EVENERGI

MANAGING THE IMPACTS OF RENEWABLY POWERED ELECTRIC VEHICLES ON ELECTRICITY DISTRIBUTION NETWORKS

Australian Government
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ARENA

Acknowledgements

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The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein

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490 South Australians and in particular the 45 that contributed their time to assisting us with the research.

Executive Summary

The introduction of Plug-in PEVs (PEVs) will deliver substantial benefits to Australia. Along with environmental benefits, they will deliver long term reductions in living expenses, ensure fuel security, and positively impact the gross domestic product (1).

Electricity network distribution businesses are focused on optimisation of asset utilisation. They are in a unique position with respect to PEVs. If the adoption is appropriately managed, they could improve the utilisation of assets while improving grid stability. This will require appropriate management of load and therefore a consciously crafted network architecture – with the ability for demand side control. If managed poorly, uncoordinated charging events could add to peak demand at some levels of the network and add to cost.

Forecasting the impact of PEVs on distribution networks is a difficult task given the uncertainty on both the adoption rates of vehicles, and the potential evolution of the transport market itself in terms of the mix of mobility types and charging infrastructure solutions.

At the same time there is ongoing disruption of the energy market due to a movement towards renewable energy sources, both in terms of both grid scale and distributed generation.

This report is part of the Strategic Regional EV Adoption Program jointly funded by Evenergi, ARENA, South Australian Government and SA Power Networks. It seeks to understand the impact of PEVs on the South Australian power network in terms of both demand and its interaction with the increasing levels of renewable generation.

The goal is to answer the question*: how can governments and electricity distribution network businesses ensure that the grid is ready to accept increasing numbers of PEV's and to do so in a manner that leverages to increased deployment of renewable energy.*

Methodology

The underlying methodology of this report is to:

- Understand potential network charging hotspots – or areas where significant charging load may occur (e.g. shopping centres, rapid chargers, workplace chargers etc.)
- Create an understanding of the key drivers that will determine whether these hotspots will have significant network impacts in future.
- Consider these types of hotspots against current SA Power Networks constraints maps and consider how they will impact the South Australian context.
- Determine the strategies that can be deployed to manage capacity issues.
- Understand the impact of renewable energy in curtailing this demand.
- Understand the broader implications of PEVs for grid scale renewable energy

To achieve this, the South Australian electricity distribution network has been used as a case study, alongside review of global research in this area. In addition, based on experiences in other markets, we have created our own activity based data, and a model to help understand where potential PEV drivers are concentrated and their potential driving and charging patterns.

To create activity based data we ran an outreach program to potential PEV buyers in South Australia. The program, Charge Together South Australia, attracted around 1600 participants of whom 480 were engaged in quantitative surveys and 42 had comprehensive car (EV-Drive application) and home monitoring installed.

Key Findings

- Based on forecast uptake rates, SAPN does not anticipate that the interaction between PEVs and their network will have significant implications for the distribution network in the next regulatory period (2019-2025). They do, however, recognise the need to ensure that the network is ready for the forecast acceleration of the EV market from 2025 onwards, and the potential for higher-than forecasted demand in this period.

- If managed correctly, PEVs could potentially improve network asset utilisation. This could improve cost outcomes for consumers (assuming that the cost of network upgrades for rapid charging was met by developers). This document provides background information to validate this hypothesis but more work would need to be done to confirm it.

- PEVs can be beneficial in terms of deployment of renewable energy at a local scale. This is due to the enhanced payback when PEVs are coupled with local generation (this was confirmed in Evenergi’s home study project).

- There is potential for PEVs to be a useful sink for over-generation during solar PV generation peak and that, with appropriate control strategies, it could help to flatten the load and improve grid stability in the midterm.

- The greatest risk area for hotspots occurring in single locations are DC rapid chargers in public carparks, DC rapid highway chargers, pool vehicles locations and bus fleets.

- A situation that could lead to unforeseen costs for SAPN and other networks is if multiple hot spot clusters occur in a localised area. For example a combination of denser than expected home chargers, with a DC rapid charger and a series of AC fast chargers within a network area. From results of our activity based research it was found that one possible such scenario was in areas surrounding universities.

- Demand management can address most hot spot situations if it is appropriately applied. This can be achieved by providing price signals to encourage ideal charging behaviour, using vehicle to grid opportunities or using local storage.

- To ensure that demand management can be adequately deployed it is critical that network businesses are informed promptly when new chargers (at any level) are planned to be added to the network, and then registered when they are deployed.

- It is important for Electricity Network Distribution businesses and policy makers to be mindful of the positive and negative impacts of DC fast charging. While it will encourage EV adoption and provide convenience (particularly to those without home charging) their demand profile is episodic which does not lead to efficient asset utilisation, and it is difficult to deploy renewable generation. Use of local storage should be encouraged to address these issues.

- Renewable energy is most supported by rooftop PV and public locations where related rooftop or solar canopies can be constructed.

- To ensure that PEVs improve asset utilisation, accurately forecasting network demand is critical, so it is important to plan based on various charging usage contexts. For example, areas with fleets, university regions and shopping centres can all give a sense of overall impact on upstream network assets.

- It is also important to understand vehicle usage contexts to understand long term impact. For example, increasing ride-share and long term potential for autonomous vehicles will have a major impact on demand.

- To understand these contexts, bottom up data sets (or activity based data) is important in more granular forecasting of demand that PEVs will place on the network. To gain statistically significant data sets large sample data pools are required with more focus on particular network typologies. Examples are data from rideshare organisations, or focus on actual network areas where more existing and potential EV drivers are recruited.

Recommendations

- Further research into the impact of PEVs should be conducted to demonstrate the ultimate cost impact on consumers when taking into account new revenue streams, local renewable power, demand management and grid stabilisation benefits.

- Development of robust bottom-up forecasting tools to help networks accurately plan for PEVs so that they are beneficial from an asset utilisation perspective and therefore have a positive impact on pricing. This should also ensure that the benefits of coupling with grid scale and local renewable energy resources will be maximised.

- These tools will require strong activity based data sets (i.e. data generated from actual users). In the short term data sets should focus on the charging scenarios determined to cause hotspots (e.g. Pool vehicles, rapid chargers) as well as ongoing consumer studies relevant to these hotspots to determine who will buy vehicles, when they will buy them and where they will charge them.

- Further develop research and case studies around capacity management strategies with a focus on the key potential hotspot areas. For example, coupling storage with DC fast charging, or providing detailed scenarios around impacts of various tariff pricing signals. Develop a deeper understanding of how consumers will react to demand response measures.

- Further develop research and case studies around renewable energy deployment and charging scenarios to help project developers understand the business cases and practicalities of integrating with distributed renewable generation.

- Ensure that Network Distribution businesses are able to engage early in the process of implementing charging infrastructure to:
  - Ensure that consumers are clearly aware of the benefits of coupling demand management and solar with PEVs, so as to maximise the potential for cost reductions to consumers and renewable energy penetration
  - Help with network planning for any upstream impacts of new charging infrastructure

- This engagement could be through the development of online tools to help networks, government and developers appropriately locate public charging infrastructure (in particular fast charging) based on the requirements of distribution networks and grid scale renewable energy generation. Also important to ensure that there is mandated registration of charging devices with distribution network operators to ensure that they are able to manage demand

Introduction

The electrification of transportation is part of an over-arching structural change in our transport and energy systems. This change is primarily driven by the well understood impacts of climate change and the significant contribution that transport has on greenhouse gas emissions.

In 2016, Australia became a signatory to the Paris Agreement, agreeing to reduce domestic emissions by 26-28% of 2005 levels by 2030. Transport is Australia's third largest emitter (3) with passenger cars contributing more than 50% of those emissions at 58Mt CO_2e in 2017 (4). PEVs powered by renewable energy have negligible emissions (as low as 6gCO_2/km), compared to an average new car. To obtain these carbon emission savings, it is crucial that we optimise the energy system to promote renewable energy sources.

The transition to PEVs has the potential to have a material impact on the electricity distribution network because PEV chargers are significant electrical loads. A typical first-generation home PEV charger today, at 3.6kW, would be among the largest single loads in an average home, comparable to a split-system air conditioner or electric hot water tank.

As PEVs that are able to charge at higher rates are now emerging on the market, the new norm for a low-cost domestic charger is already moving towards 7.2kW. Peak loads for public charging infrastructure can be much higher; the new PEV charging hub built in Franklin St in Adelaide in 2017, includes two 22kW AC chargers, two 50 kW DC fast chargers and four 125kW Tesla Superchargers. To put that in perspective, the impact on the local distribution network of connecting these 8 PEV charging stations is broadly equivalent to adding 100 new homes.

As the PEV market develops, distributors need to ensure that there is sufficient network capacity to support the mix of charging infrastructure deployed. This will likely be achieved through a combination of approaches including: leveraging 'smart' PEV charging; price signals to encourage charging to occur outside of peak demand times; encouraging high-powered public chargers to connect at locations where there is available network capacity; and targeted upgrades to the network.

The question for regulators and network distribution businesses alike is what the impact of this new capacity will be on end-consumers. The critical factor is whether this increased demand is met with increased revenues for the utility and therefore whether this will have a positive or negative impact on pricing. This will depend on the implementation of demand management measures (covered in section 4 of the report) and network policies that ensure that developers who install high speed charging infrastructure meet upstream costs for network upgrades.

In fact, Energy Networks Australia (ENA) predicts that the benefits of electrification of transport could be as much as $162 lower energy bills by 2050 given a properly managed network. (12).

To maximise the economic benefit of PEVs it is critical that we have configured the network distribution system to support large scale PEV adoption.

As the EV market develops in South Australia, SA Power Networks (SAPN) needs to ensure that asset utilisation is optimised to support the mix of charging infrastructure deployed in the state. This will likely be achieved through a combination of approaches including: leveraging 'smart' PEV charging; price signals to encourage charging to occur outside of peak demand times; encouraging high-powered public chargers to connect at locations where there is available network capacity; and targeted upgrades to the network.

SAPN believes that, as EV adoption increases over the next seven years, the impact on the electricity network will be minimal. They believe that impacts may be seen first in situations where groups of PEVs tend to come together in the same location at the same time to charge. Their key area of interest for this report was in exploring where these may occur in their next regulatory period.

1. What are charging "hotspots"?

1.1. PEV charging hotspots

A PEV charging hotspot is an area of the grid where a capacity constraint may occur due to PEV charging. Hotspots can occur in the grid at different hierarchical levels. As shown in Table 1, constraints are more likely to occur at street transformer and feeder-level where the capacity sizes and load diversities are lower and therefore more likely affected by a cluster of PEVs.

Table 1: Capacity requirement of various sizes clusters of PEVs charging concurrently on common 7.4kW and 22kW chargers. Note that this is illustrative concurrently charged PEV and not total fleet.

Network Level	Typical Size	Charger	10 PEVs charging	100 PEVs charging	1000 PEVs charging
Street transformer	50 - 250 kVA	7.4 kW	30 - 150%	Exceed capacity	N/A
		22 kW	Exceed capacity	Exceed capacity	N/A
Feeder	5 – 10 MVA	7.4 kW	0.7 - 1.5%	7 – 15%	Exceed capacity
		22 kW	2 – 4%	22 – 44%	Exceed capacity
Zone substation	30 – 60 MVA	7.4 kW	0.1 – 0.2%	1.2 – 2.5%	12 – 25%
		22 kW	0.4 – 0.7%	4 – 7%	37 – 73%

If they are not managed correctly, hotspots could present an issue for utilities. In a study commissioned by the Sacramento Municipal Utility District in the US, an estimated 17 percent (12,000) of the utility's transformers may need to be replaced due to PEV-related impacts by 2030, at an average estimated cost of 7,400 USD per transformer (9; 10). Another study in the UK found that 32% of low voltage feeders (312,000 circuits) will require intervention when 40-70% of customers have a PEV and charging at home with a 3.5kW charger. The results are higher for 7.4kW chargers (11).

The clustering of PEVs is one part of the equation, another key factor is the level of availability of capacity of a given network asset. Without proper management, load from little as 10% from PEV charging on a given grid asset could result in PEV charging hotspot and a capacity constraints. These factors are explored in detail in the "key drivers" section of the report.

1.2. Why PEV charging hotspots occur

The factors that impact whether a hotspot will occur and its likely impact on the network include:

- The available capacity of the upstream network assets
- The number and type of chargers being used in a given area
- The number and type of chargers connected to a given network asset
- The utilization of those chargers
- The start time and length of charging
- The use of demand response
- The presence of local generation and/or storage

1.3. Where PEV charging hotspots can occur

Compared to petrol cars, PEV charging can occur anywhere a power socket exists in proximity to a car parking location. That said, in practice PEVs are more commonly charged with a dedicated PEV charger at specific locations. Today, these dedicated PEV chargers can draw between 3 and 120kW and may be increasing in future. Clustering of a relatively limited number of high power chargers that have high utilisation can result in a hotspot.

Hotspots can occur at all levels of a distribution network, from several cars charging on a single street causing local transformer issues, up to issues with diversified loads at a zone substation level.

Below is a high-level typology of PEV charging locations:

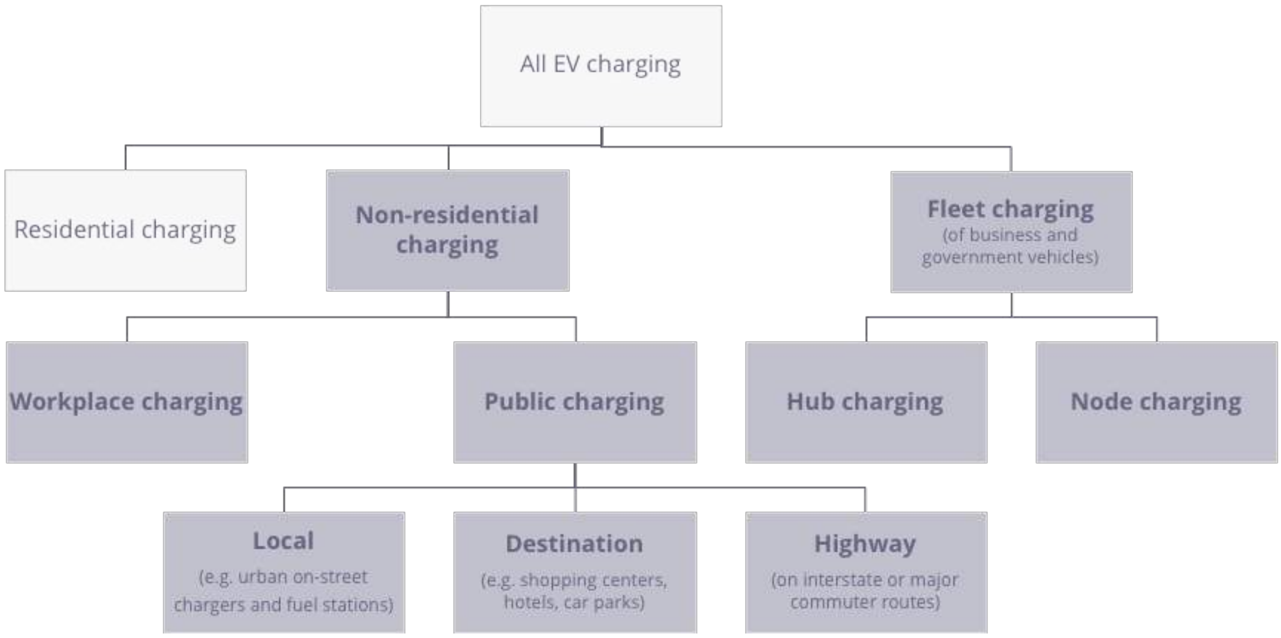


Figure 1: Typology of PEV charging

2. Key driver exploration for EV related hotspots

In this section we explore the trends and impact of the key drivers that lead PEV charging hotspots to impact on distribution networks.

