Ultra-Fast Charging Data Analysis – Webinar Materials

ARENA

5 August 2021

ENERGEIA

Table of Contents

ENERGEIA

Executive Summary

Investment and Operational Costs

Charging Patterns and Behaviour

Electricity System Impacts

ENERGEIA

Key Findings and Conclusions

- **Costs – Significant cost reductions with experience and larger configurations possible**
  - Lower capex and opex for larger (6 and 8 hose) sites compared to 4 hose sites on a per hose basis, economies of scale achievable in all key cost categories
  - 50-55% variation between most expensive to least expensive 4-hose mainly due to local requirements eg. site configuration, existing infrastructure, Geotech and remediation can impact costs
  - Cost differences between urban and regional charging sites partially explainable by average size/capacity of site
  - Data shows that higher utilisation decreases electricity running costs on a $/kWh basis

- **Charging – Pattern complements solar PV generation, likely to reduce operating costs with onsite solar PV**
  - Utilisation was impacted by 2020 COVID lockdowns, but appears to recovered when lockdowns lift
  - Charging pattern constant by day type and correlates well with solar PV generation profile
  - Average charging duration around 20 mins, i.e. the 80% full level
  - Regional sites about 30% more utilised than urban sites presently, but majority of EV drivers are from urban areas
  - EV uptake is currently low, so observed utilisation patterns are not necessarily stable in the long-run

- **Electricity System Impacts – Potentially significant grid impacts, onsite storage may be beneficial**
  - Site peak demand is between 100% and 41% of demand during the network peak, average is around 60%
  - Public EV charging patterns could provide a solution to min demand caused by solar PV

ENERGEIA

Background

Key Industry Questions

ARENA's EV Programs

ARENA's EV Knowledge Sharing Workstream

ENERGEIA

ARENA's EV Projects Included in this Insight

Year	Project	Funding	State	Lead Organisation	Summary
2018	Chargefox Electric Vehicle Charging Network Project	$6m	NSW, QLD, SA, VIC, WA	ChargeFox	This project enables the construction of a network of 21 ultra-rapid charging stations to reduce barries for consumer uptake of EVs
2019	National Ultrafast EV Charging Infrastructure Network	$15m	National	Evie Networks	This project enables the development and construction of a network of 42 ultra-fast charging sites nationally to reduce barriers for EV uptake

- ARENA has funded a wide range of EV projects to support the uptake of renewable energy
- Data from the above projects have fed into this analysis

ENERGEIA

Key Industry Questions about DC Fast Charging

The analysis for this Knowledge Sharing Insight has been designed to address the key questions facing the industry

Investment and Operational Costs	Charging Activity	Electricity Grid Impact
• How much does it cost to build and operate a public charging station? • How do these costs vary by location, configuration or over time? • How do different tariffs impact on electricity costs? • Can solar PV and storage by used to reduce costs overall?	• What is the daily profile of charging activity, and does it vary by day type, month, or location? • How long do vehicles typically charge for? • How fast is station utilisation growing over time?	• How much will fast charging stations contribute to grid peak demand? • What is the load factor of a fast charging station? • What is the average charging profile and how does it vary by power? • How diversified is charging station demand?

