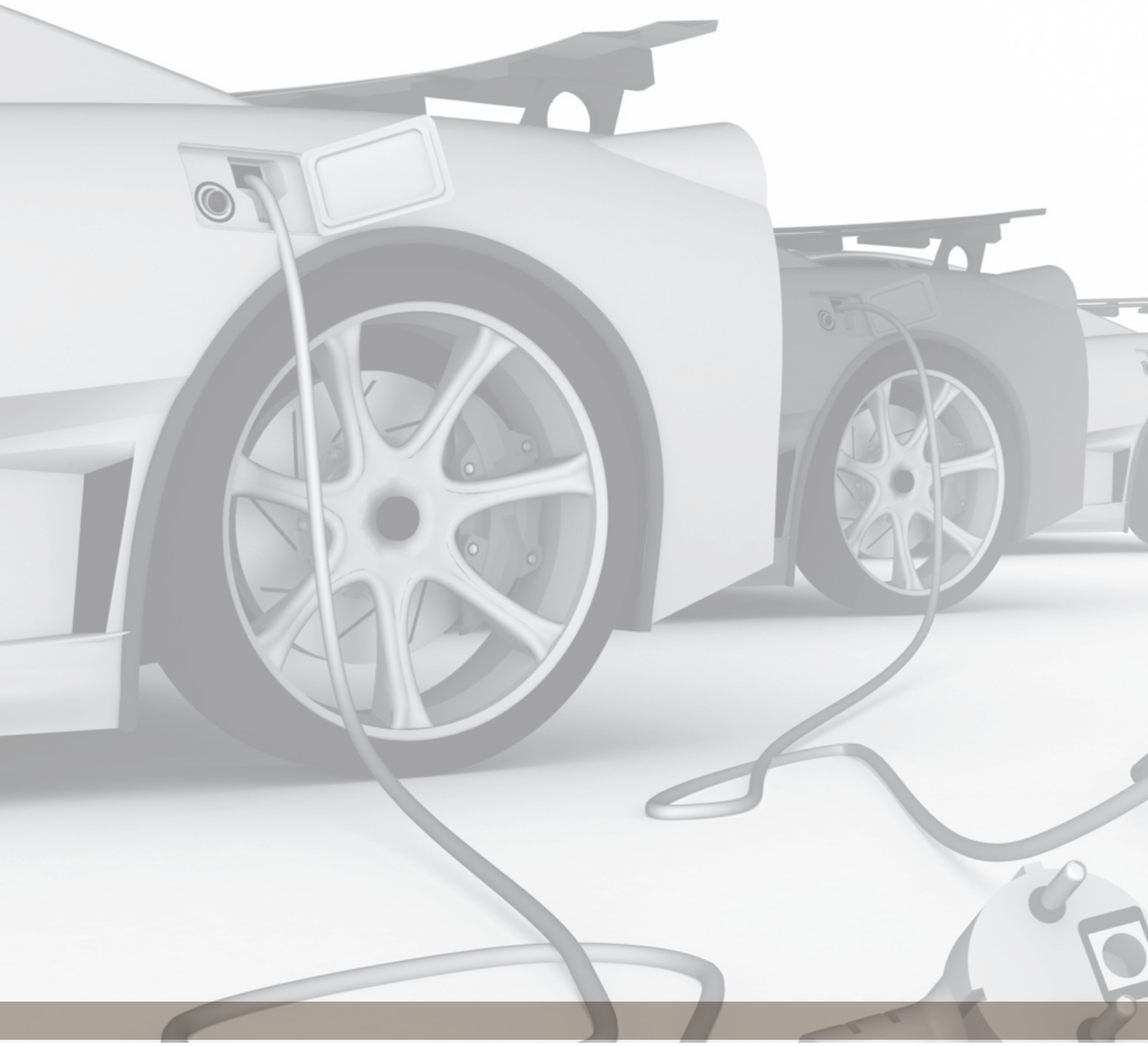
Figure 67 :Estimated cost (for both generation and network upgrades) of additional peak demand in SWIS ($ millions undiscounted)



Source: AECOM

Figure 68 Costs of additional peak demand in central take up scenario if charging is unmanaged ($million undiscounted)

Source: AECOM



Response to Submission Comments

B

AECOM have endeavoured to consider all submissions and where appropriate have updated the study to reflect better information. **Table 46** and **Table 47** summarise AECOM's response to the key comments raised in the submissions.