2.1. Potential for capacity constraints

The first components that will determine the impact of hotspots on a network are the existing network capacity constraints.

Within the greater Adelaide area, most localities and substations are projected to have sufficient capacity in 2025 with the exception of two zone substations – Campbell Town and Aldinga – that will have capacity shortfalls of -6.8MVA and -3.9MVA respectively.

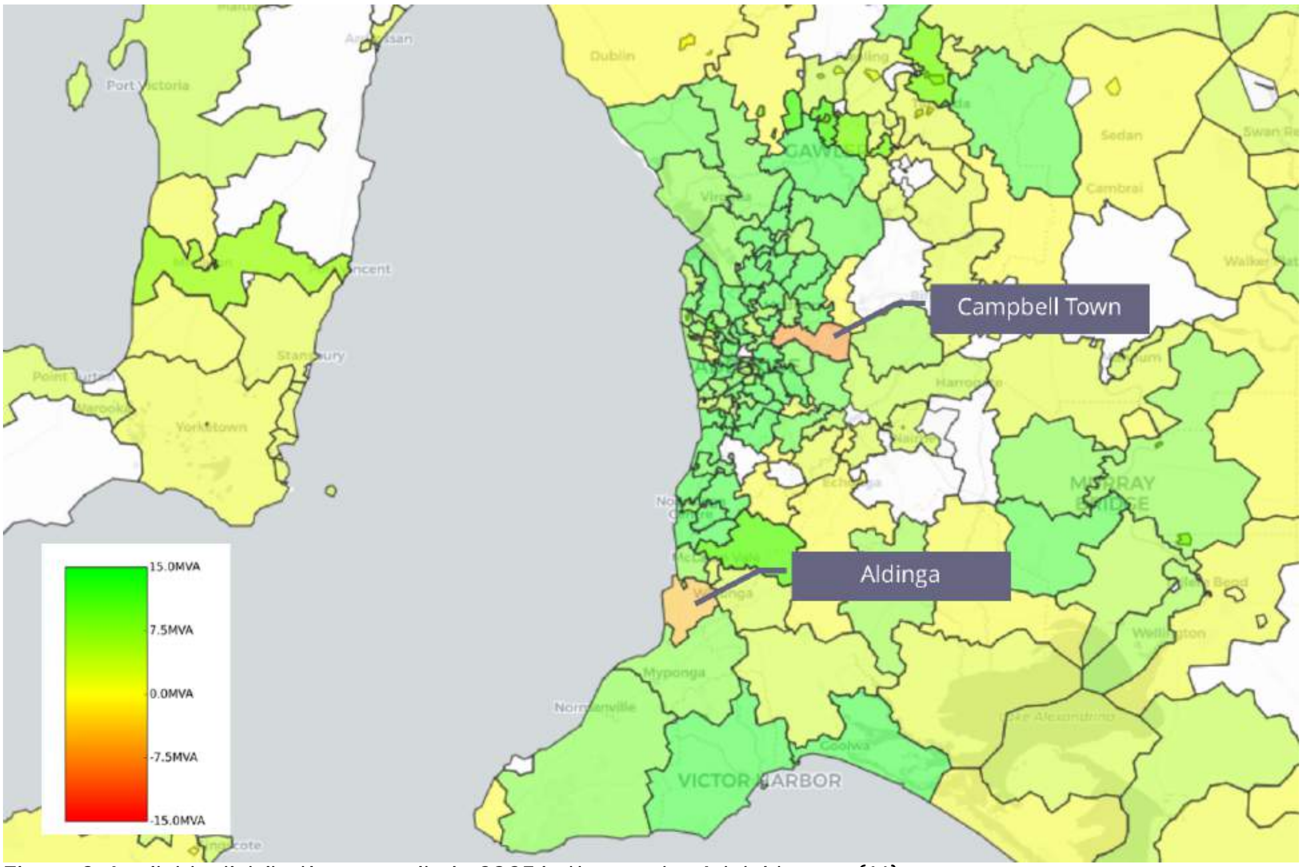


Figure 2: Available distribution capacity in 2025 in the greater Adelaide area (16).

Most other areas of greater Adelaide have 5 – 25 MVA of spare capacity which would require at least 40 PEVs to be charged simultaneously with 120kW chargers to cause a significant capacity constraint at a zone substation level. One of the most comprehensive reviews of charging station densities suggests that 36 fast chargers (i.e. Level 2) and 1 rapid charger is sufficient to cover 1000 PEVs (5). Given forecasted uptake rates of 25,000 PEV's by 2025 (17) there should be ample capacity in these areas.

Table 2: Number of concurrently charging PEVs required to create a hotspot versus available capacity levels.

Available Capacity	PEV charger size			
	7 kW	11 kW	22 kW	120 kW
500 kVA	68	45	23	4
1000 kVA	135	91	45	8
2500 kVA	338	227	114	21
5000 kVA	676	455	227	42
7500 kVA	1014	682	341	63
10000 kVA	1351	909	455	83

Capacity constraints could also occur at a local street level. During our Charge Together program we were able to map the location of the 1600 people who self-identified as PEV intenders. The bulk of these were located in the greater Adelaide area, and many were located around specific postcodes (as outlined in Figure 5). Although the data did not reach statistical significance and did not have street level information, it does suggest that street level clusters could occur in the next regulatory period. For example, there were strong clusters around university areas.

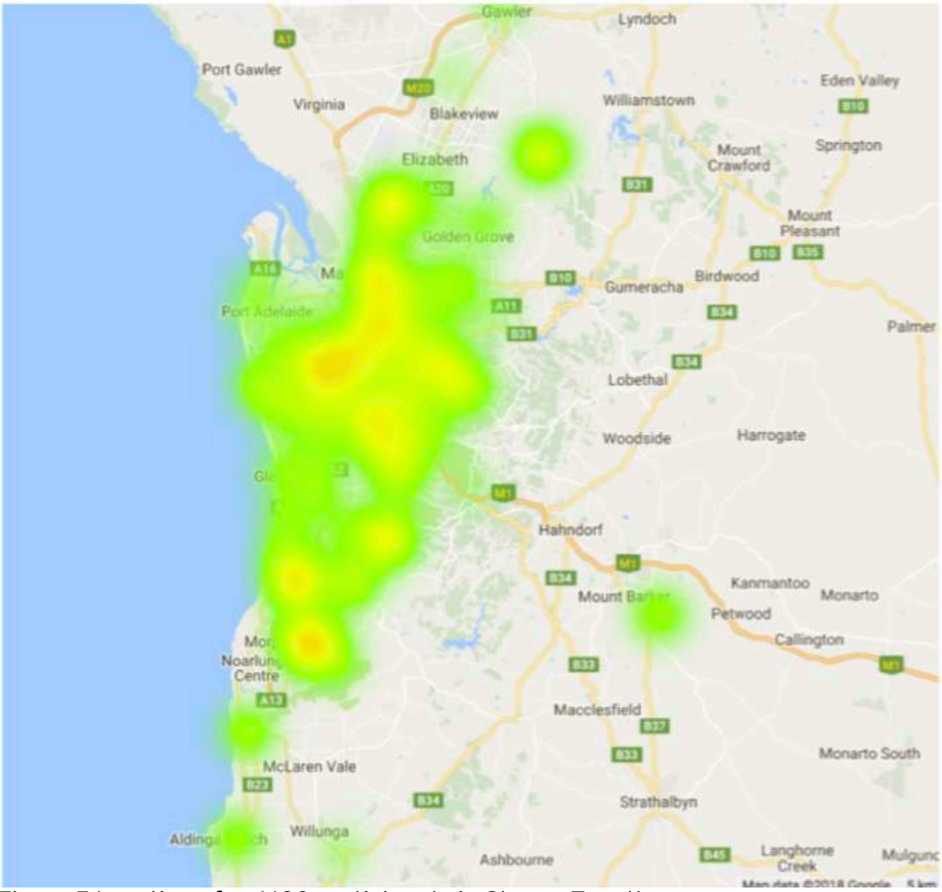


Figure 3 Location of n=1600 participants in Charge Together program

2.2. Impact of the penetration of PEVs

In 2017, the total number of PEVs in SA was around 900 or 0.07% of all South Australian light-duty vehicles (17). This excludes Tesla who do not report their sales figures. However, there is projected to be rapid growth in the use of PEVs as the costs of the technology falls and there is greater public acceptance of them.

The AEMO Energeia forecast developed in 2016 with the weak, neutral and strong scenarios for PEV penetration is outlined below (18).

Weak – 1.0% by 2025
This corresponds to roughly 11,000 PEVs on the road in the state and less than 4% of new vehicle sales being PEVs by 2025.

Neutral – 2.6% by 2025
This corresponds to roughly 29,000 PEVs on the road in South Australia and approximately 10% of new vehicles sales being PEVs by 2025. This was considered the most likely scenario in the 2016 forecast.

Strong – 8.8% by 2025
This corresponds to roughly 100,000 PEVs in the state and a ramp up to a third of all new vehicle sales being PEVs by 2025.

The following sensitivities were used in creating the scenarios.

Table 3: PEV Scenario Drivers AEMO Insights - PEVs

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

Projection Assessment

Factors driving PEV growth are evolving rapidly. As an illustration of just how fast, Bloomberg New Energy Finance (BNEF) upgraded their forecast for the percentage of PEVs in the market globally by 2040 from 35% in their 2016 PEV Outlook to 54% (nearly double!) in their 2017 PEV Outlook (19). This was due primarily to battery costs falling faster than expected and rising commitments from automakers.

In this light, the 2016 AEMO forecast appears to be conservative compared to other projections. In AEMO's March 2018 update of its electricity forecast (20), AEMO appears to agree, with AEMO maintaining its forecast out to 2027 but now forecasting much more aggressive growth after that based on the AEMO Energeia 2017 forecast.[1]

As another point of comparison, analysis by ISD Analytics in 2013 for SAPN made base, low and high projections for PEV penetration by 2025 of 5.0%, 1.3% and 21.5% respectively (21). While also out of date, this projection seems more closely aligned with the BNEFs most recent projection.

A comparison of the AEMO projections versus the BNEF and ISD Analytics projections are below. SAPN have indicated a preference towards using the AEMO forecast for this report.

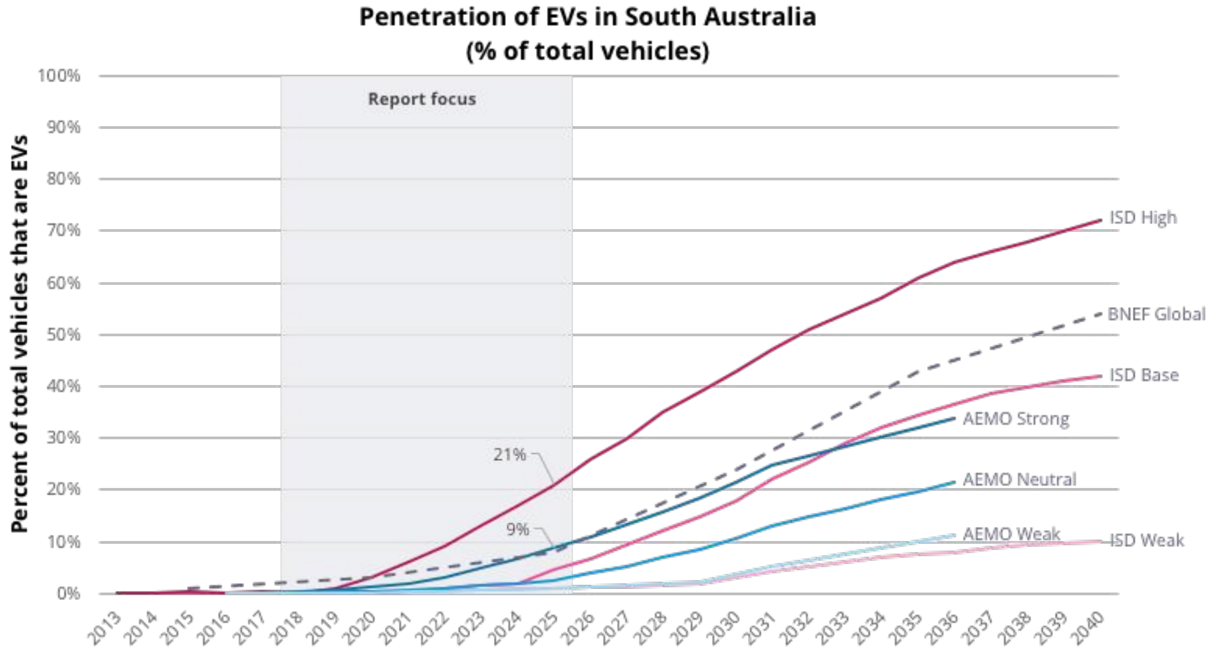


Figure 4: Comparison of AEMO Energeia 2016 (18) and ISD Analytics 2013 (21) projections of penetrations of PEVs in South Australia, and BNEF (19) global penetration of PEVs out to 2040.

This report does not provide an independent assessment of these projections. We have used the 2016 AEMO report as a basis for our modelling as it is the source relied upon by distribution companies and provides more granularity than their 2018 update.

[1] Unfortunately, updated state-by-state forecasts of PEV penetration were not available at the time of writing this report. As such we have used the AEMO Energeia 2016 forecast as it aligns with current growth projections in the analysis period.

It is worth noting that given the update, the recent analyst reports above along with several studies (22; 23) that have identified the strong appetite for PEVs in Australia, we believe that the 2016 figures are likely to be conservative.

2.3. Impact of vehicle type

The significance of vehicle type is important because it affects charging behaviour and preferences towards charging equipment.

In this report we focus primarily on light duty vehicles. Within this class PEVs are classified as:

- Plug-in Hybrid PEVs (PHEVs)
- Battery PEVs (BEVs)

Plug-in Hybrid PEVs

PHEVs benefit from two drivetrains – an internal combustion engine (ICE) as you would find in a regular car and a battery powered electric motor. The two drivetrains provide the user with options as to what fuel they use to drive on – electricity or petrol. In most cases the battery will provide limited range (40-50km) so the petrol engine is designed to take over once the battery is depleted.

In this class of PEV, we also include BEVs with range extenders. These PEVs have greater battery-only ranges (100-200km) and a small petrol engine acts as a generator to provide additional range.

Battery PEVs

BEVs have a single drivetrain – a battery powered electric motor. Compared to the PHEV, the batteries and motors are much larger and more powerful, and the range is far superior (200-500 km). The downside is that these vehicles require dedicated PEV chargers to recharge the batteries and charging times can be up to 10 hours or more depending on the charger type used.

Uptake of PEVs by type

Between 2012 and 2017, BEVs have made up 60% of all PEVs globally (12). Bloomberg New Energy Finance expects PHEV sales to only play a strong role in PEV adoption from now to 2025, after this they expect BEVs to take over and account for the vast majority of PEV sales (19). The engineering complexity of PHEV vehicle platforms, their cost and dual powertrains make BEVs more attractive over the long-run.

By mid-2017 in Australia, various data sources (26; 27; 28) show that PHEVs make up less than half (43%) of all PEVs on the road. While Tesla does not willingly disclose its sales numbers, piecing together various sources (27; 28) suggests that there are likely well over 2000 Tesla Model S and X's on Australian roads today making them the most popular PEVs in Australia.