Preliminary Insights

Public Charging Costs

ENERGEIA

Table of Charger Locations and Configurations

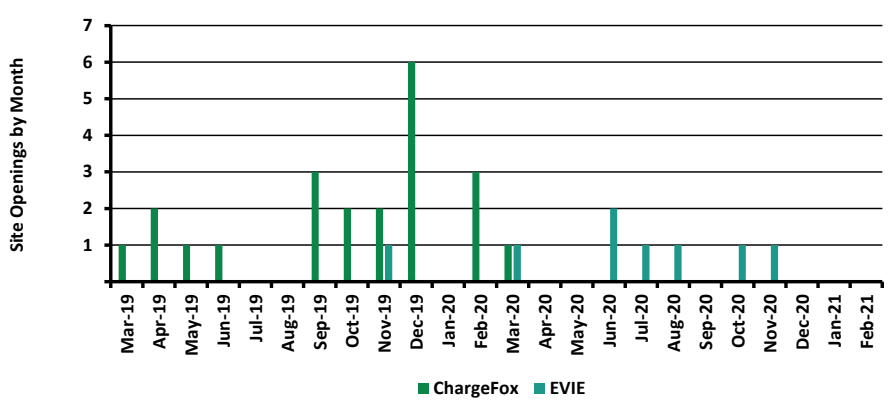
Summary Table of Charging Sites

Provider	Location	State	Power per Site kW	No of 350kW Charging Stations	No of 50kW Charging Stations	No of CC2 Hoses	No of CHAdeMO Hoses
ChargeFox	Brisbane	QLD	750	2	1	3	1
ChargeFox	Ballina	NSW	750	2	1	3	1
ChargeFox	Coffs Harbour	NSW	700	2	0	2	2
ChargeFox	Port Macquarie	NSW	700	2	0	2	2
ChargeFox	Karuah	NSW	750	2	1	3	1
ChargeFox	Sydney	NSW	700	2	0	3	1
ChargeFox	Shell Cove	NSW	750	2	1	2	2
ChargeFox	Goulburn	NSW	750	2	1	3	3
ChargeFox	Gundagai	NSW	750	2	1	3	1
ChargeFox	Cooma	NSW	700	2	0	3	1
ChargeFox	Barnawartha North	VIC	800	2	2	4	4
ChargeFox	Euroa	VIC	800	2	2	4	4
ChargeFox	Melbourne	VIC	1500	4	2	6	2
ChargeFox	Latrobe Valley	VIC	800	2	2	4	2
ChargeFox	Torquay	VIC	800	2	2	4	4
ChargeFox	Ballarat	VIC	800	2	2	4	4
ChargeFox	Horsham	VIC	800	2	2	4	4
ChargeFox	Keith	SA	700	2	0	3	3
ChargeFox	Adelaide	SA	700	2	0	2	2
ChargeFox	Perth	WA	700	2	0	2	2
ChargeFox	Bunbury	WA	700	2	0	2	2
ChargeFox	Launceston	TAS	700	2	0	2	2
EVIE	Campbell Town	QLD	700	2	0	2	2
EVIE	Cluden	QLD	700	2	0	2	2
EVIE	Coochin Creek	QLD	700	2	0	2	2
EVIE	Glenthorne	NSW	700	2	0	2	2
EVIE	Macksville	NSW	700	2	0	2	2
EVIE	Seven Hills	NSW	700	2	0	2	2
EVIE	Tarcutta	NSW	700	2	0	2	2
EVIE	Avenel	VIC	700	2	0	2	2
EVIE	Mulgrave	VIC	700	2	0	2	2
EVIE	Tailem Bend	SA	700	2	0	2	2
EVIE	Brighton	TAS	700	2	0	2	2
EVIE	Campbell Town	TAS	700	2	0	2	2

Source: ChargeFox and Evie, Note EVIE Stations per site estimated from plugshare

- Evie has rolled out a standard charging site model of 2 350 kW chargers
- Chargefox has incorporated 50 kW chargers into their network, as well as 350 kW chargers

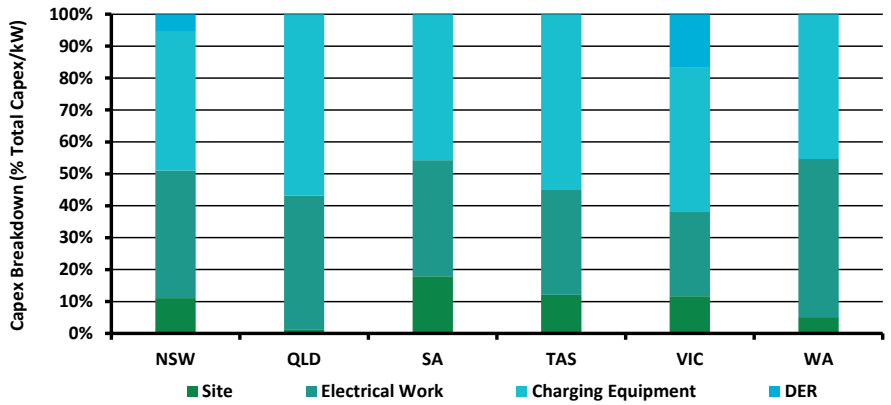
Site Openings to Feb 21



Source: ChargeFox and Evie, Note: Opening date of Evie sites not available. First available bill date used as an approximation

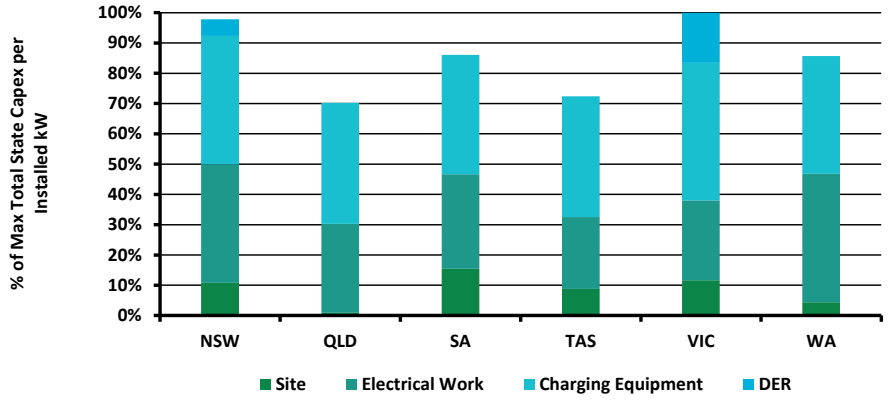
Investment Cost Breakdown by State and Driver (1 of 2)