Table 46: Summary of responses – Electric Vehicles

Stakeholder	Submission response	AECOM's response	Changes to report
Q1 Is the range of estimates provided by AECOM appropriate for assessing the potential impacts of EVs on the electricity market and developing our advice? Does the range of scenario estimates provide a credible view on the potential penetration of EVs?			
Government of SA	Uptake. Need to take account improvement in conventional liquid-fuel vehicles and other technologies (eg. hydrogen vehicles) would have an impact. (p1)	The analysis includes consideration of improved vehicle efficiency for conventional vehicles, which are consistent with recent work by CSIRO in their study 'Road Transport Sector Modelling' in 2011. See Section 3.3.1.7 (p19) for details. Hydrogen vehicles (fuel cell and combustion types) were not considered since a preliminary desktop review revealed they were unlikely to have a significant impact on the Australian vehicle market for the forecast period. At present, most vehicle manufacturers have scaled back their R&D of hydrogen vehicles and are focusing their efforts into EV research (Wall Street Journal 2009, 2011, CSIRO 2011).[20]	Following sentence added to section 3.3.1.1: This study has also not considered take up of hydrogen vehicles. Based on our research of current literature, hydrogen vehicles are not considered to be commercially viable within the study timeframe. Consequently, we have excluded them from the vehicle choice model.
Tasmanian Department of Infrastructure, Energy and Resources	Suggests that an additional scenario of a 'very rapid' uptake of EVs be modelled with large majority (greater than 75 per cent) of new vehicle sales of EVs (with majority BEVs) with capacity for 'ultra fast charging' - a worst case scenario if a tipping point is reached (p5)	AECOM's vehicle demand forecast model is based on a number of consumer choice parameters which subsequently determine their vehicle purchasing behaviour, and thus, the demand for different types of vehicles available on the market. Whilst an analysis of the suggested scenario may provide some valuable insight into the consequences	Not required

[20] Wall Street Journal May 7, 2009 *Running on Empty: Obama Budget Cuts Funding for Hydrogen Car*, available at http://blogs.wsj.com/environmentalcapital/2009/05/07/running-on-empty-obama-budget-cuts-funding-for-hydrogen-car/. Wall Street Journal May 22, 2011 *Hydrogen Fuel Cells Are Down, but Perhaps Not Out*, available at http://online.wsj.com/article/SB10001424052748703778104576286620950028178.html

Stakeholder	Submission response	AECOM's response	Changes to report
		of a significant 'worst case scenario', AECOM's forecast model does not operate by prescribing a fixed 'outcome' (i.e. 75 percent EV sales by a specific year) but rather, generates uptake rates based on the input parameters listed in Section 3.3.2 of this report. Our view is that there is not enough reason to warrant a recalibration of the forecast model to fit the outcomes described in the suggested scenario. The high take up scenario, combined with the sensitivity undertaken assuming everyone charges in peak periods with a fast charge, is considered to be a valid worst case scenario.	
Energy Supply Association of Australia	EV take up. Agrees with AECOM that uptake of EVs seems likely to be of minimal impact until 2020.		Not required
Ergon Energy	Concerned only used NSW and VIC data. AEMC should note that AECOM report not broken into regional and urban areas (p1)	AECOM acknowledges Ergon Energy's concern that only NSW and VIC data were used in the model, and that vehicle uptake is unlikely to be universal across regional and urban areas. The reasons for only using data from these two states, and how the model addresses the issue of differences in regional and urban vehicle uptake are as follows: • AECOM's modelling of EV uptake relies on assumptions made about existing total passenger vehicle market share by vehicle size and historical vehicle kilometres travelled (VKT). There are two reasons for this: o PHEVs and EVs will not be available in all vehicle sizes at the same time o The demand for PHEVs and EVs is likely to differ based on vehicle size and anticipated VKT, since larger vehicles are expected to be more expensive in the early years, and long-distance	Not required

Stakeholder	Submission response	AECOM's response	Changes to report
		drivers will benefit more from fuel-efficiency savings. • As such, our model is sensitive to the driving behaviour and thus, expected demand for EV vehicles by type, which is unique to regional and urban users. • Crucially, data for the breakdown of vehicle size and VKT were only available for NSW and VIC, which were provided to AECOM by the respective governments. These datasets were made available to AECOM in the past, for the purpose of undertaking EV uptake studies in each state. Since similar data were not available for other states and territories, AECOM used NSW and VIC datasets as proxies for the remaining jurisdictions. Comparison between Victoria and NSW take up rates showed that over the long term the take up rates are relatively similar so the impact of this assumption is not expected to significantly alter the conclusions. For further details on AECOM's modelling assumptions, see Section 3.3.1.2 of this report and AECOM (2009, 2011).	
Origin Energy	Origin supports AECOM's estimates (p6).		Not required
Citipower and Powercor	Difficulty in predicting EV uptake (p1)		Not required
Energex	Risk that assessment of uptake could be too optimistic and therefore supports the need for national forecasts within the NEM. (p2)	Due to the inherent uncertainties in making forward estimates, this study developed three scenarios around the key factors identified as affecting the take up of EVs. AECOM and AEMC also agreed to a conservative	Not required

Stakeholder	Submission response	AECOM's response	Changes to report
		approach to estimating take up and that a conservative estimate on the potential impact of EV uptake on the electricity market is a better outcome than to underestimate it. This is because one of the objectives of this study was to identify the potential planning requirements for AEMC to accommodate future uptake of EVs. Underestimating the take up may result in a delay to take action; hence, the importance of having a conservative high uptake scenario outcome. There are a number of factors that impact on the take up of EVs and these factors are continuously changing. We agree it is important to have national forecasts that are updated regularly to assist in the preparation for EVs. The AEMO Statement of Opportunities now includes consideration of Electric vehicles.	
SP AusNet	The most significant factor not reflected in the modelling is the future status of growth in peak demand related to existing load requirements, which already appear in decline. EV load could thus represent a greater proportion of growth in peak load and a greater augmentation requirement (p 3). Fast charging should be defined as anything greater than 10 amps.	Figures A1-A7 of AECOM's report show peak load growth due to EV's compared to the SOO load growth forecast and in the case of the 2030 forecast an extrapolation of SOO load growth forecasts. If load growth from other sources is lower than these forecasts then the proportion of augmentations required to address EV charging will be higher. However, this will not affect the cost of EV charging related augmentations, unless existing peak load actually decreases. In that situation, EV charging can use unused capacity, reducing the need for EV related augmentations. AECOM have based estimations in their report on level 1, 2 and 3 chargers, which vary according to power and speed. See Table 22 for more details.	Not required
Betterplace	AECOM's analysis a credible view of potential market penetration of EVs, but thinks that BEVs will take a larger	Key drivers of EV uptake, as identified through AECOM's literature review and modelling, include vehicle price, driving range, infrastructure	Added the following text: Sensitivity analysis was undertaken to assess the energy consumption from EVs