Compared to the annual sales of conventional hybrid PEVs (HEVs), this is still low. HEVs are being sold at a rate of 12-14,000 units per annum since 2012 (26). Previous studies, such as the one commissioned by SAPN in 2013, predicted that hybrid PEVs will out sell PHEVs and BEVs until 2025. (21).

Charging behaviour versus PEV type

The split of PHEVs and BEVs is important as it affects charging behaviour. In the US PEV Project Trial, PHEVs drivers driving Volts plugged in more often than BEVs drivers driving similarly sized Leafs. Volts were charged an average of 1.5 times per day on the days the vehicle was driven, whereas Leafs were charged an average of 1.1 times per day (14). The Victorian PEV Trial found consistency with the US PEV Project Trial (albeit with a much smaller sample) with the average number of charge events per day for a Nissan Leafs also found to be 1.1 times per day.

In addition, Volt drivers tended to more fully deplete their batteries prior to recharging (See chart below, left), whereas Leaf drivers tended to recharge with significantly more charge left in their batteries (See chart below, right). It's worth observing though that all the charging events of Volts (with an electric only range of 40 miles), would occur within all starting state-of-charge (SOC) events greater than 50% for Nissan Leafs (with a range of 85miles). We can surmise that PHEV drivers are much more likely to opportunistically charge than BEV drivers.

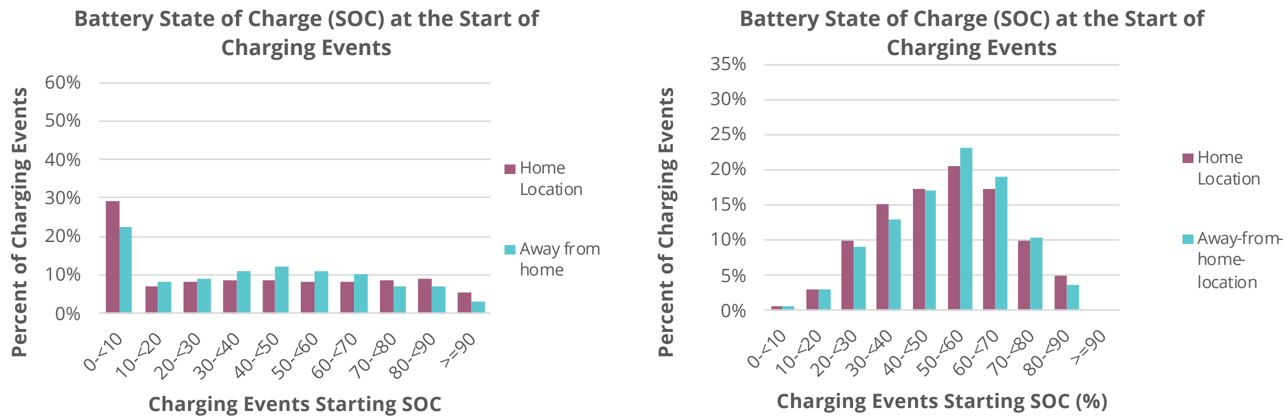


Figure 5: Battery State of Charge at the Start of Charging Events for PHEVs (left) and BEVs (right) (14)

While this data shows that today home and away-from-home charging (that is mainly at a workplace) is roughly equal for these types of vehicle, we expect that as BEV battery ranges increase due to falling technology costs, there is likely to be less charging away-from-home of BEVs for those who have off-street parking.

Note that the same US study showed that electric miles by PHEV Volts and BEV Leafs were roughly equal and about 15% less than the national average mileage.

Impact of PEV type on charger preference and use

The type of fleet in use will affect the type of chargers likely to be used. Charging is likely to be Level 2 charging rather than Level 1 due to faster charge times (29). For BEVs with greater range and therefore larger battery capacity, higher powered chargers will be preferred.

Box 1: PEV charger types

In general, there are considered to be three levels of PEV charging:

Level 1 – AC charging using a standard wall socket at 120 V AC. Charging is up to 10A or 2.4kW. No specialised installation of charging equipment is required. These chargers provide about 10km/hour of charge.

Level 2 – AC charging at 240 V AC using up to 22kW (32A three-phase). This requires the installation of specialised PEV charging equipment. Common sizes of charger also include: 3.3kW (16A single phase), 7.4kW (32A single phase), 11kW (16A three phase). These chargers provide 15 - 100km/hour of charging.

Level 3 – AC and DC. Currently available Rapid AC chargers are rated at 43kW, while Rapid DCs are typically 50kW or up to 120kW (Tesla). These chargers are capable of 80% charging a long ranged Tesla within 30min. In the US and Europe DC chargers of up to 350kW are being installed.

Analysis of the nearly 100 PEV chargers currently listed in SA on PEV charger mapping service PlugShare shows that most common type of charger is a Level 2 - 22kW charger provided by Tesla (30) and that there are on average 1.5 chargers per location. Most other chargers are at least 6kW.

2.4. Driving distance

The distance that vehicles are driven per day will impact the frequency and longevity of charging. The average light passenger vehicle in South Australia travels 12,500km per annum or 34 km's per day. The average commuting distance in Adelaide is 12.4 kms per day (39). As part of this project an application was developed and study was launched of driving patterns. At time of writing we had completed 600 trips and the average distanced travelled was 22 km's per day. Further insight into the impact of Driving distance is provided in the sections below.

2.5. Impact of location, density and use of PEV chargers

Density of PEVs is going to be a significant driver for potential PEV hotspots, especially when considering the workplace and destination charging of privately-owned vehicles.

City of Adelaide

The City of Adelaide will have the highest density of workers in South Australia and therefore we have focused on this area as a potential for PEV hotspots. 117,500 people are employed within the City of Adelaide area, nearly 16% of all jobs in South Australia. Of this, only 4.5% of those people live in the same local council area with the majority commuting in from other areas as shown in the graphic below. (24)

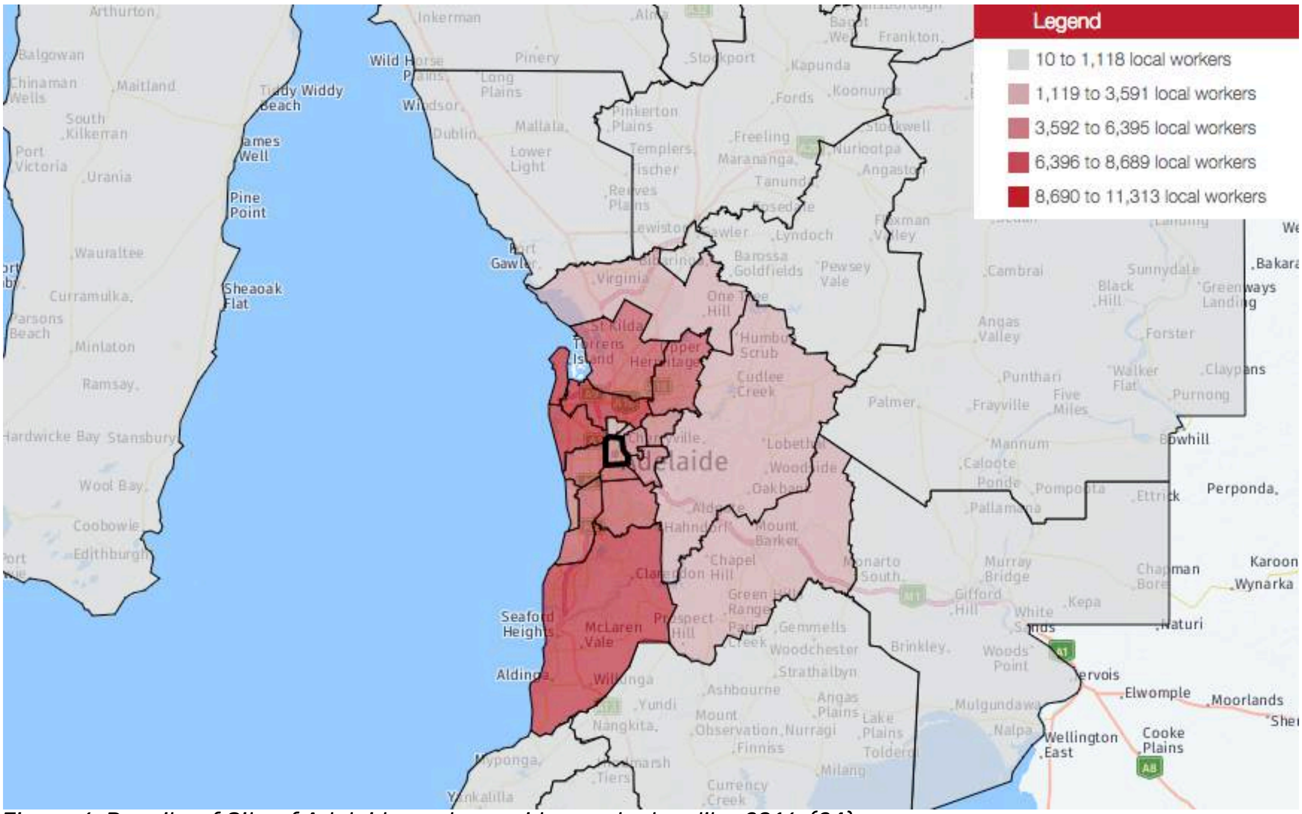


Figure 6: Density of City of Adelaide worker residences by locality, 2016. (24)

In the greater Adelaide area, 66% of employed persons commute to work by car (25), with an average daily commute of less than 14 kms (26). Assuming that the percentage of car commuters to City of Adelaide reflects the greater Adelaide area average and the forecasted number of PEVs is spread uniformly across the whole SA fleet, then the number of PEVs being driven to the City of Adelaide under the various 2025 scenarios will be:

Table 4: PEVs commuting to City of Adelaide in 2025 under various scenarios

Scenario	PEVs Commuting	7.4kW charger demand[2]	22kW charger demand[3]
Weak	800	3 MVA	4.5 MVA
Neutral	2000	7 MVA	11 MVA
Strong	7000	25 MVA	37 MVA

Using these assumptions and assuming there were a large number of chargers installed in the city by workplaces and carparks, there is potential for hotspots to occur within the city by 2025 under the strong scenario. As per Figure 7, available capacity at 9:00AM on the peak capacity day is between 10 – 15 MVA.

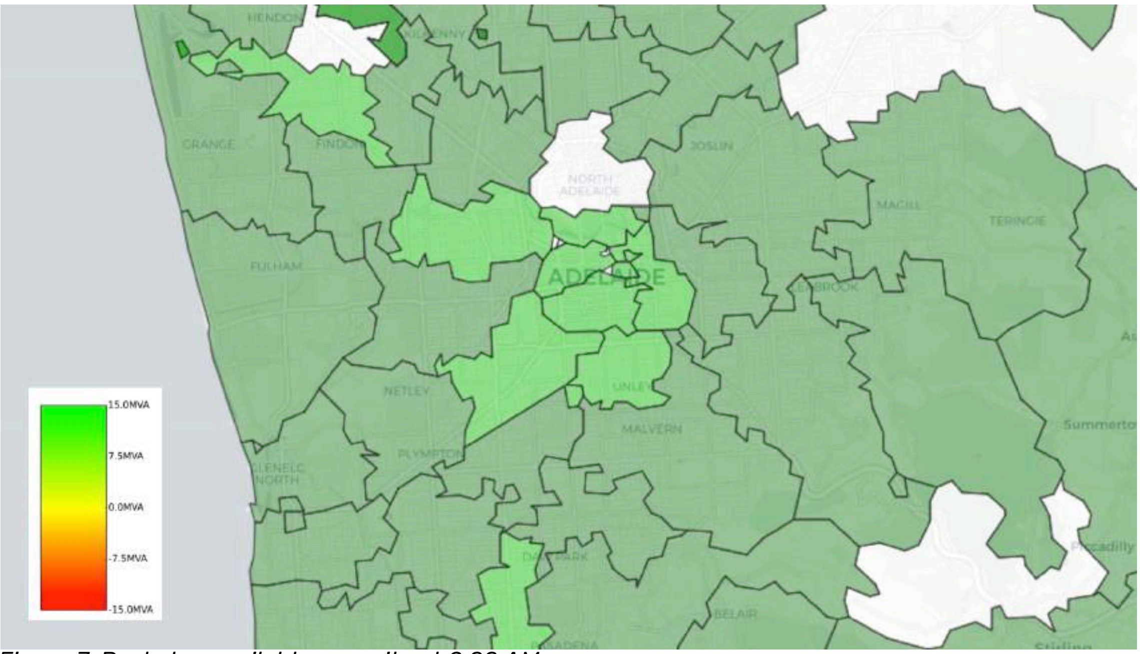


Figure 7: Peak day available capacity at 9:00 AM.

Depending on the spread of these vehicles, there may also be issues at a street transformer or feeder level. A likely source of issues for street transformer and feeders would be fleets. It is important to note however, that with an average of only 14 kms travelled each day, the opportunity to stage charging during the day is significant which would mitigate almost all the impact if appropriate charging strategies were deployed.

[2] Assumes that 50% of PEVs charge at their destination all simultaneously charging with 7kW chargers.
[3] Assumes that 25% of PEVs charge at their destination all simultaneously charging with 22kW chargers.

Residential charging

Residential charging will become an issue if there is a density of PEV's within small geographic location (e.g in a number of homes behind a local distribution transformer or upstream feeder). As a proportion of all PEV charging, residential charging has traditionally been the largest source of load. In an extensive study conducted in the US involving 17,000 PEV charging locations and 8200 PEVs, the majority of charging (~96%) was found to be done at home and work, regardless of the vehicle type (PHEV or BEV) (4). These results are reflected in Norway (12), as well as in local studies (13).

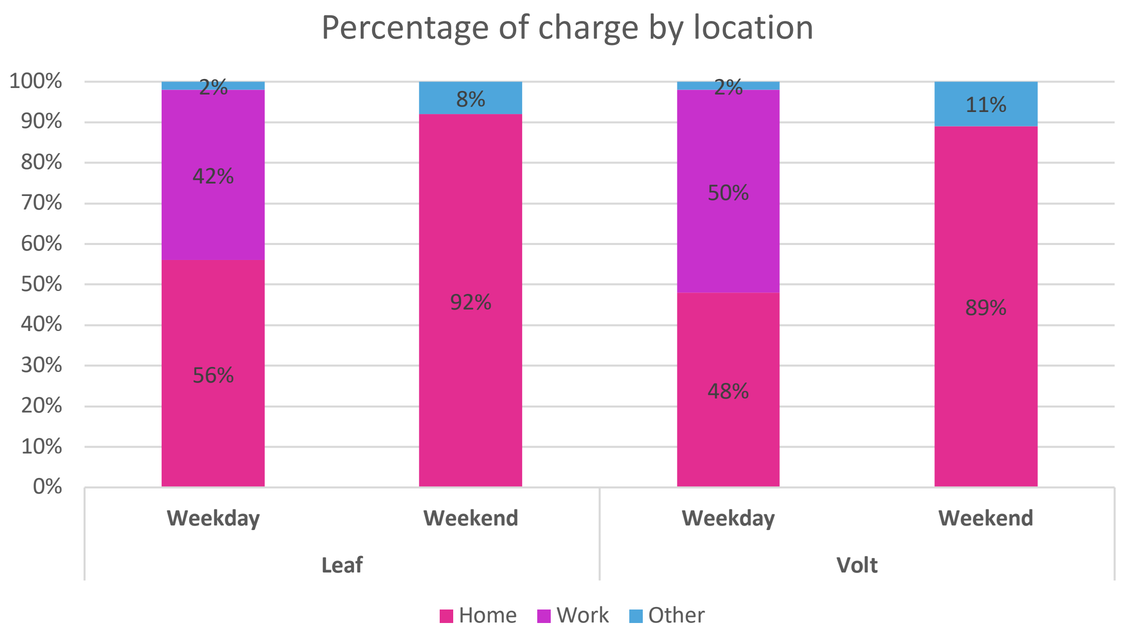


Figure 8: Leaf (left) and Volt (right) drivers with access to home and workplace charging performed nearly all of their charging at those locations (Source: Idaho National Laboratory (14))

In the same US study, diversity of public chargers use was found to be limited, with most drivers who charged away from home favouring three or fewer away-from-home charging locations, with one or more of these locations being at a workplace.