Capex per Installed kW as Percentage of Total



Source: ChargeFox, Note: DER capex includes solar and battery

Capex Costs vs. Highest Cost State

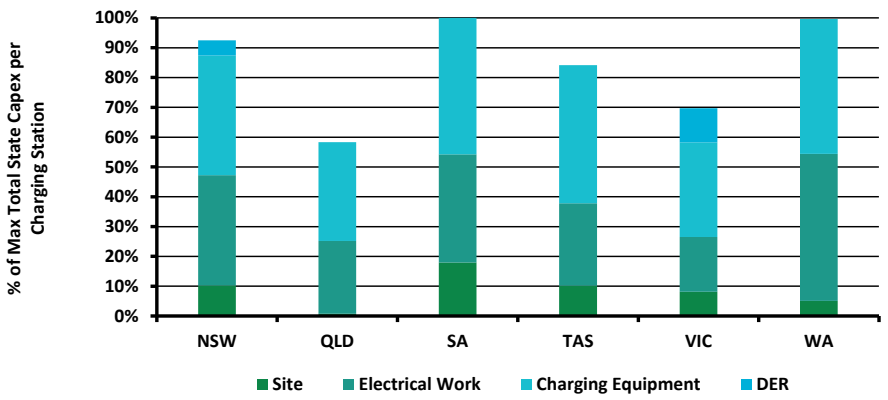


Source: ChargeFox

- Charging equipment cost is roughly equal across states
- The site and electrical works required are the main determinant of cost – but cost categorisation can vary between sites
- It should be noted that only NSW and VIC had cost data for more than 2 sites, so sample is likely to be biased and more data is required to provide robust insights

Investment Cost Breakdown by State and Driver (2 of 2)

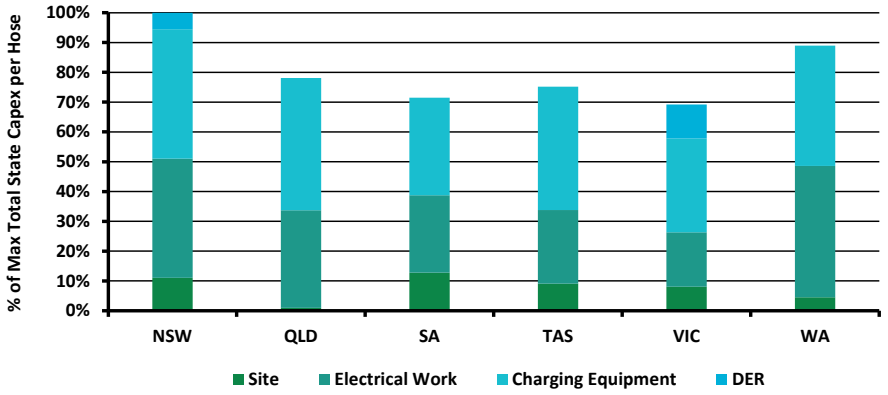
Capex per Charging Station vs. Highest Cost State



Source: ChargeFox, Note: DER capex includes solar and battery

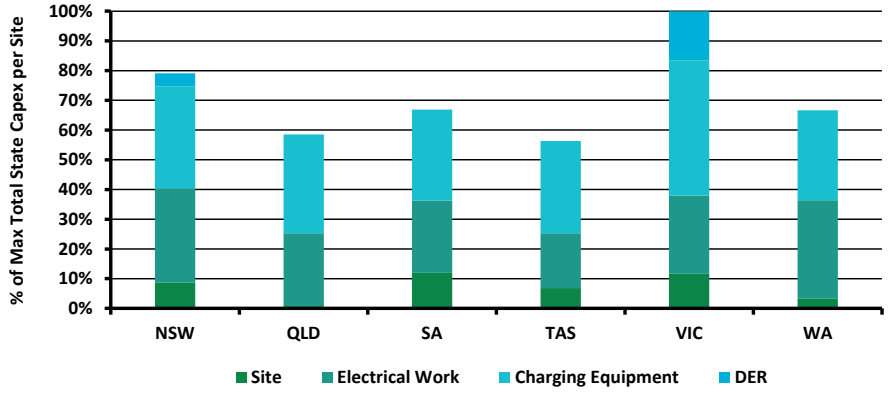
- Cost metrics move around considerable depending on the underlying normalising factor, due to differences in configuration, e.g.
  - Max power per station (more is more)
  - Average power per site (more is more)
  - Number of hoses per site (more is less)