Stakeholder	Submission response	AECOM's response	Changes to report
	proportion of EVs by 2020s. (p13)	availability and fuel price. Given the current state of the EV market and future outlook, it is much more likely for PHEVs to remain superior to BEVs on all of these factors, at least until 2020. The results from our modelling support this hypothesis. It is expected that, only once prices of BEVs approach parity with other vehicles, infrastructure is made readily available, and petrol prices rise, that they are likely to become competitive enough for significant uptake. Until then, AECOM's conjecture, based on our modelling results, is that PHEVs will be the preferred choice over BEVs in the short to medium term. However, given the uncertainty in the market we have undertaken sensitivity analysis to assess the impact on electricity consumption if there is a higher proportion of BEVs.	if there was a higher proportion of BEVs. Currently, PHEV's make up between 70 percent and 90 percent of total EVs depending on the time and state considered. If this proportion is reversed total energy consumption does not change significantly in the long term (less than 10%) due to a shift towards more BEVs anyway and PHEVs using a higher proportion of their electric drivetrain as more charging infrastructure becomes available. However, in the short term (2015) energy consumption would be 25% higher and in the medium term (2020) would be 270% higher. Essentially, a higher proportion of BEVs brings forward the higher energy use seen towards the end of the study period. As discussed elsewhere in this report, whilst this analysis provides an indication of how the EV market may evolve, it will be important to monitor the actual take up of EVs and the key factors affecting take up. If a higher proportion of BEVs occurs, this will place greater emphasis on managed charging options which use real time information to encourage off peak charging.
ChargePoint	Range of estimates are appropriate (p1)		Not required
Australian Electric	Uptake somewhat high - consider	See response to Energex above.	Not required

Stakeholder	Submission response	AECOM's response	Changes to report
Vehicle Association	uptake is between low and central scenarios. Note be wary of international comparisons as no EV subsidies here		
Alternative Technology Association	Expect that the uptake rate would at least be in the 'central range' and believe that the demand for EVs will exceed supply until at least 2015 (p2).	AECOMs analysis assumes supply constraints until at least 2020 in the core scenario and 2015 in the high take up scenario which is consistent with ATA's view.	Not required
Centre for Energy and Environmental Markets UNSW	The success of EVs will depend on factors external to the electricity industry including vehicle technology, international oil prices, but NEM arrangements play a key role in facilitating or hindering deployment. (p3)	Agree.	Added following text: It is important to recognise that the NEM arrangements can play a key role in facilitating or hindering deployment of EVs. This analysis assumes the NEM supports the efficient take up of EVs. The barriers to efficient take up of EVS (steps 4 and 5 of the AEMC work) are considered in a separate report.
Q2 Are these estimates on the cost of additional peak demand provide the correct magnitude of the potential impacts of EVs? Are there any categories of costs not included in this discussion?			
Ergon energy	Costs of additional peak demand at a market level, but analysis should look at local (low/medium voltage network) with network simulation and demographic analysis. (p1)	Analysis includes an estimate of the costs of network upgrades in low and medium voltage networks based on the historic cost of increasing capacity on these networks. However, AECOM acknowledges that a network simulation at a higher level of granularity that is sensitive to the demographic characteristics of local areas would result in more reliable estimations of EV impact on load demand, given scenarios and assumptions. However, there is significant uncertainty in the scenarios and assumptions themselves which are unlikely to resolve until the technology matures. Consequently, the improvement in reliability, offered	Following added to Section 5.1: This approach models costs through all sections of the electricity market (distribution, transmission and generation) but only at the state level of granularity. It is likely that certain areas (particularly in early years where the market is dominated by early adopters) may experience network issues at a local level. We anticipate that in due course utilities will incorporate EVs into their demand forecasting, providing much more detailed projections of system impacts.