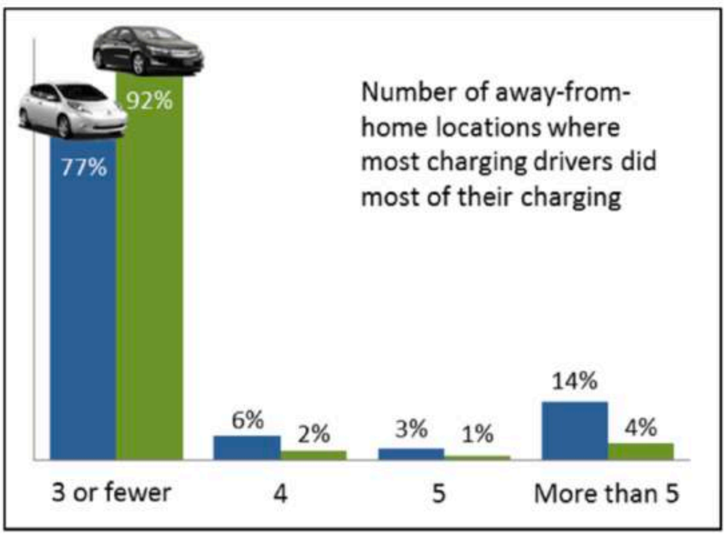


Figure 9: 92% of Volt drivers and 77% of Leaf drivers did most of their away-from-home charging at three or fewer locations. (Source: Idaho National Laboratory (14))

Evenergi conducted a home energy monitoring work stream as part of this project, in part to understand the potential for home charging to create hotspots. While there have been many studies of EV charging behaviour, a key purposes of this trial was to help understand the way that home charging, local PV generation and distributed storage would impact on potential hotspots within residential areas.

Energy monitors were installed in the homes of 42 people in South Australia. It is important to note that this study was focused on those that were intending on buying an electric vehicle rather than electric vehicle owners, to identify behaviours of more mainstream buyers.

Of the 42, 28 had solar this was monitored on a separate circuit. This allowed the creation of four aggregated charging profiles representing home energy usage and driving patterns. It is important to note that at time of writing the monitoring was only over three months (March to May 2018), however for the purpose of potential network impact outlined below it is still instructive. Evenergi has developed model that enables creation of load curves based on travel patterns, energy consumption, home charger size, home solar size, and with and without home battery storage.

The key drivers of the model were distances driven (mean of daily trip data from our logger device validated against statistical databases (39)) , home load profiles (taken from energy monitors) and solar/export import (also taken from home energy monitors).

The following table represents a number of profiles we have created to investigate the network impacts of charging. These are based on some aggregated profiles from our cohort.

	Solar	Driving patterns	Living patterns
Jim	Larger demand, solar installed 7.2 kW charger	20 kms weekend, 40 weekends	Steady daytime use
Jess	Solar installed, evening peak 3 kW charger	30 kms weekend and 30 weekdays	Out all day
Bill	No solar, steady use 7.2 kW charger	20 kms weekend and 30 weekdays	Out some of the day
Tracey	No solar, larger user, out all day 3 kW charger	40 kms weekend and 50 weekdays	Out all day

Figure 10 Average weekend load profile – no PEVis an simulation of an average weekend day in a street where our persona's live. In this chart this stage none of them have a PEV.

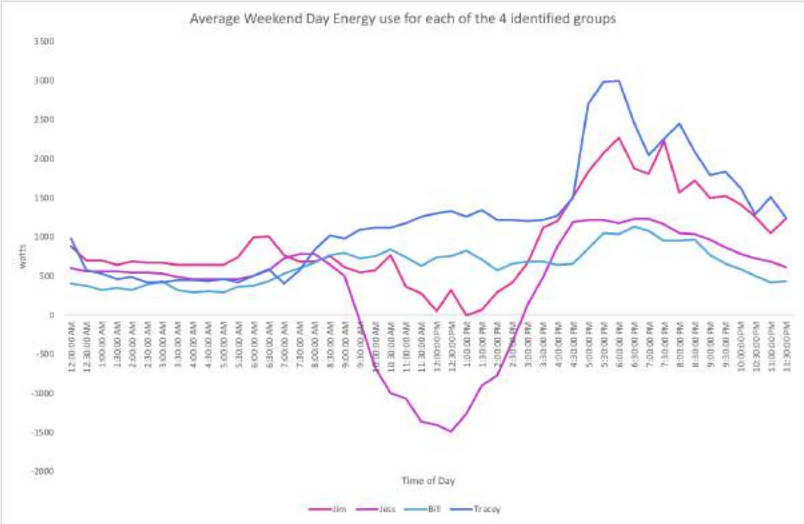


Figure 10 Average weekend load profile – no PEV

All our persona's then buy a PEV. They decide to buy the same vehicle (40kW capacity), but different chargers.

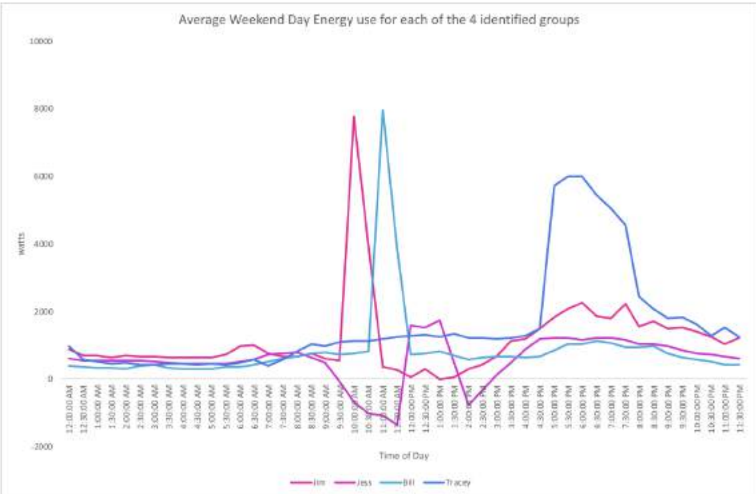


Figure 11 Average Weekend Energy use - with PEV

We can see that Jess, with a large degree of solar spill and 3kW charger has the least impact on capacity requirement in the street. Tracy travels the longest journeys (50kms) and with a 3 kW charger has the longest charging session. Jim and Bill have larger chargers with moderate driving and their co-incident load will cause the biggest impact on capacity at the transformer.

Jim and Jess then decide to buy a 13.5 kW battery. Jim was not over-producing solar so it has little impact, but Jess is able to eliminate her solar spill.

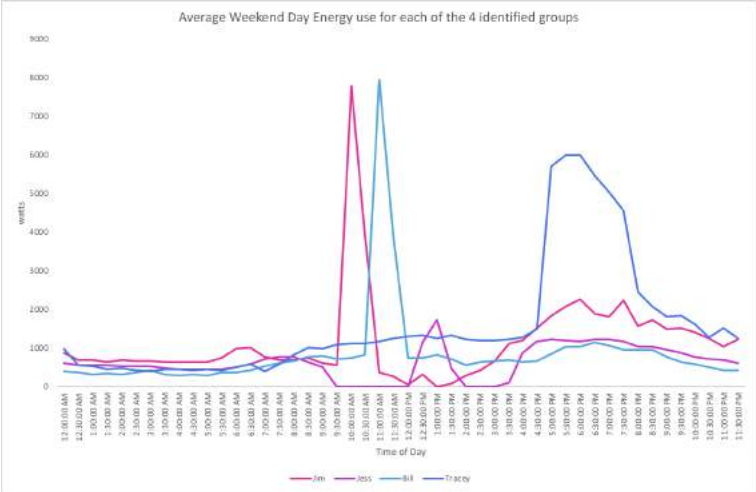


Figure 12 Average weekend with battery storage

Now if we remove the local battery storage and assume that we are in a street where there are very steady work-life patterns we can see the worst case scenario which would impose considerable additional load on a transformer as we can see in Figure 12.

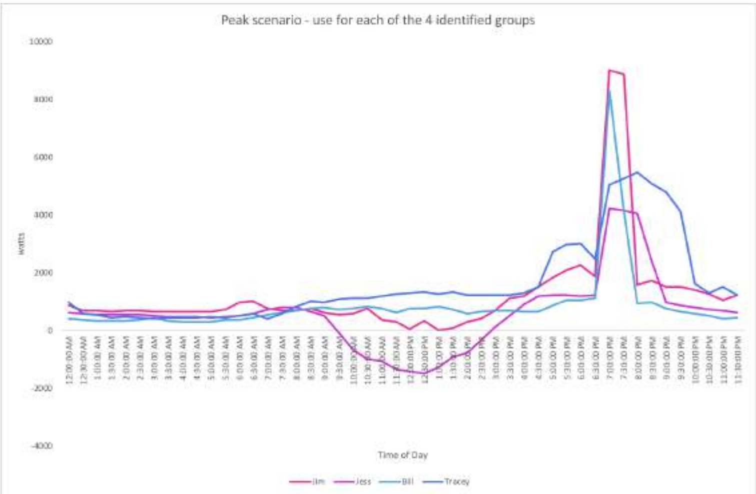


Figure 13 Peak scenario - four persona's

The data from this study is still being collected to account for seasonality however it is clear that the emergence of a residential hotspot will depend on :

1. The number of PEV's on a single transformer- given the density of postcodes in some of campaign it is conceivable that there are dense areas where the PEV ownership will be over-represented
2. The co-incidence of charging on that transformer – it can be seen that where homes share work/life patterns this could present an issue
3. The amount of solar generation or battery storage used to charge vehicles will reduce the peaks

Overall due to the low average driving distances in South Australia and great potential for capacity management (as outlined in Section 4 of this document) it is unlikely that hotspots will emerge in the next regulatory period (up to 2025).

Workplace charging

Details on workplace charging in Australia are scant, however data exists in the US that demonstrates likely high utilisation of workplace charging. The Workplace Challenge, a corporate partner program run by the US Department of Energy to boost workplace charging, found that 90% of its 150 corporate partners experienced 100% utilization 5 days a week for its chargers (38).

Data from the Queensland Household Travel Survey gives indication of typical driver behaviour in relation to arrival and departure times. From this data we see that approximately 70% of drivers arrive at their destination in the 4 hours between 6 AM and 10AM. By 3:30 PM vehicles start to leave their destinations en-masse, with 60% of vehicles leaving their destination between 3:30 PM and 7:30PM.

Destination Arrive Time

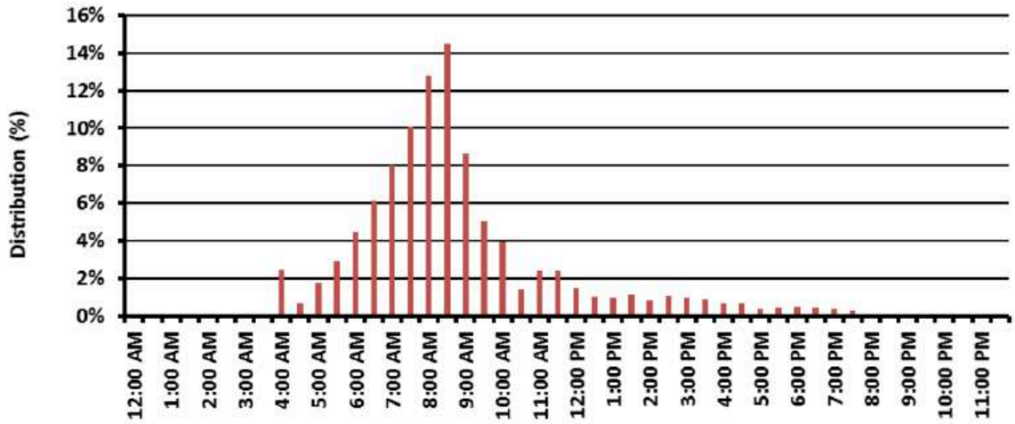


Figure 14: Vehicle distribution by destination arrival times for an average day. Source: Energeia analysis of Queensland Household Travel Survey (40)

Destination Departure Time

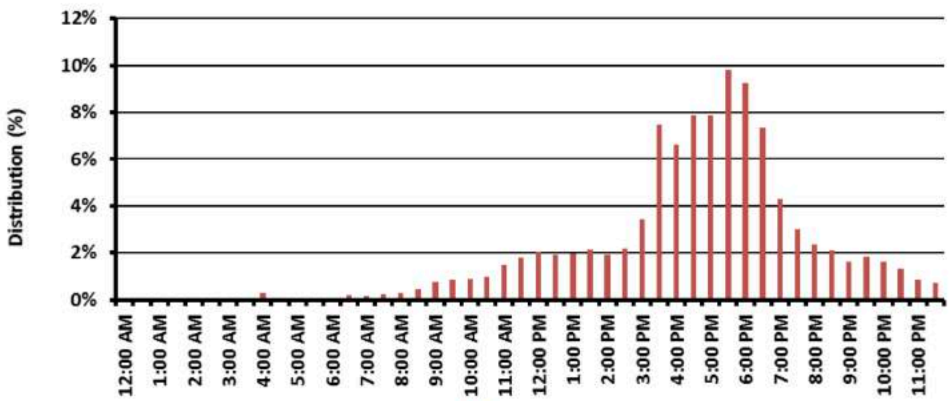
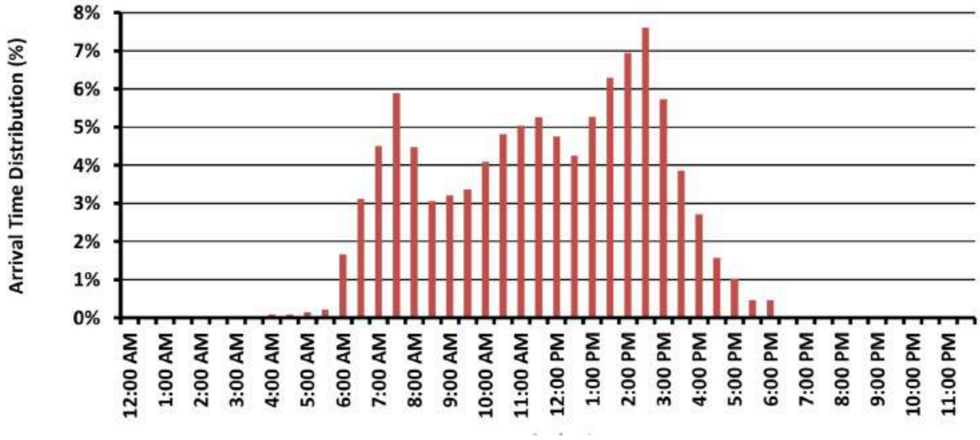


Figure 15: Vehicle distribution by destination departure times for an average day. Source: Energeia analysis of Queensland Household Travel Survey (40)

Fleet Charging

There are two types of fleet vehicles, those that are pooled, and those that are dedicated to individuals. Due to this, fleet arrive times have much greater dispersal throughout the day.