Capex per Hose vs. Highest Cost State



Source: ChargeFox, Note: DER capex includes solar and battery

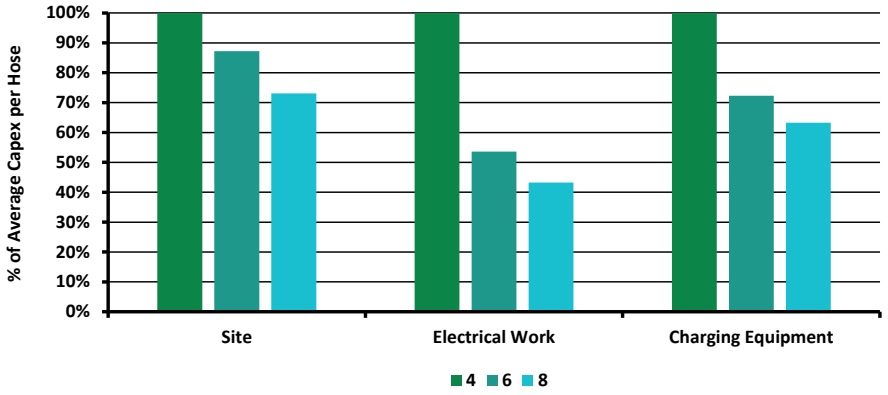
Capex per Site vs. Highest Cost State



Source: ChargeFox, Note: DER capex includes solar and battery

Investment Cost Breakdown by Component

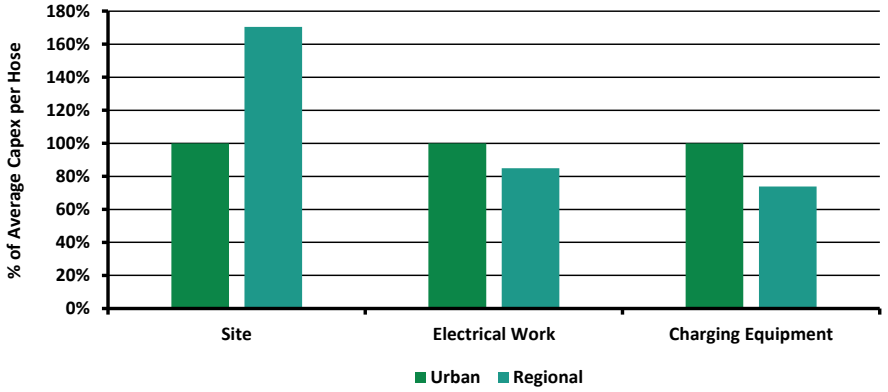
Establishment Capex % by Number of Hoses vs. 4 Hose Site



Source: ChargeFox, Note: Legend denote number of hoses per site

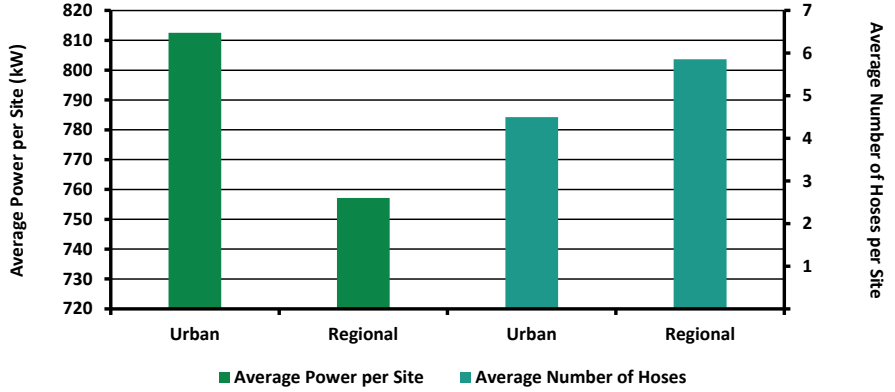
- Charger equipment and installation capital expenditure (capex) represents the largest upfront factor per site
- Data shows a decreasing marginal additional cost for additional hoses, suggesting a significant economies of scale opportunity
- The upstream network costs are also quite significant, as is the installation of any solar PV or storage resources on site
- Urban sites have generally installed fewer hoses per station than the regional sites, resulting in higher electrical and equipment cost per hose compared to the larger regional sites
- Regional locations have greater site costs, correlating with the larger site size