Stakeholder	Submission response	AECOM's response	Changes to report
		by network simulations, may be somewhat limited and is unlikely to justify the considerable additional complexity [and expense to AEMC]. It is anticipated that utilities will incorporate EVs into their demand forecasting, providing much more detailed projections of system impacts.	
Origin Energy	Supports smart meter charging and TOU pricing. Important to distinguish wholesale vs. network peaks. Recommends dynamic analysis (not just static analysis). Un-managed charging scenario in Issues Paper is extreme and should be more reflective of business as usual environment. TOU charging scenario should be made more realistic (p8). Controlled charging scenario extreme and overstated (p9).	AECOM acknowledges the importance of undertaking a dynamic analysis. However, for the purpose of the present study, a static approach was undertaken because it provided the simplest method for estimating the scale of potential impacts within the resources available to undertake this study. [Similar to the Ergon response], the additional complexity is unlikely to actually improve accuracy when assumptions are so uncertain. Further, we would had to have made more assumptions with limited evidence to support these assumptions. AECOM acknowledges Origin Energy's suggestion that the unmanaged scenario may be extreme. However, for similar reasons discussed in relation to the advantage of overestimating EV uptake than to underestimate it, our view is that projecting a high increase in load demand under an unmanaged scenario was better suited for the purpose of the study, which was to identify potential network augmentation requirements over the forecast period. Having said that, based on evidence provided in the submissions to the Issues Paper, AECOM have adjusted the unmanaged charging scenario to assume around 50 percent of charging occurs in peak periods and every EV owner has a level 1 charger (15A). This is still considered to be relatively	Assumptions around unmanaged charging changed to assume around 50% of charging occurs in peak periods and every EV owner has a level 1 charger (15A).

Stakeholder	Submission response	AECOM's response	Changes to report
		conservative. Sensitivity was undertaken assuming 25% and 100% of charging occurs in peak periodswith a level 1 charger (15A). Furthermore, while there are differences in the take up assumptions of EVs, a recent report released by AEMO provides similar projections on network load impact of EVs.	
Energex	Costs outlined are not unreasonable (p2)		Not required
Betterplace	Expect demand for fast charging (e.g. 50 amps, 3 phases) by 2015 and a result AECOM understates potential peak demand problem in its unmanaged scenario (p13). Little evidence that TOU 30% premium will eliminate peak demand so AECOM unrealistic. Also customers unlikely to voluntarily adopt TOU if they expose their entire household to that pricing structure (p14). AECOM's smart meter charging scenario based on little evidence. Also AECOM does not include a scenario where BP's proposed model where a load manage (not the EV owner) is the party financially liable for energy and network charges. (p15).	AECOM's assumptions for EV charger power took into account industry outlook based on submissions made to the AEMC Approach Paper for the present study. Whilst we acknowledge that demand for fast charging may exist by 2015, our view is that it will be limited for the following reasons (details presented in Section 4.3 of AECOM's report): - At Level 2 charging, households may require strengthening of their connection to the grid to reduce overloading - Very few households have three phase supply, which is generally required to provide Level 2 charging - Consumers may lack understanding about the requirements for home charging and the impact home charging may have on their household - For Level 3 charging (commercial fast charging stations), connecting to the local distribution network is likely to be costly and possibly require an upgrade to local network assets near the point of connection These reasons suggest that there are technical and financial barriers to the widespread provision of fast charging infrastructure.	Not required

Stakeholder	Submission response	AECOM's response	Changes to report
		Moreover, this, coupled with AECOM's modelling results which show that BEVs are not likely to take up nearly as fast as PHEVs in the short-term, suggests that the demand for fast charging infrastructure are likely to be relatively low in the short term. AECOM's modelling of load impact under the TOU arrangement does not assume that a 30% premium would eliminate peak demand. In our analysis, we have clearly recognised that range anxiety will remain, and that not all EV drivers would shift to off-peak charging under TOU pricing. Modelling assumptions under TOU is detailed in Section 4.4.3 of our original submission to AEMC. For the purpose of impact modelling, we assumed 35.45% of EV drivers and all PHEV drivers charge during off-peak periods. The 35.45% reflects the 2006 census data for the proportion of Australian households which owns more than one car. With limited information on response to TOU tariffs this was considered an appropriate basis for an assumption. However, we have acknowledged that further work should be undertaken to test responsiveness of PHEV and BEV driver to TOU pricing in our report. Smart charging is still in its infant stage in terms of technological viability, and requires a complex mix of pricing, technical and regulatory arrangements before it can realistically be rolled out. One prediction that can be made, with confidence, is that smart charging is more likely to avoid charging during system peaks because smart chargers will receive	

Stakeholder	Submission response	AECOM's response	Changes to report
		real-time information on the rest of the electricity system, making it easier to avoid actual periods of peak demand. Hence, our assumption that a further 50% of users under the smart meter scenario, charge in the off-peak period relative to TOU arrangements. Whilst AECOM recognises Betterplace's concern that there is little evidence to support this relative reduction on peak load compared to TOU, given that smart meter charging is still in a highly conceptual stage of development, our view is that this scenario is acceptable. BP's proposed business model is one of the many possible business models which fall under the smart charging scenario. Under this scenario, charging technology acts on real-time network and market information to reduce the overall cost of charging. There is currently insufficient data on which to make any meaningful quantitative comparison of these business models. However, Step 4 will consider the relative economic efficiency of potential regulatory arrangements and proposed arrangements are likely to influence the market's choice of business model.	
ChargePoint	Managing peak demand done holistically rather than focusing on EV loads only. Require additional data to confidently estimate magnitude of EV impact on peak load. (p3). Raised concerns about use of basic low cost charge units that result in unmanaged charging. (p4)	As ChargePoint note, peak demand can be managed holistically incorporating a variety of residential loads into a single energy management system for an entire household. Under this type of arrangement household peak load could be reduced as well as the additional peak load from EV charging. AECOM's analysis focuses on the EV component of load. However, this is not meant to suppose that the load management technology adopted manages just EV charging. Agree that more data is needed to confidently estimate peak load impacts. However, most of the	Not required