Destination Arrival Time



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

Figure 16: Vehicle distribution by arrival time for fleets for an average day. Source: Energeia analysis of Victorian Department of Economic Development, Jobs, Transport and Resources (18)

The trial being undertaken by the Victorian government gives some insight into how ownership affects charging. While households with a PEV generally charged at night, as shown in Figure 17, the fleets participating in the trial have mostly charged their vehicles during business hours (13).

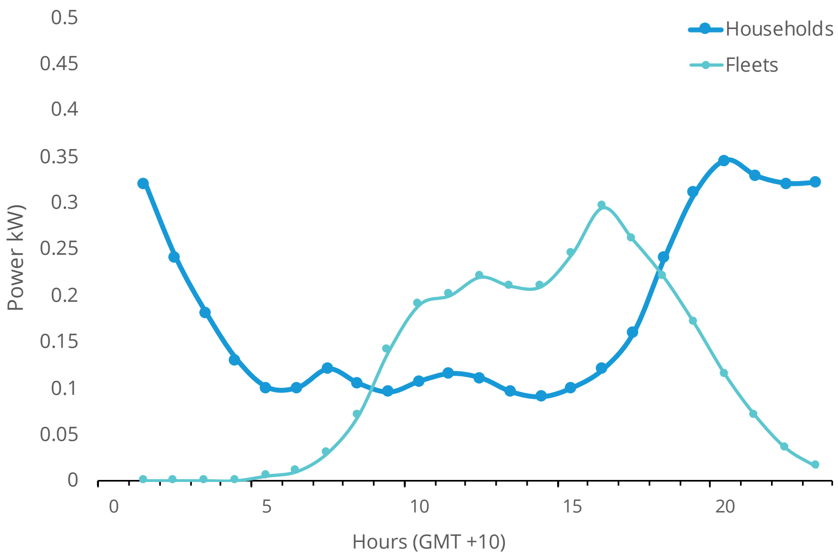


Figure 17: PEV charging demand profiles for fleet and households in the Victorian Government PEV trial (n = 41 and 83 respectively) (13)

Very few fleet participants deployed ‘network’ charging strategies that provided overnight charging options outside of the central charging location for the vehicle. Because of this, the majority of the fleet participant charging has taken place at the business premises during business hours. It is also interesting to see the difference between pooled fleet vehicles and fleet vehicles (Org Fleet) with a dedicated driver (Org Ind)

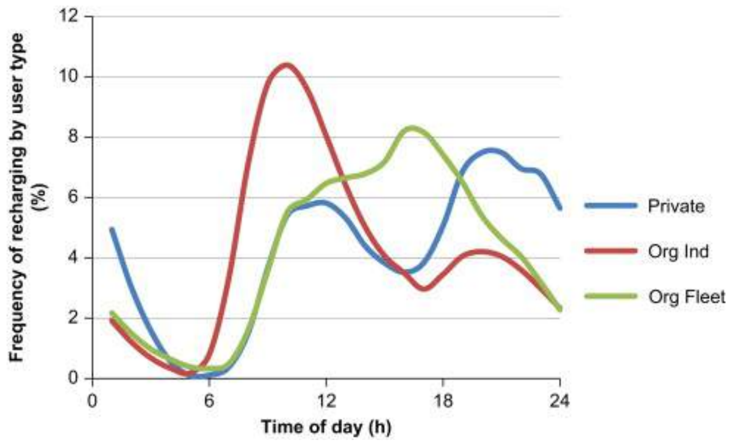


Figure 18 Frequency of charging by user type (32)

Box 2: Case Study – Fleet SA

Fleet SA, the fleet management arm of the South Australian Government currently own 7000 vehicles that are provided and managed by Lease Plan. Within the fleet are 600 Hybrids, 2 BMW i3 BEVs and 20 Mitsubishi Outlander PHEVs. They are trying to increase the number of PEVs in the fleets but it is early days.

Fleet SA has a target for 30% Low Emission Vehicles in their fleet by December 2019. Fleet SA's definition of low emission is set by class of vehicle. Below is a table of emissions limits for passenger vehicles in order for them to be classed as Low Emissions Vehicles. Most of the vehicles that fall under these limits are hybrids, LPG vehicles, high-efficiency diesels and, of course, PEVs. As of March 2018, 18.8% of Fleet SAs were considered Low Emissions, of which about 10% were hybrid electric. As of the time of writing, there was no target beyond the 2019, nor a target specifically for PEVs.

Passenger Vehicle Class	Emissions Limit (g-CO2-e/km)
Micro	100
Lite	125
Small	135
Medium	145
Large	190
Upper larger	210

That said, Fleet SA has been working with "all the manufactures" to find PEVs that suit their needs. They have an order in for the Tesla Model 3 and are interested in purchasing more Mitsubishi Outlanders and Hyundai Ioniqs when they are released. This was after considering many other models in the market. These will likely be executive vehicles.

Given the change of government, it is hard to predict what will happen after 2019.

Public Chargers

As outlined above, the nature of PEV charging today for passenger vehicles is seen as being home charging with constant "top-ups" and then highway charging for longer journeys. The reality in the short term is that range anxiety necessitates that significant numbers of public chargers are deployed to appease this psychological barrier to purchasing a PEV. Nilsson and Nykvist (2016) (37) and others have recognised that the availability of public rapid charging is an important signal for consumers and will support PEV adoption.

It is also possible for charging network pricing to influence where people charge. A major UK study, SwitchEV, was conducted at the time that the UK government implemented the Charge Your Car (CYC) program, which subsidised home, work and street level charging. People were provided with a CYC card which offered a flat monthly recharging cost. It was found that this approach led to significantly greater workplace and on-street charging than a similar trial CABLED, which was also run in the UK without the extensive on-street and workplace charging investments (30).

In addition, if PEVs are to have a significant impact on those who do not have off-street parking at home, (and therefore cannot charge at home), then street charging, and in particular rapid charging will need to become wide-spread. At the point where on-street charging infrastructure becomes fast enough to roughly imitate petrol refuelling, we may find a tipping point for both PEVs and for fast charging infrastructure.

Experience in the US has been that Level 2 charger usage (excluding workplace charging units) has been found to be quite low (14). The median charging frequency per site was 1.4 charges per week, with 75% of the 2,400 public AC Level 2 EVSE sites nationwide averaging four or fewer charging events per week. However, popular public AC Level 2 EVSE sites saw very high usage. Well-designed charging sites at retail stores, especially shopping malls, and parking lots and garages serving multiple venues demonstrated the potential to support from 7 to 11 charges per day. It is also likely that as PEV adoption increases these utilisation rates will improve.

Charging sites at venues where vehicles are parked for long periods of time (e.g. airports, ride-share parking lots, or parking lots at public transit stations) should not be measured by the number of events per week, but rather by the time vehicles spent connected to charging stations in a day or week. During the US study, these kinds of sites had vehicles connected for an average of 8.6 hours per charge cord per day. The average time vehicles were plugged in for each individual charge event ranged from 4 to 42 hours, with a median plug-in time of 22.6 hours per event. These types of locations are potential candidates for slower, lower cost AC Level 2 charging equipment.

In the US study DCFCs were used much more frequently than most public AC Level 2 EVSE (14), with a median use frequency of 7.2 events per week, based on averaging each DCFC's use over the course of the entire PEV Project. A quarter of the DCFCs averaged over 15 events per week, and one unit averaged 70 events per week. The most highly utilized DCFCs tended to be located close to interstate highway exits. Interestingly, these units were used by local vehicles as much or more than they were used to recharge vehicles traveling on the interstate. The most utilized DCFC stations were located along major commuter routes within the major metropolitan areas. Many of the highly utilized DCFCs were located near or associated with high-tech employers.

Exact factors that determine what makes a public charging station popular are predominantly community-specific (14). Public charging station usage varies significantly by region, with average utilization rates generally tracking with regional PEV sales. Aspects of location may contribute to a PEV charger site's popularity (or lack thereof), including the following:

- A site's geographic proximity to a large business district or an interstate highway.
- The general location of the EVSE site (e.g., the part of town, city, or region where it is located) may also influence its use.
- The demographics of local drivers or drivers commuting to workplaces, and local commercial venues also contribute.

As mentioned above, there are currently 100 PEV charger locations and 150 chargers in SA. Only 20% of these chargers are in the greater Adelaide area. This means there is about 1 charger for every 30 PEVs in the city. The ultimate number of chargers per PEV will depend on the ratio of rapid chargers to Level 2 chargers; however Californian cities have on average 30 PEVs per public PEV charger (36). The Californian market is likely to reflect the South Australian market, given the common levels of garage ownership.

As shown in Figure 19 most PEV chargers in South Australia are in regional areas at hotels and tourist destinations. Under an agreement with the South Australian government, Tesla will provide another 50 destination PEV chargers. These too will be predominately regionally located.

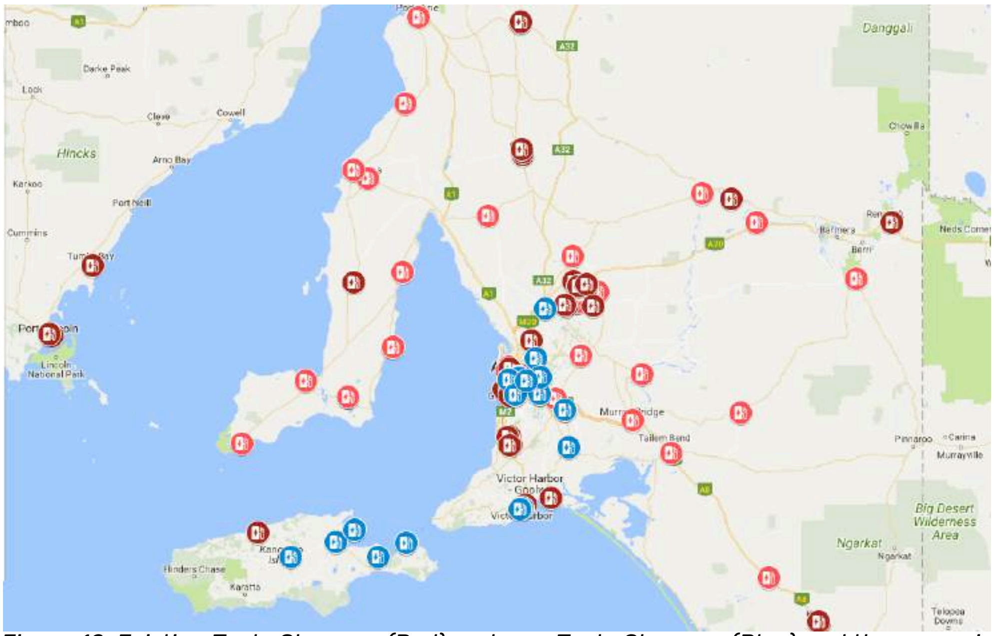


Figure 19: Existing Tesla Chargers (Red) and non-Tesla Chargers (Blue) and the approximately 50 proposed Tesla Chargers currently being explored with the SA government (Pink). Location data collected from PlugShare (30) and directly from the South Australian government.

This lack of density shows that there are unlikely to be PEV charging hotspots developing from public Level 2 PEV charging in the near term. As the number of PEVs grows so too will the number of PEV chargers. If Adelaide keeps deploying 1 charger for every 30 PEVs, then it could have up to 3000 Level 2 chargers installed across the city by 2025. Depending on the type of charger being installed the network capacity required could be up to 75 MVA.

Table 5: Number of chargers and total capacity requirements by 2025 for varying sizes of Level 2 public chargers under different AEMO PEV penetration projections.

Scenario	Charger size	15 PEVs per charger	30 PEVs per charger	45 PEVs per charger
Weak	# chargers	733	367	244
	7.4 kW	5.4	2.7	1.8
	22 kW	16.1	8.1	5.4
Neutral	# chargers	1933	967	644
	7.4 kW	14.3	7.2	4.8
	22 kW	42.5	21.3	14.2
Strong	#chargers	6667	3333	2222
	7.4 kW	49.3	24.7	16.4
	22 kW	146.7	73.3	48.9

Currently there are 6 rapid chargers in Adelaide, 4 of which are in Franklin St which required an upgrade to the local low voltage transformer, but did not create a network issue as it was funded by the developer. With these chargers potentially reaching 350kW output, constraints in the network could more easily occur. Figure 20 shows the relative number of Level 2 chargers to DC rapid chargers in cities within major PEV markets around the world. The proportion of Level 3 charging has varied quite considerably but the degree to which home charging is available appears to be a significant underlying factor.

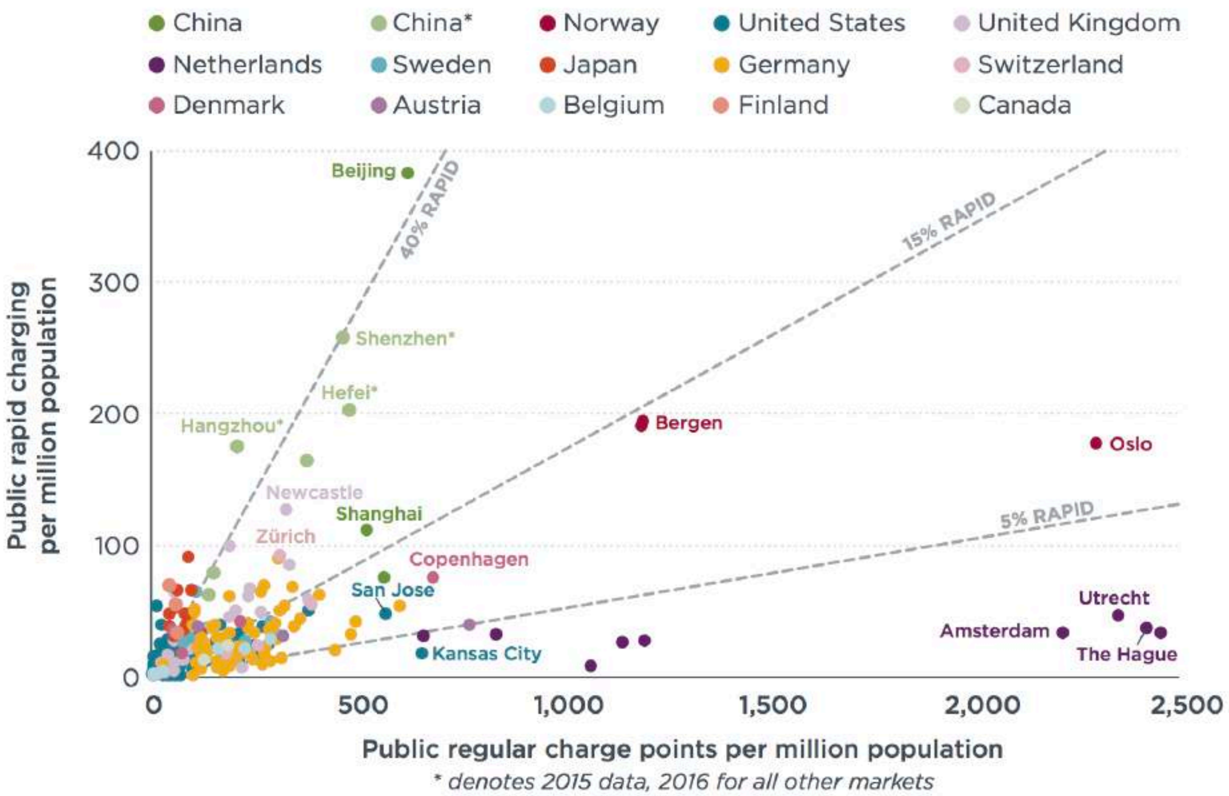


Figure 20: Relative numbers of public regular Level 2 and DC fast charge points per million population in selected major metropolitan areas (36).