Establishment Capex % by Location vs. Urban



Source: ChargeFox

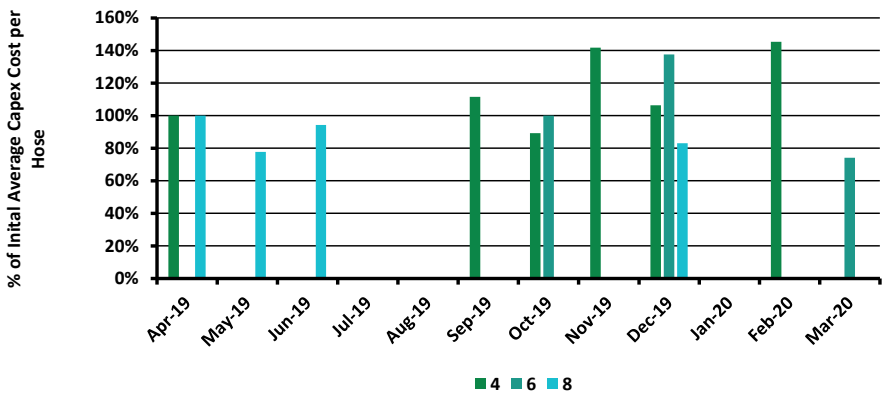
Average Hoses per Site by Location



Source: ChargeFox

Investment Cost Learning Over Time

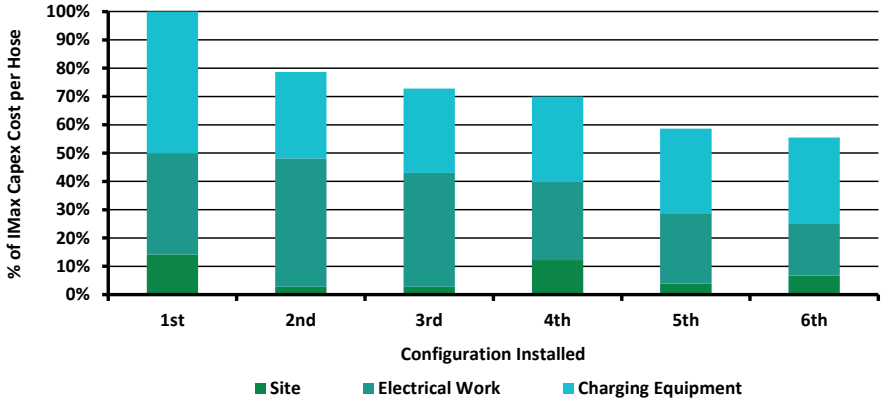
Avg. Establishment Capex by Number of Hoses Over Time



Source: ChargeFox, Note: Legend denote number of hoses per site

- Chargefox generally opted for smaller sites, potentially to enable a larger network, despite higher costs
- Interestingly, the 4-plug site costs does not seem to reduce over time

Most Popular Configuration Cost Variation (4 Plugs)



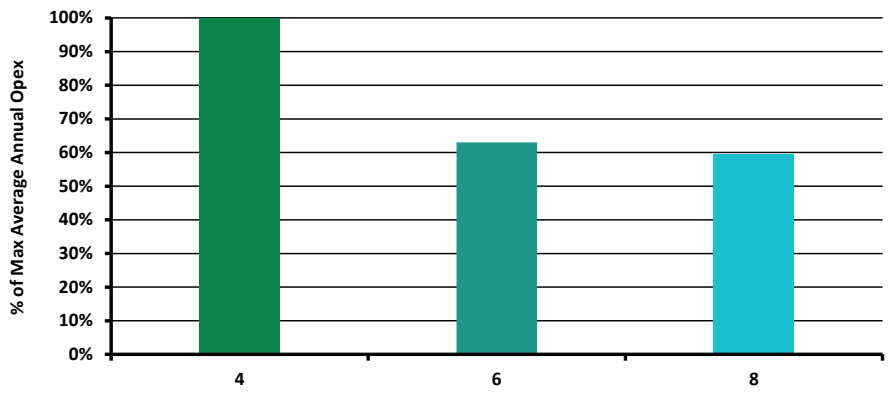
Source: ChargeFox. Note: Site configuration of 2x 350kW charging stations with 2x CC2 plugs and 2x CHAdeMO plugs

- In-depth analysis of the most common 2 charger, 4 hose configuration found costs could vary by almost 50%
- As these are basically the same type of charging site, the analysis suggests significant savings are possible
- It will be key to analyse and account for the variations to maximise industry learning