Stakeholder	Submission response	AECOM's response	Changes to report
		data needed relates to technologies and business models that are not currently implemented in energy markets. Instead, AECOM's analysis estimates the scale of impacts given general assumptions contained within each scenario.	
Australian Electric Vehicle Association	Unmanaged scenario is worse case and is extremely unlikely. For example, Issues Paper looks at system demand at a transmission level which is a poor model for peak demand as majority of peak network costs are at distribution level.	See response to Ergon energy above. Although not discussed in the issues paper, the cost of upgrading distribution systems has been considered in AECOM's report. Consistent with the view of Australian Electric Vehicle Association AECOM also found that the cost of upgrading distribution networks was higher (See Section 5.1.1 of AECOM's report)	Not required
Centre for Energy and Environmental Markets UNSW	AECOM's method of estimating network investment requirements seems to be a reasonable first estimate (p3). Suggests a 'dynamic' analysis (as opposed to a static analysis) done by AECOM to better assess potential costs. V2G/V2H should be incorporated into scenarios of EV impact on cost of peak demand.	AECOM acknowledges the importance of undertaking a dynamic analysis. However, for the purpose of the present study, a static approach was undertaken because it provided the simplest method for estimating the scale of potential impacts within the resources available to undertake this study. [Similar to the Ergon response], the additional complexity is unlikely to actually improve accuracy when assumptions are so uncertain. Further, we would had to have made more assumptions with limited evidence to support these assumptions. We recognise that V2G and V2H are potentially significant arrangements in curbing peak load in the future. We have provided a discussion on V2G and V2H in Chapter 7 of our original submission to AEMC. These were not included in the modelling due to the infancy of their technology and therefore, the large uncertainties entailed with their realisation over the forecast period.	Not required

Stakeholder	Submission response	AECOM's response	Changes to report
Verdant Vision	AECOM should include take up of electric buses and trucks (3). BEV battery costs are significantly lower than those presented in the Issues Paper (3).The relative cost of batteries is not directly relevant to consumer uptake of EVs- rather it is price of EVs themselves (p5). It is actually EV production volumes that is the greater drive of EV product prices (p5). In fact BEVs are available both globally and locally in significantly greater volumes, with a significantly greater range of products and generally lower prices than PHEVs (p5). AECOM's assumptions on the 'utility factor' of HEVs is too low (p6/7). It would be better to assume PHEVs have a higher UF as this will increase their electricity demand leading to a more conservative network impacts analysis (p 8).	Agree that new information suggests buses and trucks may have higher take up but do not expect this to have a significant impact on the electricity market because the charging of electric buses and trucks will be relatively predictable and can occur in off peak periods and charging will occur through specialised commercial charging infrastructure with any significant costs to the national electricity market being borne by the commercial operator at the time of connection As Verdant point out it is not the cost of batteries but the over cost of EVs that affects take-up. AECOM's forecast take-up is based on the overall cost of EVs at the time the report was prepared and this was unaffected by battery price observations. However, we accept that the difference in battery price may affect the proportionate take-up of PHEVs and BEVs. We have added an additional scenario. See comment above for BetterPlace about sensitivity around take up of BEVs/PHEVs. AECOM have undertaken sensitivity using a higher utility factor as recommended by Verdant. Overall, the increase in electricity usage increases but not enough to change the key conclusions of this study. See changed text for more information.	Following text added to Section 3.3.1.1 The estimates of EVs focus on passenger vehicles and light commercial vehicles, which together account for 92 percent of all vehicles in Australia. Whilst some electric buses and trucks do exist they are relatively more expensive due to the weight to battery ratio and purely on a financial basis are unlikely to see significant take up in the next 10 to 15 years until battery prices significantly reduce. ADDED: However, most buses are operated by government who will face increasing pressure to reduce their greenhouse gas emissions so there could be increased take up of electric buses, despite not being financially viable, to assist in meeting greenhouse gas reduction targets. Even if there is a significant take up of electric trucks and buses in the short to medium term this is not expected to have a significant impact on the electricity market. The charging of electric buses and trucks will be relatively predictable and can occur in off peak periods and charging will occur through specialised commercial charging infrastructure with any significant costs to the national electricity market being borne by the commercial operator at the time of connection. As such, the rest of this analysis of EVS focuses on passenger

Stakeholder	Submission response	AECOM's response	Changes to report
			and light commercial vehicles which are expected to have the largest take up and the biggest impact on the electricity market. Following text added to Table 12: As there are no commercially available PHEVS in Australia at the moment there is no data available on what proportion of driving uses electricity. Data from the US indicates that two-thirds of Chevy Volt fleet miles are electrified (Peterson, 2011). However, this result is unique to that particular vehicle (which has a range of 40 miles) and is derived from US driving behaviour, AECOM have undertaken sensitivity analysis with a higher proportion of electricity consumption from PHEVs to assess if this would significantly impact on electricity consumption. This shows that if a higher proportion of electricity is consumed, the cost per kilometre falls (because electricity is cheaper than petrol) resulting in higher take up of PHEVs, at the expense of BEVs. Whilst electricity usage increases this is offset by a switch from BEVs to PHEVs. Overall, the increase in electricity usage increases but not enough to change the key conclusions of this study.
Q3			