Given that many Adelaide homes have off-street parking and based on this international experience, we can expect that between 5 and 15% of chargers could be DC rapid chargers. For reference, currently the proportion of DC rapid chargers to Level 2 charges in Adelaide is 17%. Table 6 shows that rapid chargers could require up to 60 MVA on top of the Level 2 capacity requirements.

Table 6: Number and capacity requirement for Level 3 DC Rapid chargers by 2025 at varying proportions of rapid to Level 2 chargers for different AEMO projections. It has been assumed there will be one charger to 30 PEVs and the rapid chargers will be 120kW on average.

Network Level		5%	10%	15%
Weak	Number rapid chargers	18	37	55
	Capacity req. for rapid chargers (MVA)	2.2	4.4	6.6
Neutral	Number rapid chargers	48	97	145
	Capacity req. for rapid chargers (MVA)	5.8	11.6	17.4
Strong	Number rapid chargers	167	333	500
	Capacity req. for rapid chargers (MVA)	20	40	60

With longer ranges available in vehicles (some are predicting over 600 km's) and emerging charging technology a new paradigm in charging may ultimately prevail which is a reversion back to a petrol station style of charging (ie drive to empty and the refill at a service station). ABB recently demonstrated a charger capable of refilling 200kms in 8 minutes. In the United Kingdom this exact analogy is playing out as those who own petrol stations are acquiring charging network providers. A project driven by Shell in Europe is aiming to make this a reality (15).

There are still a number of technical and commercial, hurdles to ultra-fast charging scenario. Firstly, are few vehicles today that can accept that speed of charging and secondly the convenience of home and workplace charging will likely prevail for those with off-street parking.

If these do become prevalent these refuelling stations would likely become major hotspots on networks. From a cost recovery perspective related capacity upgrades are paid for by the customer, however long term they may lead to upstream issues due to the episodic nature of its demand.

In terms of how public charging affects the planning for SA Powers Networks:

- At a feeder and street transformer level, capacity needs to exist for those rare occasions that a cluster of PEV chargers connected to those assets are concurrently in use. That is, if 10 chargers are connected to a street transformer, SAPN should allow for the rare occasion that all 10 chargers are operating simultaneously and mostly likely have some form of demand response implemented.

- At a zone-substation level, diversity factors can be applied on the total capacity requirements of all PEV chargers in a given area. That is, if 100 chargers are connected to a zone substation, SAPN can likely safely apply a diversity factor of 30% or less as its unlikely that all charges will be operating simultaneously (40).

Inter-regional charging networks

Highway chargers are provided by companies wishing to respond to a particular customer need (e.g. to facilitate a journey between Adelaide and Melbourne).

They predominately occur along highways and interstate routes but commonly have charging hubs within cities too (see Figure 21). Typically these chargers are Level 3 - DC faster chargers, so will inherently require network upgrades which will be paid for by project developers.

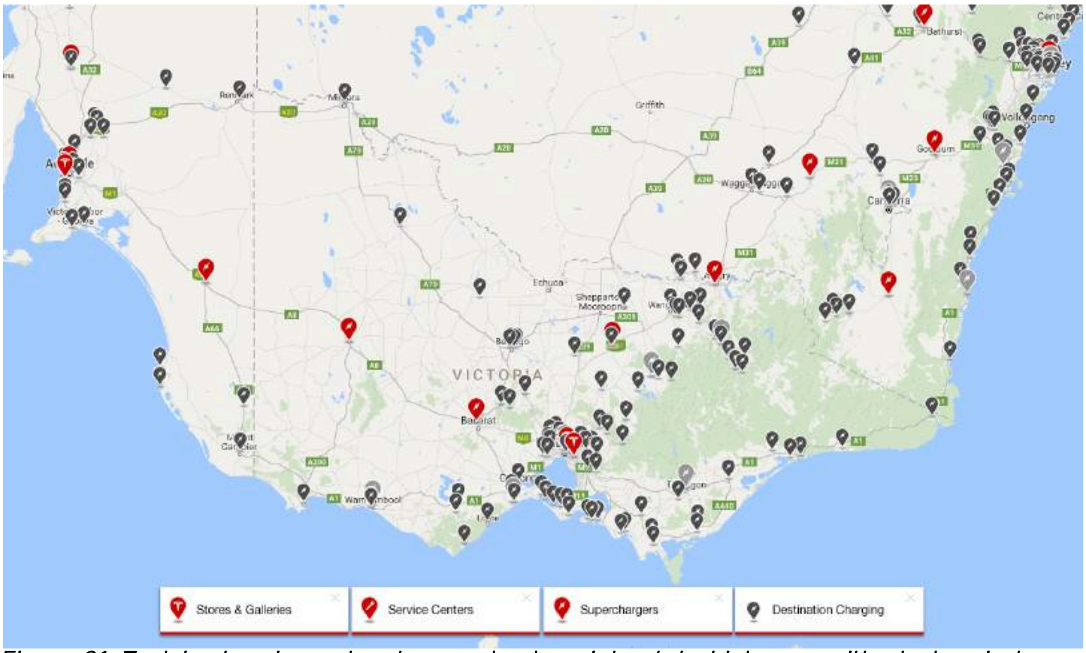


Figure 21: Tesla's charging network spreads along interstate highways with clusters in towns and cities (Source: Tesla (35))

Public charging and distributed generation

In Appendix A we have provided a view on which of the public charging scenarios deployment would be appropriate to pair with local generation. In general, any site where the charging infrastructure is owned by a party with a long term interest in the property, upon which the charging station is located, is a potential fit for local generation if there is suitable adjacent roof-space. It is logical since PV is non-dispatchable and “time-floating” and PEV’s are controllable and could represent storage capacity. (42)

For many of these scenarios the reality is that any rooftop solar generation will be absorbed by base building load rather than the PEV charging specifically, whereas solar canopies can be attributed directly to PEVs.

2.6. A note on other eMobility trends

Exploration of mobility trends such as increased ridesharing, car sharing and autonomous vehicles is beyond the scope of this study, however may have major impacts on the nature of network demands.

For example, autonomous vehicles have the potential to dramatically change the use and charging habits of vehicles. In a private setting, an autonomous vehicle could return home to charge and avoid paying for parking in the city. In a fleet setting like Uber, autonomous vehicles could operate 24/7 and return to fleet hubs only for recharging.

In a recent report by National Grid, there were arguments as to whether private autonomous vehicles would put more or less strain on the grid, and it was determined that it may be similar due to the fact that despite the efficiencies of one car being used for multiple people, it may encourage more people to drive rather than take public transport. In the fleet scenario it is likely that autonomous PEVs could provide better opportunity for balancing services if fleet owners are open to data sharing with distribution grid operators.

It is important that these trends are monitored and that the shifting mobility context is incorporated into SAPN and other network operators planning and forecasting processes.

2.7. Conclusion – likely hotspot locations

The following specific charging typologies have been developed and details of each have been assessed in Appendix A. In the following table – "High" potential for solar or DSR means that it is technically possible and commercially feasible, Mid means it is technically possible and commercially marginal, and Low means it is technically and commercially challenging.

Table 7 Charging typologies

	Typical Charger size	Hotspot risk	Upgrade funding	Rooftop solar	Solar canopy	Potential for DSR
Universities	7 - 22 kW	Mid	Customer	High*	High	High****
Shopping centres	7 - 22 kW	Low	Customer	Mid**		
Airport parking	7 - 22 kW	Mid	Customer	Mid	Partial	High
Public carparks	7- 22 kW	Mid	Customer	Mid	Mid	Mid
Workplace charging	7 - 22 kW	Low	Customer	Mid	High	Mid
Apartment buildings	7 - 22 kW	Low	Customer	Mid	Low	Low
Hotel Parking	7 - 22 kW	Low	Customer	High	High	High
Local on-street charging	7 - 22 kW	Low	Customer	Mid	Mid	High
Highway charging	43-330 kW	High	Customer	Low***	Low	Low
Pool vehicles	7 - 22 kW	High	Customer	High	Mid	High
Taxi fleets	7-330 kW	High	Customer	N/A	N/A	Mid
Ride sharing fleets	7-330 kW	Mid	Customer	N/A	N/A	Low
Car sharing fleets	7-330 kW	Mid	Customer	Low	Low	Low
Bus fleets	50-150 kW	High	Customer	High	High	High
Street level residential	3-7 kW	Mid	SAPN	High	Low	High
Clusters of local, fleet and destination chargers	Aggregated load	High	SAPN	High	N/A	N/A

3. Managing capacity issues

In the time horizon of 2020 to 2025 considered in this report, there is potential for capacity issues in the network, specifically in City of Adelaide and at locations where private vehicles and fleets are being charged in an uncontrolled way. In assessing this, we have considered the following:

- Strategies for managing capacity issues
- Control methodologies for charging infrastructure
- Potential value for fleets from managed charging

3.1. Strategies for managing capacity issues

By virtue of the fact that PEVs are typically parked for long periods and charging can be controlled, either by the car or a PEV charger, there are many options available to SAPN to manage capacity issues. Below is a summary of the main options.

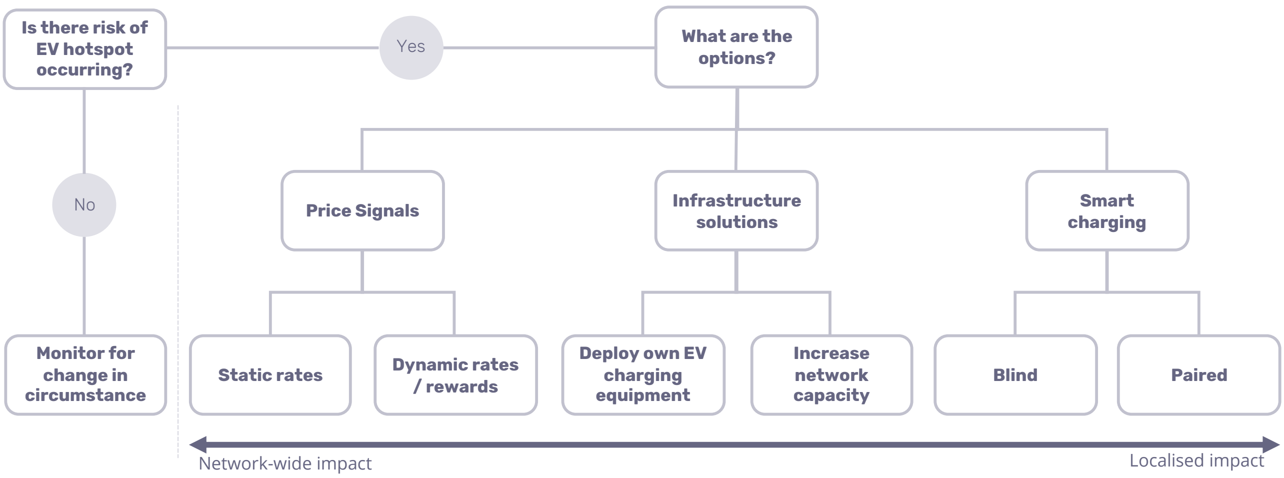


Figure 22: PEV hotspot management options

The nature of the hotspot, whether it occurs at zone-substation level or more localized level (such as at a street transformer level) might determine the response from SAPN.

Broadly speaking, there are three main categories of response:

1. Providing price signal to the market to encourage ideal charging behaviour either statically or dynamically
2. Infrastructure solutions that either resolve a likely hotspot from proposed PEV charging solutions, or provide a viable charging alternative that removes its need
3. Smart charging that controls the charging of a PEV

In our view, these options above are in increasing levels of local effectiveness.

Pricing signals: Static rates

Time-of-use (TOU) tariff structures have been used effectively in the United States, Germany, the United Kingdom, Japan and other regions (47). In Evenergi's own experience in the UK, PEV drivers actively seek out price competitive two-rate "Economy 7 tariffs" that provide for low cost charging for 7 night-time hours of the day.

However, static tariffs are a blunt instrument for encouraging behaviour and can "miss the mark" – either by being too effective, being ineffective or resulting in unintended consequences. For example, many customers on the same TOU tariff may all schedule to charge their vehicles with the same start time and cause higher peaks in "off-peak" periods than "peak" periods as was the case for utility Progress Energy in North Carolina (48).

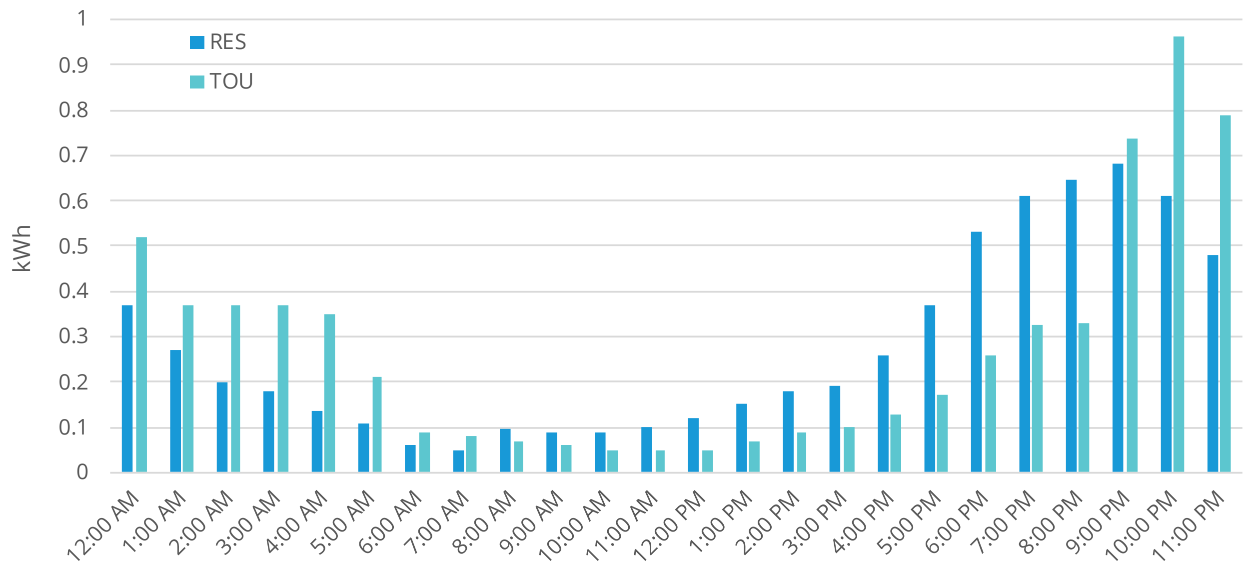


Figure 23: Charging Patterns with (TOU) and without (RES) during summer weekdays at Progress Energy, North Carolina. Peak period is in grey (48).

SAPN offers an interesting option in South Australia for home charging. EV charging can be put on a separately-metered off-peak controlled load tariff, normally used for overnight hot water heating. This was something that the local EV community was asking for, as it significantly improves the economics of home EV charging (15c/kWh vs 40c/kWh). The downside is that it requires a new meter if you don't already have off peak hot water, and we've had lots of delays and issues with meter replacements this year due to the new metering rules that have transferred responsibility for meter installations to the retailers.

Customers are placed on standard controlled load terms, same as have always been in place for hot water: you have to have a separate controlled load circuit which anything on that tariff connects to (typically your hot water service and your EV charger). That circuit is only normally switched on overnight, by a time switch in the meter, and any energy consumed is metered separately and billed at the lower rate. Customers get a 'boost' button on the meter in case they need to turn it on during the day, but in that case the energy used is billed at the standard rate.