ENERGEIA

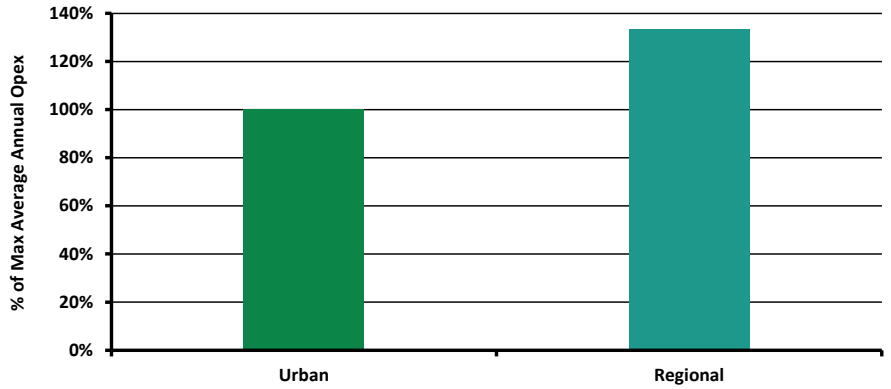
Running Cost Breakdown

Normalised $/kW Opex by No. Hoses



Source: ChargeFox Operating Data, Note: Normalised on a site kW installed basis

Normalised $/kW Opex by Density vs. Urban

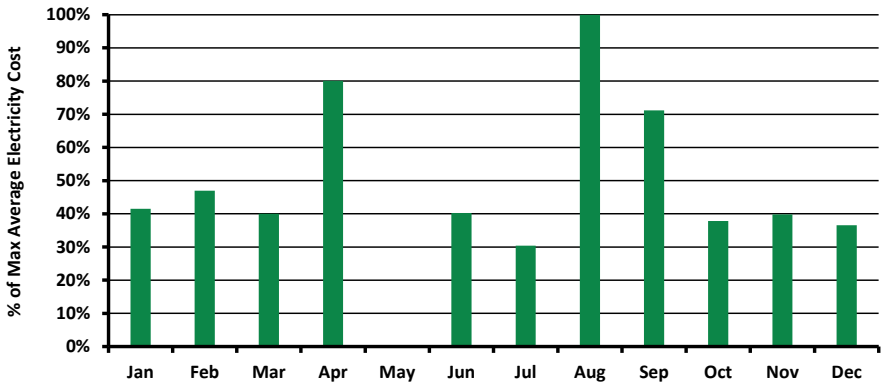


Source: ChargeFox Operating Data, Note: Normalised on a site kW installed basis

- Similar to capex, opex costs are also reduced on a per hose basis due to economies of scale
- Regional charging stations had a higher maintenance cost than urban on average and after accounting for size

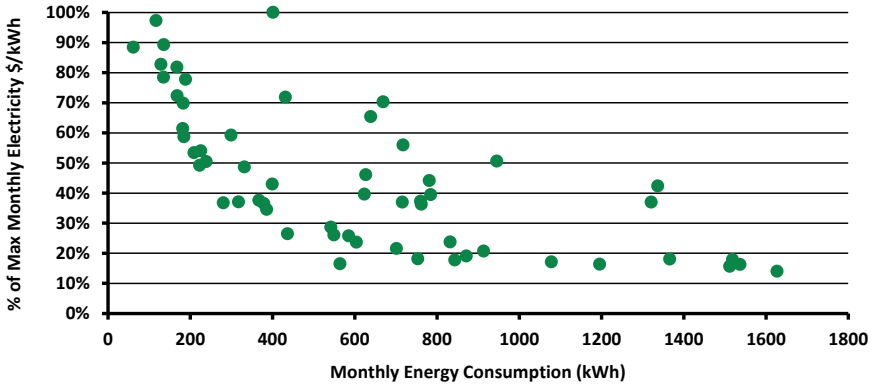
Site Energy Cost Breakdown

Variation of Avg. Energy $/kWh per Month



Source: Evie Networks, Note: Where bill and consumption values were available and able to be averaged

Monthly Site Electricity $/kWh by Energy Consumption



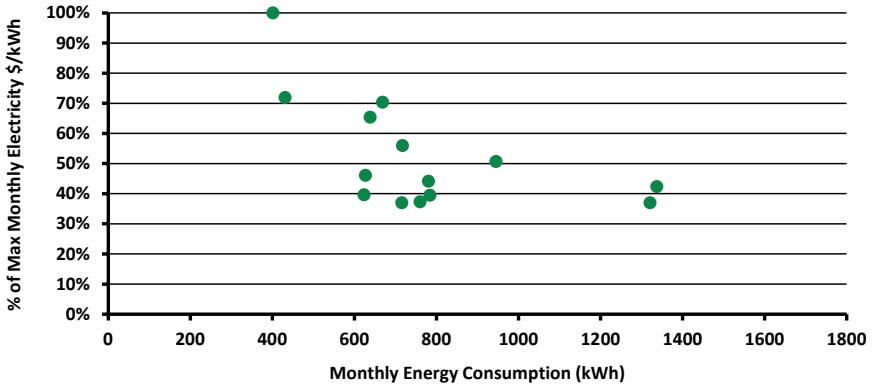
Source: Evie Networks

- Utilisation is the key for keeping net running costs low
- Results are currently distorted by timing of sites going live changing the mix of bills
- Energy costs are likely to flatten on a per kWh basis in the future as EV uptake increases
- Analysis shows that cost per kWh falls on average with higher kWhs per site per month

ENERGEIA

Site Energy Cost Breakdown – By Tariff

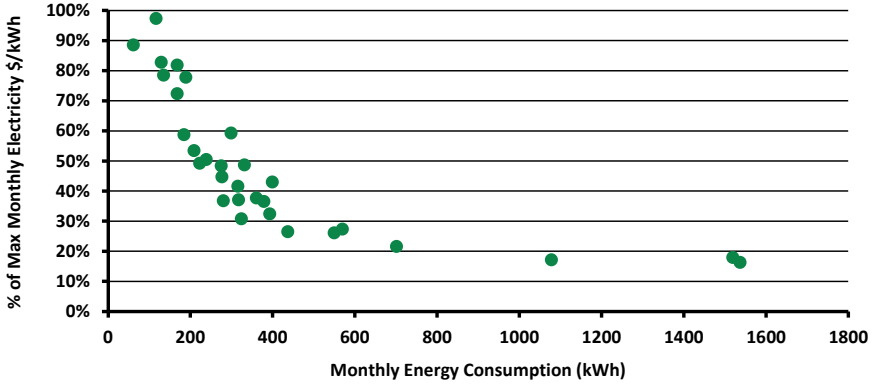
MD Tariff - Electricity $/kWh by Energy Consumption