Stakeholder	Submission response	AECOM's response	Changes to report
Does this discussion capture all the potential cost impacts that EVs could impose on the electricity market?			
Ergon energy	Interaction between DNSPs, retailers and EV charge providers modelled to assess costs (p1)	This is addressed in the stage 4 analysis.	Not required
Origin Energy	Parent-child metering arrangements are complex and suggest a cost-benefit analysis be undertaken. Institutionalising embedded networks with child NMIS barrier to competition. (p 10) EVs should be sale of electricity and subject to electricity consumer protections.	This is addressed in the stage 4 analysis.	Not required
Energex	Costs should also include issues relating to voltage and power quality. Also cost of service upgrades at customer premises and charging installations could require upgrade to three phase supply. (p3)	This study focuses on the impacts to electricity markets, rather than the full costs and benefits of EVs more generally. Consequently, all capital costs to EV users have been deliberately excluded from this part of the analysis including the cost of vehicles, charging units and the cost of upgrading supply. However, these factors are considered when estimating the take up of EVs.	Not required
SP AusNet	The assessment using the SA load profile as the worst case scenario may not be the most appropriate. A flat scenario may be the worst as minimal opportunities before peak is affected. The assertion by AECOM that additional peak demand due to EVs will not impact reliability seems somewhat optimistic. (p4)	SP AusNet correctly notes that managed charging is most likely to affect the peak daily load on days where the load profile is flat. However, additional peak load from managed EV charging will only create a cost where the total daily peak load (including load from EVs) exceeds system capacity. Although not shown, AECOM did in fact check that managed EV charging could always occur without exceeding this system capacity (where system capacity has been approximated by peak load during 2010). We accept that the addition of more load will increase the load at risk and therefore the amount of lost load, even at the same service level. However, this should not affect reliability relative to the load	Not required

Stakeholder	Submission response	AECOM's response	Changes to report
		served and so the reliability of the non-EV load should stay the same. Section 5.1 (page 49) provides our reasoning for the belief that reliability is unlikely to be significantly affected by EVs. In brief, we believe regulatory incentives are likely to be effective in maintaining reliability at current standards, so long as take-up is gradual.	
Betterplace	This is a comprehensive overview of impacts.		Not required
ChargePoint	Costs dictated by business model employed, cost of supply and cost of metering (notes high cost of remaining NMI and parent-child metering) (p4)		Not required
Australian Electric Vehicle Association	It is important to distinguish between costs to the general electricity market and costs to the consumer.	See response to Energex above	Not required
Centre for Energy and Environmental Markets UNSW	Costs and benefits on electricity markets accrue to different parties within those markets and that these costs/benefits differ depending on correlation between charging/discharging with peaks in demand and other market outcomes (e.g. wholesale prices). (p4)	The correlation of charging activity with peak demand from other loads is one of the most important factors affecting the cost to electricity markets. This is addressed in Section 4 of the AECOM report which develops three scenarios with varying degrees of correlation between charging and existing market peaks.	Not required
Verdant Vision	AECOM's study includes specific assumptions around the lack of diversity in EV charging loads that we believe leads to an overestimate of the peak demand and network costs impacts from EVs. Furthermore, we believe that EV impacts will be less than the scenarios outlined in this study even under scenarios of higher BEV vs.	Charging diversity in the unmanaged case will be affected by a wide number of factors including, the timing of peak demand on peak days, home arrival times on peak days (which are more likely to be holidays), charging power and the distribution of non-residential charging infrastructure. In addition, many of these parameters will change over time. Rather than speculate on these, AECOM consciously sought to identify a worst case diversity scenario,	Assumptions around unmanaged charging changed to assume around 50% of charging occurs in peak periods and every EV owner has a level 1 charger (15A).

Stakeholder	Submission response	AECOM's response	Changes to report
	PHEV uptake. (p 10). Un managed charging scenario is too extreme (p10). Given the above analysis, AECOM's EV charging scenarios lack the diversity inherent in a real-world fleet and are unrealistically extreme (p12). Furthermore, a shift to higher charging rates, should decrease the coincidence of EV charging loads, not increase it. (p12). The extent to which coincidence between EV loads and existing network peaks was accounted for by AECOM is not clear (p13)	which identifies the maximum potential impact. However, we accept that Verdant's figure of 52% coincident charging using Level 1 charging is reasonable estimate and have used this new evidence for the modelling. We have however assumed that this would occur coincident with peak load rather than only 50% coincident.	
Q4 Have we correctly identified the range of benefits of EVs on the electricity market? What are stakeholders view on the materiality of these benefits and the appropriate arrangements of capturing such benefits?			
Origin Energy	The benefits of EVs likely to be greatest when EVs are integrated with all demand side participation rather than in isolation (p 11)	This is being considered in power of choice review.	Not required
Energex	The key issue is scale. Most of benefits to EVs will only materialise at relatively high penetration so the method of incentivising off-peak charging must not incur significant costs early as benefits materialise later, if at all. (p 3)	This is addressed in the stage 4 analysis.	Not required
SP AusNet	Range of benefits appropriate but SP AusNet has not estimated benefits due to current uncertainty around scenarios. (p 4).		Not required
Betterplace	Benefits of EVs are substantial and include DSP options	Agree. EVs are likely to create a large flexible EV charging load. The flexibility of this load creates DSP options that have value in their own right.	Not required
Australian Electric Vehicle Association	Benefits of EVs should be quantified (3)	Quantifying benefits seems highly speculative at this stage and would create a false sense of certainty.	Not required