SAPN have the right to vary the on and off times. Typically they all come on around 11pm and run through to 7am, with some randomisation of start times, but they have reprogrammed some to come on in the middle of the day as well in some locations where we have excess solar PV, and we may do more of that in future.

In theory they also require maximum of 40A on that circuit, which for a decent sized EV charger can mean that the EV charger should not be on at the same time as the hot water service. This is a bit tricky for customers, as it probably means they have to add an extra time switch to delay the EV charging for a couple of hours to give the hot water time to finish heating.

Given the small community currently using this tariff there is not sufficient data to judge the impact; however it would be fair to assume this will significantly relieve any capacity issues at a residential level

Pricing Signals: Dynamic Rates and Rewards

One way of overcoming the side effects of static rates is by deploying dynamic rates or reward structures. This gives utilities more options to incentivize ideal charging behaviour and acknowledges that not all customers will respond to price signals in a uniform way. Optionality around dynamic rates and rewards includes:

- Staggering low rate or rewarding charging periods
- Offerings rates and rewards at different value levels for different customer groups
- Offering different types of rewards

Dynamic rates are still relatively untested, although there are trials underway by Nord-Trøndelag Elektrisitetsverk Nett in Norway and San Diego Gas & Electric in California, with prices posted one day ahead in the ongoing and so far successful latter trial (49; 50; 51).

Infrastructure solutions: strategic deployment of PEV charging infrastructure

Around the world, large energy companies are deploying their own networks and are now responsible for a significant proportion of charging infrastructure. In Germany, power companies including RWE, Vattenfall, E.ON and EnBW, account for 35% of all public charging stations (47).

One option to incentivize customers away from deploying their own PEV charging equipment and creating capacity issues for the network is to deploy an alternative PEV charging infrastructure that is more desirable and better located, to manage capacity constraints.

In a recent thought piece, National Grid in the UK proposed to build a network of super-fast chargers that draw 350kW at similarly located locations to petrol stations (52). These chargers are capable of three-quarter charging a 22kWh battery (e.g. similar one found in older model Nissan Leafs) within just four minutes and 12 minutes to charge a Tesla P75D to the same level.

National Grid projects that just 7000 fast charging locations with 7-9 chargers per location would be sufficient, slightly less than the current number of petrol stations and pumps in the UK. National Grid argues that this strategy reduces the need for private charging (at home and work), and specifically, Level 2 chargers in the home that require both upgrades to home connections and ultimately large scale upgrades to last mile infrastructure. It also argues that this strategy creates options for drivers who don't have access to off-street parking.

Infrastructure Solutions: Deployment of strategically placed battery storage solutions

There is also an emergent case for large scale batteries being paired to Rapid chargers, synergising transmission level connections with the paired business cases of rapid charging and flexibility payments. In May 2018 Pivot Power announced a fast charge network which is funded through deployment of transmission level battery storage (46).

Given discussion in this document about the potential impact of DC Fast Charging on grid stability and renewable generation this could be an exciting way to deliver grid services and synchronize with over-generation of renewables to provide a very positive impact on the grid at large.

Infrastructure Solutions: Vehicle to Grid

Another possible opportunity is Vehicle to Grid (V2G) technology (45). While this has been seen as difficult to implement due to impact on the vehicle battery and need for unprecedented co-ordination and communication between power uses and the grid, this technology has gained significant traction in several markets including the United Kingdom where the government has funded £30m in commercial projects to advance the technology.

The highest selling BEV, Nissan Leaf, is enabled for V2G. In 2016 Nissan conducted a V2G pilot with Enel with 100 vehicles. The company's vision is to bring all of its PEVs into V2G networks which would currently combined into over 200 MW of capacity. In San Francisco BMW held a trial of 100 i3 owners who provided demand response signals and were paid by the utility via BMW.

It can be seen that in the South Australian context, where wind is a major resource, being able to charge and discharge a battery given signals from SAPN could deliver grid stabilisation benefits. With the consumer profile of charging demonstrated in our trial, it would seem that there would be little consumer impact to obtain this benefit.

Infrastructure Solutions: Increase network capacity

In late 2017, OFGEM approved a £18.3 million UK Power Networks project called Active Response. The project will install LV Soft Open Points (SOP) and HV Soft Power Bridges (SPB) and associated automation and software that allow for sharing of power between feeders and substations respectively (53). SOPs and SPBs provide AC-DC-AC voltage conversion and provide a link between parts of the network with different fault currents and voltage/phases. They allow for the creation of hybrid networks that leverage the advantages of radial networks (which are better for protection schemes) and mesh concepts (which are more reliable). The project will materialise 3.5GW of peak demand and save customers £271m by 2030 across the UK unlocking the way for greater penetrations of PV and PEVs in the grid (54).

Smart Charging: Blind

Smart charging allows for the active control of the PEV charging by a utility or intermediary such as an aggregator or PEV charging provider. There are two types of smart charging – blind and paired

Blind smart charging involves actively controlling vehicle charging without use of vehicle-side data. The downside of the blind charging versus paired charging is that it lacks the input of the owner or vehicle on the state of charge or driving intentions. As such, a control event can occur but detrimentally degrade the utility of a vehicle, so support of such technology is likely to be dampened due to the lack of vehicle user control.

Smart Charging: Paired

Paired smart charging incorporates the vehicle-side data. It allows a user to guarantee charge levels and can opt out of throttling events if a car is below a certain charge level.

Pilots of this technology, such as of FleetCarma's smart charging platform in Toronto, Canada demonstrate how effective paired smart charging can be (see Figure 24 below).

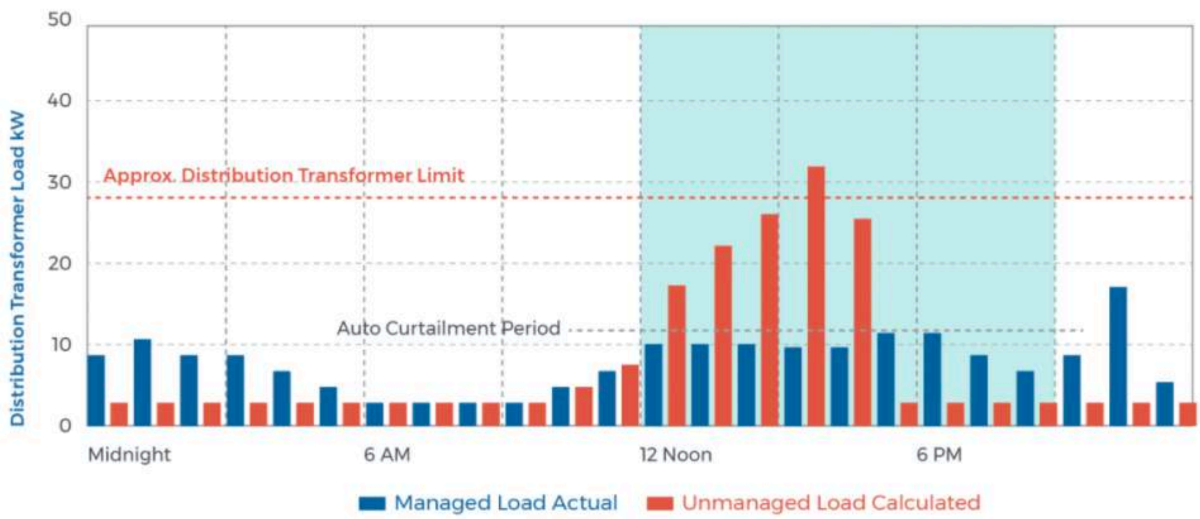


Figure 24: The results of the FleetCarma ChargeTO study - smart-charging program demonstrated the ability to reduce peak charging loads by half (55)

3.2. Control methodologies for charging infrastructure

There are three elements to consider in terms of control methodologies for charging infrastructure:

1. The commercial construct that is being managed for
2. The controller being used to manage the charging
3. The signal to the controller

Commercial construct

Price signals for incentivising behaviour can take the following form:

- Time of use tariffs
- Demand charges
- Financial or non-financial rewards derived from a market based contract

The financial or non-financial rewards typically reflect value generated in markets that standard customers (i.e. “first-tier customers”) do not have access to and need a third party (e.g. a retailer or aggregator) to act as a middle man. These include (but are not limited to):

- Wholesale market
- Frequency control ancillary service (FCAS) market
- Incentives for demand management by the Revenue Investment Tests for Distribution and Transmission (RITD and RITT)

Where a third party is involved, contracts with the users will set when, how often and how charging will be impacted. Participants of smart charging programs will have a risk reward structure they will personally manage, or have a controller provide the management on their behalf.

Controller

There are two main means of (automatically) controlling the charging:

- Control by the car. Many PEVs in the market have control devices in them which allow the user to schedule charging to avoid peak pricing events. Manufacturers of PEVs are developing more sophisticated controllers that can accept dynamic signals from the market. For example, the Nissan Leaf is now enabled with Intelligent Charging that enables its charging to be remotely controlled. (56)
- Control by a wall charging device. Smart charger devices can be used to control and modulate charging. These devices can be as simple as managing charging times, or more sophisticated with the ability to accept dynamic signals and modulate charging rather than simply switching charging on and off.

Control of the charger device (the car or the wall charger) can be performed locally by the charger or remotely by a third party with signals sent to the charging device. A control algorithm to control the charger will deliver on specific objectives as created by the commercial construct.

Signal to the controller

Signals to the controller can be of several different types:

- Time signals – an internal clock determines when charging should occur
- Load shedding – a controller can manage predetermined peak load at the point of connection and use real time monitoring of the power demand as a signal to modulate charger output.
- Grid frequency – the controller can locally monitor the frequency and adjust charging proportionality in response
- Dynamic – delivered by an aggregator or supplier for load shedding or shaving

3.3. Potential value-capture for fleets

It is important to note that managed charging can, in some cases become a positive for customers.

- Time of use managed charging can avoid charging at peak times that can be 2 or more times expensive.
- Load shaving and shedding can reduce demand charges. Typical demand charges for business connections in South Australia can be range from $0.1282 to $0.3189 per kVA per day (57). Controlling charging to avoid increasing a sites maximum demand could save up to $116 per kVA. On a Level 2, 22kW charger this would be up to $2560 per annum saved.
- Put power onto the grid to provide localised grid support. For example, a RITD program in United Energy is currently offering up to $75/kW per annum for remotely controlled demand curtailment and supply (in this case through vehicle-to-grid) for a localised part of their network where the user avoids charging in times of peak network demand.(58) This represents up to $500 per annum per vehicle (for load curtailment on a 6.6kW charger).
- Modulate charging in response to frequency demands or wholesale pool prices. For example, Reposit Power offers GridCredits for demand curtailment during times of high wholesale pool prices. These operate in much the same way as $300 caps used by retailers to hedge against peak prices in the national electricity market. Currently GridCredits are only offered by Reposit Power via Diamond Energy and they pay $1/kWh (2 – 3 times standard time of use peak prices). (59)

Box 3: Case Study – UPS

In March 2018, UPS announced it had led a consortium to deploy "radical new charging technology" in London to enable the company to charge its PEV fleet without an expensive upgrade to its connection to the grid. Off the back of the announcement, UPS plans to upgrade its fleet size at its central London site from 65 to 170 trucks.

Key to the initiative, onsite energy generation and storage allows it to generate electricity during the day to charge the fleet overnight, and intelligent charging to spread demand and avoid exceeding its grid connection capacity.

UPS has hinted at plans to roll out the technology to other sites.

Intelligently controlling charging can also avoid upgrades to connections as demonstrated in Box 3: Case Study – UPS.

3.4. Impact of PEV co-ordination with grid-scale renewable energy over-generation

South Australia is characterised by leadership in renewable energy. In March 2018 the state had 1,800 MW of wind and 900 MW of rooftop PV, with a further 1,199 MW of solar and 3,639 MW of new wind generation projects committed or proposed. The state is a global leader in rooftop solar with 37% of homes having solar installed. It has a unique grid characteristic in that solar PV causes minimum demand to shift from overnight to near midday. In addition the South Australian government has proposed two projects which will see up to 90,000 home batteries installed in coming years (41).

South Australia is the first region on the National Electricity Market (NEM) that has so much rooftop PV penetration that it shifted minimum demand from overnight to midday (20). AEMO has forecasted that there may be negative minimum demand by 2025-26, which they predicted could have operational challenges for the system.

There have been several studies which look at the benefits of PEV in a grid with wind generation. In 2016-17 South Australia had 4.342 GWh of power sourced from wind (or 39.2%) of their grid supply. One such study showed that in the context of the Netherlands the grid could cope with one million PEVs and 10GW of wind power, provided PEVs are charged using load shifting (43). Another study in Germany concluded that PEVs could be used to absorb a substantial part of unused wind power, limited only by bottlenecks in transmission network. Most of these studies emphasise the fact that at times of excess wind (generally night) and excess solar (always day) PEVs can be a grid stabilising resource if their loads can be shifted. This means controllable loads during the night and ensuring that sufficient charging occurs during the day (requiring a focus on workplace and on-street charging (44)).

Given the South Australian situation described above, SAPN could definitely benefit from this type of charging profile to improve the return on network asset investments through better utilising capacity.

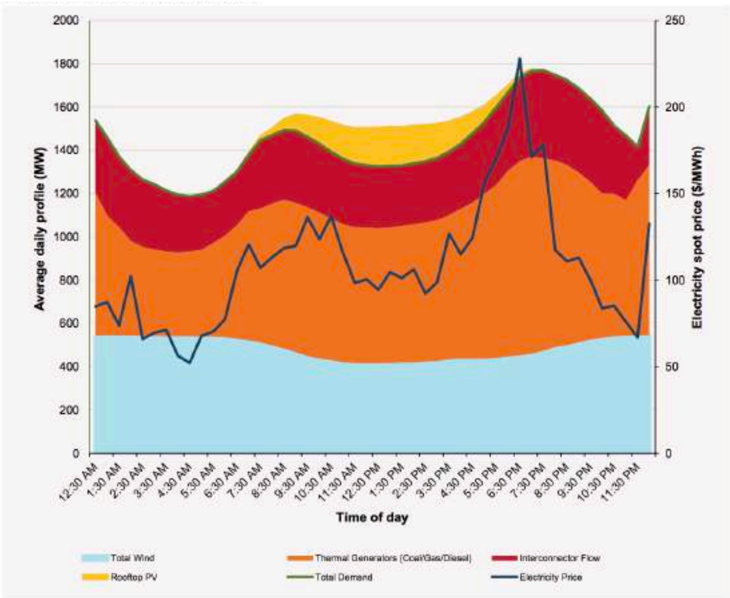


Figure 25 Average Daily Supply Profile South Australia 2017

Appendix A: Specific use cases

In Evenergi's view, the greatest risk for hotspots will occur from public carparks, highway chargers, pool vehicles, bus fleets and clusters of multiple use cases in a localised area.

The following table provides a snapshot of the potential for hotspots, solar implementation and DSR based on various charging contexts.

Universities

Description	Universities are installing their own charging infrastructure for staff workplace charging. This exists behind very substantial load (ie from heating and cooling buildings primarily) so would require significant volumes of chargers to have an impact.
Typical charger use	7-22kW
Charger utilization estimate	<20%
Potential for local renewable generation	Most universities already have strong commitments to renewable energy so the idea of local generation using solar canopies would likely appeal to them where appropriate.
DM potential	High
Hotspot risk	There is some potential over-time for upgrades to be required
Hotspot risk owner	University would meet the cost of any required upgrades
Case study example	Currently University of South Australia has only one charging station at its Mawson Lakes campus.