Source: Evie Networks

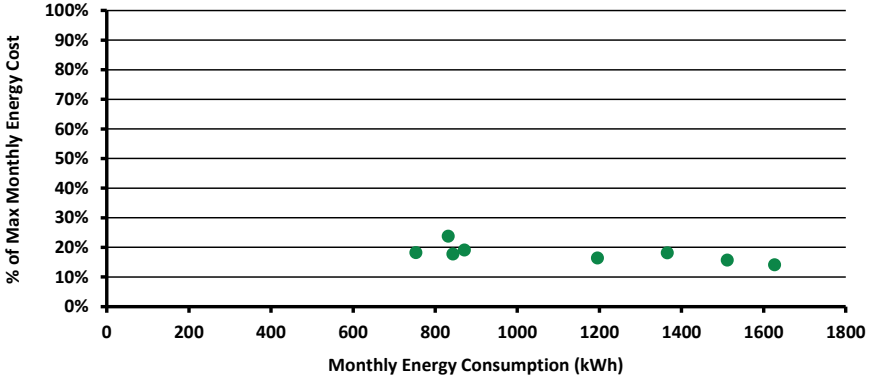
- MD costs are generally lower per kWh as consumption rises, but higher than other tariffs for the same monthly energy consumption
- ToU bills are higher on a per kWh basis than the flat bills, however costs appear converge at higher kWhs
- Flat $/kWh lowest of all
  - This may reflect differences in distribution network cost structures between those offering flat vs. those offering ToU or MD rates

ToU Tariff - Electricity $/kWh by Energy Consumption



Source: Evie Networks

Flat/BT Tariff - $/kWh by Energy Consumption



Source: Evie Networks

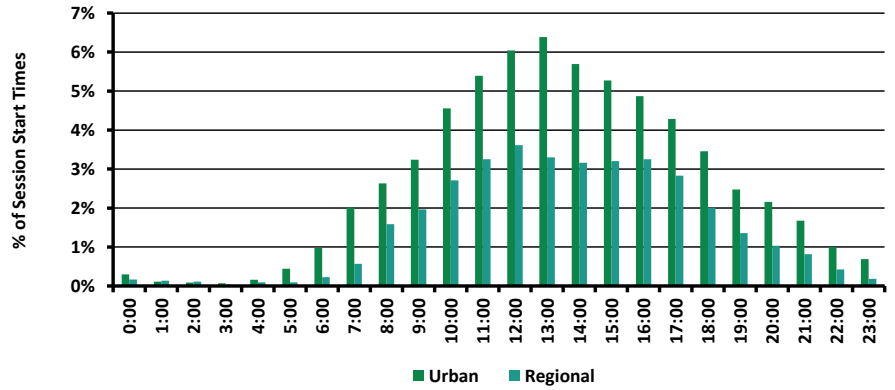
Preliminary Insights

Public Charging Activity

ENERGEIA

Site Usage by Driver Residence

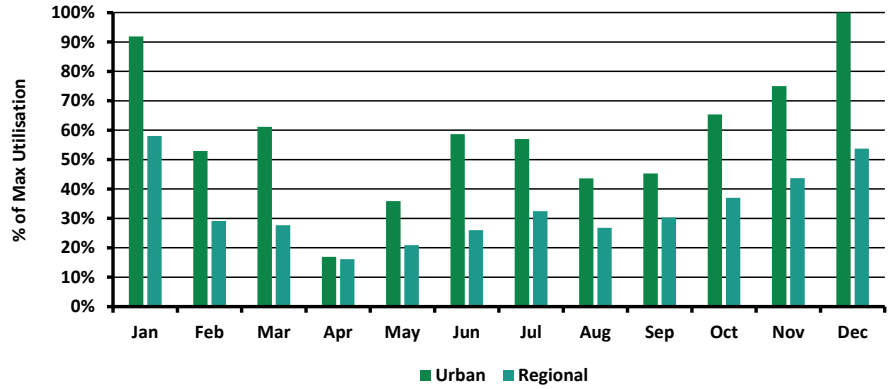
User Frequency by Time of Day and Driver Residence



Source: ChargeFox, Energeia

- The hourly load shape is very different to those in the public domain, which more frequently reflect commute times rather than business hours
- However, utilisation is generally too low at this stage of EV uptake to form definitive insights about the time and date of use preference