Stakeholder	Submission response	AECOM's response	Changes to report
Centre for Energy and Environmental Markets UNSW	Benefits to electricity market are similar to other potential controllable loads so integrate this with Power of Choice work. EVs are materially different to other controlled loads is the storage capacity of battery and potential to return power to the grid. Flexibility with EV charging is best harnessed through retail market arrangements that facilitate competition in the delivery of energy services. EVs represent an important opportunity to improve dynamic efficiency (support for technology and business model innovation). (p4-5)	AEMC are considering many of the overlapping issues within the Power of Choice review.	Not required

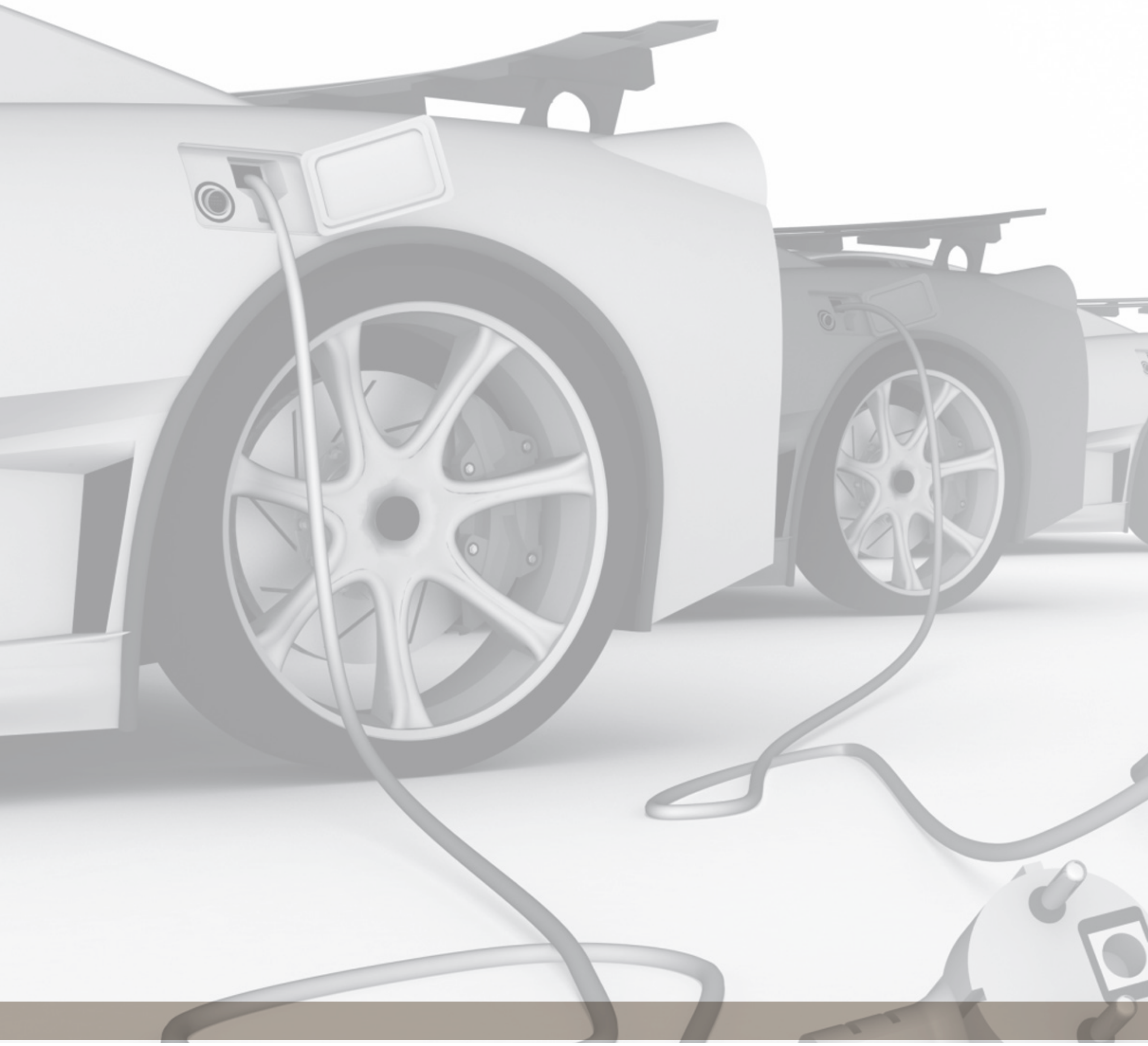
Table 47: Summary of responses - Natural Gas Vehicles