Shopping Centre

Description	As a means of brand differentiation and attracting shoppers, shopping centers are deploying PEV charging stations in their car parks. Spaces with PEV chargers typically have priority locations close to entrances.
Typical charger use	7-22kW
Charger utilization estimate	<20%
Potential for local renewable generation	Possible if carpark has open parking areas. Very difficult to attribute rooftop solar to charging specifically.
DM potential	Low – owners will likely want their cars charging for the period they are plugged in. There may be some potential for frequency response.
Hotspot risk	Very low – utilization of these assets is low and low power Level 2 chargers are likely to be more common. These will be behind the meter assets so shopping center owners as unlikely to install large volumes of charging equipment assets if it requires major upgrades to connection infrastructure.
Hotspot risk owner	Shopping center owner/operator
Case study example	Westfield shopping centers In 2016, BMW Group Australia and Spectre Group (that owns Westfield) partnered up to install 40 new PEV (PEV) charging stations at 10 Westfield shopping centers across NSW, Victoria and Queensland. (60)

Airport parking

Description	As a means of brand differentiation and attracting traveler, airports are deploying PEV charging stations in their car parks. Spaces with PEV chargers typically have priority locations close to entrances. While airports are similar in many ways to shopping centers, what differentiates them is the longevity of the stays by travelers versus shoppers at shopping centers.
Typical charger use	Level 1 (3.6kW) and low-power Level 2 chargers (7.4kW)
Charger utilization estimate	20-50%
Potential for local renewable generation	Possible if carpark has open parking areas. Also possible for taxi or rideshare stands given extensive wait times at many airports.
DM potential	Excellent – cars will be sitting for long periods (multiple days) with potential for demand management and in the longer-term vehicle-to-grid (V2G)
Hotspot risk	Very low – while utilization of these assets is higher than shopping centers and charger demand is likely to be on average lower. These will be behind the meter assets so airport owners will be strongly incentivized to manage the demand of these assets so they don't impact connection capacities.
Hotspot risk owner	Airports owner/operator
Case study example	Adelaide Airport (61). In December 2017, Adelaide Airport became the first airport in Australia to offer PEV charging to its customers. Four Level 2 charging stations have been installed – two for Teslas and two for remaining brands of BEVs and PHEVs. Charging is being provided for free for the first 12 months.

Public carparks

Description	As a means of brand differentiation and attracting car parkers in the city, carparks have been deploying PEV charging stations.
Typical charger use	7 -22 kW
Charger utilization estimate	20—50%
Potential for local renewable generation	Good. Either in open areas or on rooftop as it would be easier to attribute solar to charging applications.
DM potential	Depends on type of carpark. Some have longer parking durations (e.g. 8:30 – 5:30) leaving ample time to control and stage charging Others are short-stay which would be less controllable.
Hotspot risk	Moderate – car park owners will likely respond to demand of PEV owners. If PEV adoption grows as forecast, car parks will likely adopt more PEV chargers to satisfy demand. Car park owners will likely see the value of upgrading connections in the long term. Connection upgrades will be borne by the owner but sufficient demand may trigger upstream upgrades that cannot be on-charged.
Hotspot risk owner	Car park owners
Case study example	Secure Parking Australia (62). In 2015, Secure Parking became the first Australian car park owner to be part of Tesla's Destination Charging Program. Secure have made available 18 dedicated and prominent parking bays for Tesla charging between nine locations in Brisbane, Melbourne and Sydney. Tesla owners can charge for free while parking at the locations with "High Power" Wall Connectors (3 - 6kW).

Workplace charging

Description	Workplaces will offer PEV charging as a means of attracting or retaining employees or building its brand
Typical charger use	7-22kW
Charger utilization estimate	> 50%
Potential for local renewable generation	Depends on whether carpark is open and nature of operations. For major commercial buildings roof-top solar could not be attributed to car charging. In light industrial and warehousing it could be.
DM potential	Excellent – many cars will be parked all day (e.g. 8:30 – 5:30) providing sufficient time to control and stage charging. Charging times also coincide with times of the day most likely to have peak demand events. In South Australia, short commute distances would make it trivial to do demand management.
Hotspot risk	Low – workplaces are unlikely to offer workplace charging if it requires upgrading their network connection.
Hotspot risk owner	Workplaces
Case study example	See Workplace charging section in this document.

Apartment buildings

Typology	Destination charger
Description	Developers or Owners Corporations will install PEV chargers as a means of differentiating their building. Chargers will either be offered in two ways: • There will be a limited number of car park spaces that developers or OCs offer to tenants. Each space has one dedicated owner and user. Charging is separately metered and paid for by the tenant. • There are a smaller number of car park spaces with PEV chargers. These spaces are shared by a group of PEV owners. Charging is managed by a third party. This is less attractive to tenants but better for developers.
Typical charger use	Level 2 – low power (7.4kW)
Charger utilization estimate	>50%

Potential for local renewable generation	Typically very difficult to attribute
DM potential	Good – cars will be parked overnight providing sufficient time to control and stage charging.
Hotspot risk	Very low – developers will be unlikely to install an abundance of charging where it creates excessive new costs from an increased connection size. Even if increased connection sizes are required, this will be at the cost of the developer as part of their customer contribution to the network connection. Owner's corporations are unlikely to retrofit the building if it requires connection upgrades as it will require a special resolution by, and funds contribution from, all the owners which is extremely difficult.
Hotspot risk owner	Developer/Owners corporation
Case study example	Pyrmont Apartment Building (63). This relatively small building in Pyrmont currently has two Tesla Model S's with individual charging facilities. No further chargers can be connected until the connection is upgraded or "the lift will stop working".

Hotel parking

Description	Hotels install PEV chargers as a means of differentiation and attracting wealthy PEV owners.
Typical charger use	3- 22 kW
Charger utilization estimate	<20%
Potential for local renewable generation	Depends on format of hotel. If low rise hotels would be a good use case.
DM potential	Good – cars will be parked overnight providing sufficient time to control and stage charging.
Hotspot risk	Low – while hotel owners are likely to install charging equipment in large volumes in the future, it is unlikely to install extensive charging equipment until the market demands it. In the time frames being assessed, we view it unlikely hotspots will be created.
Hotspot risk owner	Developer/Owners corporation
Case study example	Tesla Destination Chargers (35). About half of Tesla's Destination Chargers in South Australia are

	located at accommodation around the state. Of these locations, 60% utilize 22kW chargers and 65% have 2 chargers (the remaining 35% just 1 charger).

Local charging

Description	Councils and/or network service providers (NSPs) install chargers adjacent to on-street parking.
Typical charger use	7 – 22 kW
Charger utilization estimate	<20%
Potential for local renewable generation	High. Many councils in Europe are exploring the opportunity to co-locate with local renewables.
DM potential	Good – cars can be parked during all hours of the day and night.
Hotspot risk	Low – new network connections will be sized appropriately. It may also be possible to use demand management to limit usage during peak times.
Hotspot risk owner	Developer/Owners corporation
Case study example	City of Adelaide. City of Adelaide has installed 19 PEV chargers between two locations – Franklin St and Central Market UPark, with another 25 charging stations planned. Adelaide city council is also providing rebates of up to $5000 for installing public PEV charging stations.

Highway charging (Single)

Description	Manufactures (e.g. Tesla), PEV charging providers, councils and/or network service providers (NSPs) install chargers at strategic locations along highways and interstate routes.
Typical charger use	DCFC
Charger utilization estimate	Likely to be low in the short term but scale quickly with BEV uptake. There are examples of existing petrol companies such as Shell providing chargers alongside traditional petrol pumps (64) or newer dedicated models such as that announced by Gridserve (65)
Potential for local renewable generation	High

DM potential	Poor users of these chargers expect fast and uninterrupted charging. Could be better if paired with local storage to provide DR.
Hotspot risk	High – new network connections will be sized appropriately however multiple charging stations on a single long feeder might result in upstream capacity issues.
Hotspot risk owner	Charger provider / network service provider

Dedicated fast charging stations

Typology	Destination charger
Description	Dedicated fast charging stations aimed at replicating the service station experience. Several service station chains in Europe, along with dedicated private players, have entered this space
Typical charger use	DCFC
Charger utilization estimate	Likely to be low in the short term but scale quickly with BEV uptake. (64)
Potential for local renewable generation	Good. Either in open areas or on rooftop as it would be easier to attribute solar to charging applications.
DM potential	Poor – service relies on speed of recharge. Could be better if paired with local storage.
Hotspot risk	High – new network connections will be sized appropriately however multiple charging stations on a single long feeder might result in upstream capacity issues.
Hotspot risk owner	Provider and Network service provider
Case study example	Shell has launched a PEV charging station network of 80 stations across Europe. They aim to have 6-8 minute charging capacity. As demand grows it would make sense to have multiple chargers in each station. (15)

Pool vehicles

Typology	Fleet vehicles
Description	Businesses, governments and NGOs have tens or hundreds of vehicles in a pool that are partially or completely upgraded to PEVs.
Typical charger use	7- 22kW
Charger utilization estimate	>50%
Potential for local renewable generation	Moderate - Depending on location of garaging but good if building is owned by organization, as is often the case with governments.
DM potential	Good – vehicles are likely parked during the day for long periods allowing for staged charging
Hotspot risk	High – new network connections will be sized appropriately, however upstream capacity issues might arise if a large number of PEV chargers are installed.
Hotspot risk owner	Fleet owner/operator & network service provider
Case study example	Australia Post Delivery vehicles (66). In 2014, Australia Post introduced 4 Renault Kangoo ZEs to its fleet – 2 each for Australia Post's Port Melbourne Business Hub and StarTrack House in Sydney - as part of a 12-month proof of concept. Charging facilities at the depots were powered with certified GreenPower and part funded by the Victorian Government Department of Transport. As far as New Energy Ventures and Evenergi are aware, the trial has not yet catalyzed further purchases.

Taxi Fleets

Typology	Fleet vehicles
Description	Taxi fleets partially or completely upgraded to PEV. This is a future use case as currently there are no examples PEV taxi fleets in Australia. Cars return to strategically placed depots around the city to recharge.
Typical charger use	DCFC
Charger utilization estimate	>50%

Potential for local renewable generation	Mid – opportunity for depot to be located so as to allow for solar charging.
DM potential	Very poor – users of these chargers expect fast and uninterrupted charging to ensure minimal downtime of taxis
Hotspot risk	Moderate – new network connections for the fleet chargers will be sized appropriately, however upstream capacity issues might arise if a large number of PEV chargers are installed. Given the limited number of examples of this use case globally, while hotspots are likely if this use case was to occur we believe it is unlikely that this use case will eventuate by 2025.
Hotspot risk owner	Fleet owner/operator & network service provider
Case study example	London PEV Company (LEVC) (67). In collaboration with Transport for London (TfL), LEVC have launched the TX eCity London Taxi, a PEV with a ranger extender with a 120km electric range and a 650km combined range. To support the rollout, TfL rolled out 100 fifty kilowatt rapid chargers, 51 of which are dedicated for use by LEVC. The chargers can provide an 80% charge in 25 minutes.

Ride Sharing Fleets

Typology	Fleet vehicles
Description	Ride sharing fleets like Go Get upgrade their fleets to PEV.
Typical charger use	Level 2 low to mid-sized chargers (7.4 - 11kW)
Charger utilization estimate	>50%
Potential for local renewable generation	Mid/Low – most would be located on street or in parking lots without additional space for solar
DM potential	Poor – charging will need to be uninterrupted to avoid downtime with vehicles
Hotspot risk	Low – new network connections for the fleet chargers will be sized appropriately however upstream capacity issues might arise if a large number of PEV chargers are installed in a small area. That said, ride sharing trips tend to be short and local (e.g. runs to the supermarket) therefore instances of charging will be shorter and more frequent than other use case examples
Hotspot risk owner	Fleet owner/operator & network service provider

Case study example	MEVO electric car ride sharing (68) NZ ride sharing company MEVO has a fleet of 10 Audi A3 e-Tron PHEVs that have a 40km electric only range. MEVO currently only operates in Wellington but has publicly expressed interest in expanding to five Australian cities with up to 2000 cars on the road (69). Fleet users can pick up and end their ride anywhere within a relatively localized Home Zone covering Wellingtons CBD. MEVO has 21 dedicated spaces that guarantee a park and that have charging facilities.

Car sharing Fleets

Typology	Fleet vehicles
Description	Fleet providers for Uber drivers (rent and drive schemes) convert to PEV. As part of the package, fleet operators provide charging locations.
Typical charger use	DCFC
Charger utilization estimate	>50%
Potential for local renewable generation	Mid – would depend on drivers' situation at home.
DM potential	Very poor – users of these chargers expect fast and uninterrupted charging to ensure minimal downtime of the fleet
Hotspot risk	Moderate – new network connections for the fleet chargers will be sized appropriately, however upstream capacity issues might arise if a large number of PEV chargers are installed.
Hotspot risk owner	Fleet owner/operator & network service provider
Case study example	Uber PEV Program (70; 71) Starting in 2016, Uber has been progressively offering PEV leasing to drivers in London, Madrid and Portland, Oregano. In London, drivers can flexibly lease a Nissan Leaf, Hyundai Ioniq or Kia Soul from £99/week or rent a vehicle from £160/week. Uber is installing a network of Rapid Chargers around London to support the initiative and already has 8 installed at London's major airports that can be used without losing a place in the queue at the airport taxi rank.

Bus Fleets

Typology	Fleet vehicles
Description	Bus fleets partially or completely convert to PEV. Bus return to strategically placed depots around the city to recharge.
Typical charger use	DCFC
Charger utilization estimate	>50%
Potential for local renewable generation	Mid/High – depots should be light industrial with ability for solar.
DM potential	Average – users of these chargers expect fast and uninterrupted charging to ensure minimal downtime of the fleet. However, scope exists to schedule charging and optimize bus routes to avoid charging during peak times.
Hotspot risk	Medium to High – new network connections for the fleet chargers will be sized appropriately, however upstream capacity issues might arise if a large number of PEV chargers are installed. The current South Australian Liberal Government has a policy to conduct "an investigation into the use of high capacity electric buses and a more efficient city-center bus interchange network". This policy may ultimately result in electric buses being deployed by 2025. (72)
Hotspot risk owner	Fleet owner/operator & network service provider
Case study example	London bus fleet and Waterloo Bus Depot (73) In an attempt to address air and carbon pollution, the Mayor of London and Transport for London have upgraded 51 buses to electric buses. The bus depot to be used for charging the buses - the Waterloo garage - initially assumed it would require a network upgrade with sufficient power available to charge all the buses. Due to capacity constraints in the local high voltage network, UK Power Networks was unable to provide an upgraded connection for at least nine months until a reinforcement project had been undertaken. UK Power Networks implemented a timed demand connection, allowing the customer to draw the required 2.5MW in the off peak and 0.5MW during the day for charging a smaller number of standby buses and topping up buses between routes. This approach postponed the need for a connection upgrade at the site.

Clusters of local and destination chargers

Typology	Cluster of local, fleet and destination chargers
Description	Tens to hundreds of chargers are installed in a localized area that is not centrally controlled to manage charging. As an example of this, multiple work places and car parks could install destination charging in a business district (e.g. Adelaide CBD). Individual connections to the network would not exceed their capacity, but in aggregate, charging may create hotspots in feeders and zone-substations.
Typical charger use	All types
Charger utilization estimate	N/A
Potential for local renewable generation	Low – no clear site owner
DM potential	Poor – a centralized management system would be difficult and costly to implement.
Hotspot risk	Moderate to high – the risk is dependent on the prevalence of both PEVs and destination chargers.
Hotspot risk owner	Network service providers
Case study example	N/A

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