Stakeholder	Submission response	AECOM's response	Changes to report
Q20 What are your views on AECOM's methodology for assessing the take-up of NGVs? What are your views in relation to their findings on the expected take up of NGVs?			
Energy Network Association	Modelling of uptake of CNG buses and LNG trucks appears reasonable. Should consider opportunities for CNG in light commercial vehicle and passenger fleet vehicles and home based CNG refuelling. (p1)	Whilst AECOM's analysis did not explicitly state that light commercial vehicles and passenger fleet vehicles were considered in the modelling, these categories of vehicles were incorporated under the broad definition of 'passenger vehicles'.	Not required
BOC	Consider that the analysis in the 2011 Alternative Fuels Strategic Issues Group report is more reflective of the long term prospects of LNG vehicles (p1). Suggest that the AEMC liaise with the Commonwealth Department of Resources, Energy and Tourism to	AECOM has reviewed the suggested Department of Resources, Energy and Tourism (DRET) document, *Strategic Framework for Alternative Transport Fuels* (2011) (which was released after AECOM provided their initial advice to AEMC) and have found that the conclusions presented in the report are mostly supportive of our own analysis.	AECOM have revised the gas section to highlight the uncertainties in both electric and gas vehicles going forward. Further, the main focus of this study is identifying impacts on the energy markets. Even if take up of gas vehicles is high they are not expected to have a

Stakeholder	Submission response	AECOM's response	Changes to report
	ensure data is consistent in relation to LNG heavy vehicles (p2).	In particular, we highlight the following excerpt from the report, which demonstrates the limitation of CNG and LNG (along with some of the other alternative fuels) as viable options as transport fuel: - "Throughout the Framework development process, end user representatives in these sectors (road and rail freight) indicated there is willingness to adopt alternative transport fuels and technologies if they are competitively priced, supply chains are reliable and sufficient, and the fuels and technologies are suited to their operational requirements." In reference to LNG trucks, the DRET report states the following: - "...CNG and LNG use may increase in the medium term with investment in distribution infrastructure and improvements in fuel tank technologies" (p.55). - "The availability of CNG and LNG OEM (original equipment manufacturer) vehicle products in Australia is also limited to the heavy line haul segment" (p.57). - "Improvements to vehicle fuel tank technologies are also required to increase the driving range of natural gas vehicles without taking up too much ... pay load capacity (in trucks)" (p.57) - "While only a small number of vehicles operate on natural gas in Australia, CNG and LNG use may increase in the medium term with investment to address technology constraints including distribution infrastructure and improvements in fuel tank technologies" (p.57). These statements from the report suggests that, whilst CNG and LNG *may* have the potential to be	significant impact on the gas market.

Stakeholder	Submission response	AECOM's response	Changes to report
		used as viable alternative transport fuel, it requires significant amount of time, investment and R&D to make them competitive against existing transport fuel (such as petrol and diesel) and the EV industry. AECOM's conjecture is that these findings reported in the DRET report are not different to the conclusion presented in our own report to AEMC.	
Envestra	Given the uncertainties in the technology, it is premature to conclude that EV technology will be the dominant emerging technology and that NGVs will not have great market reach (p2). There is a high risk that the conclusion in the paper will work to stymie development of NGVs and more prudent to put policies in place to facilitate development of these technologies. Note the DRET Paper on 'Strategic framework for alternative transport fuels' is less conclusive/predictive of potential EV/NGV outcomes. (p3)	See above response to BOC. AECOM shares Envestra's view that there are large uncertainties surrounding NGV technology. Our analysis is based on an investigation of the current domestic and comparative international NGV vehicle market, and the details of our modelling assumptions are reported in chapter 8 of our original submission to AEMC. Furthermore, we acknowledge that the DRET report may not be as conclusive as that presented by our modelling, focusing on identifying the barriers to take up rather than the impact of the barriers. AECOM recognises the importance of further investigating the potential uptake of NGVs and the conclusions have been changed to reflect this.	The conclusions have been revised to highlight that there are uncertainties around the future of the gas vehicle market but even if there is high take up of gas vehicles this is unlikely to have major impact on gas markets.
iGas Energy	Admit there is a high capital cost of fitting a gas engine/fuel system relative to diesel but this can be offset by lower gas price compared to diesel. Suggests that AECOM contact them to discuss their technology (p3). They believe that 10,000 trucks could be running on	AECOM agrees with iGas Energy that lower gas prices can offset the capital expenditure for NGVs for *some* of the LNG trucks in the vehicle market. Our view is that this will not be universal for all LNG trucks, and the economic viability of using LNG trucks depends on the VKT and cost of capital for refuelling infrastructure, as well as economies of scale.	Not required

Stakeholder	Submission response	AECOM's response	Changes to report
	CNG by 2020.		
Q23 Are there any network issues such as connection, metering or system augmentation that are currently inefficient or need to be handled differently for NGVs as compared with any other large commercial gas customer?			
iGas Energy	CNG trucks fitted with iGas systems will be refuelled directly adjacent to high pressure transmission pipelines. There will be issues related to off-pipeline storage, use of line pack and load factor considerations, but these should be able to be managed through gas haulage and supply contracts. (p4) Do not believe that significant changes are necessary at this time, but it would be wise to observe the rate of change in other gas rich countries.	Agree.	Not required
Q24 Are there any issues raised by commercial refuelling for the choice of supply – from a retailer or other intermediary, from a producer or from the relevant spot market; • Should NGV refuellers be treated differently from other commercial customers who purchase gas?; • Should NGV refuelling be included within the scope of existing gas retailing licences? Alternatively, is another category of licence required? Or none at all?			
iGas Energy	Major energy users would have gas supply contracts with wholesalers/producers or be spot market traders. (p5)	Submission response not directed at AECOM's analysis	Not required



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