User Frequency by Driver Residence and Month of Year



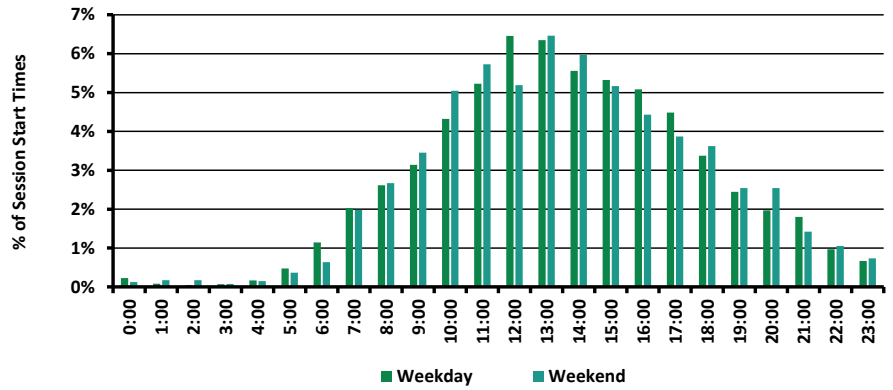
Source: ChargeFox, Energeia

- Public charger usage appears to be dominated by urban drivers, reflective of current EV uptake demographics
- Urban and regional drivers utilised public charging most in the summer holiday months (Dec-Jan)

ENERGEIA

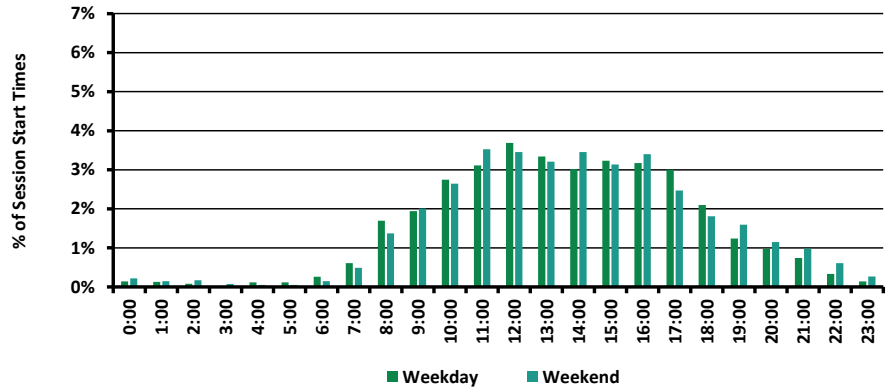
Site Usage by Driver Residence

User Frequency by Day Type for Urban Drivers



Source: ChargeFox, Energeia, Note: Where driver location data was available

User Frequency by Day Type for Regional Drivers



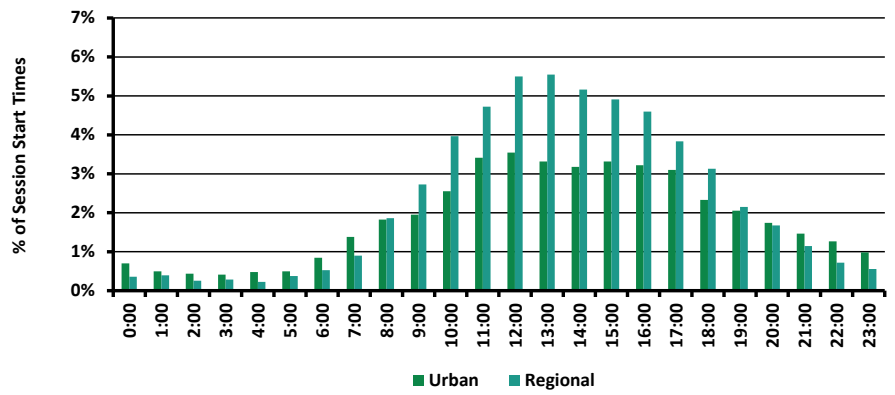
Source: ChargeFox, Energeia, Note: Where driver location data was available

- Data suggests that both urban and regional drivers use public charging most in the middle of the day, closely resembling a PV load shape
- Very interesting that there is almost no different between weekday and weekend charging

ENERGEIA

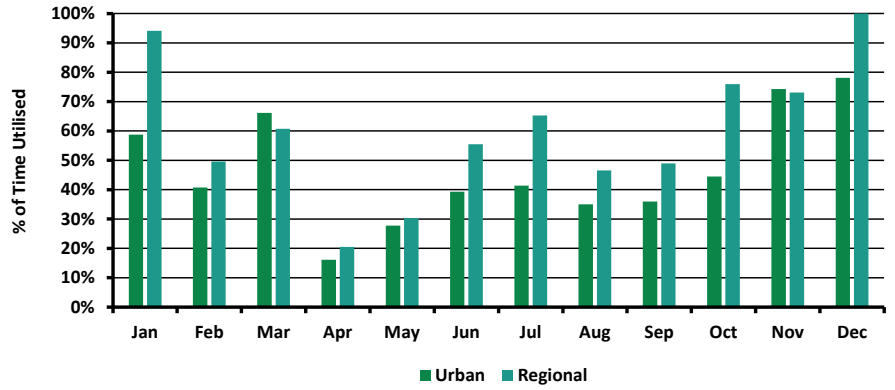
Site Usage by Site Location

User Frequency by Time of Day and Site Location



Source: ChargeFox, Evie, Energeia

User Frequency by Site Location and Month of Year



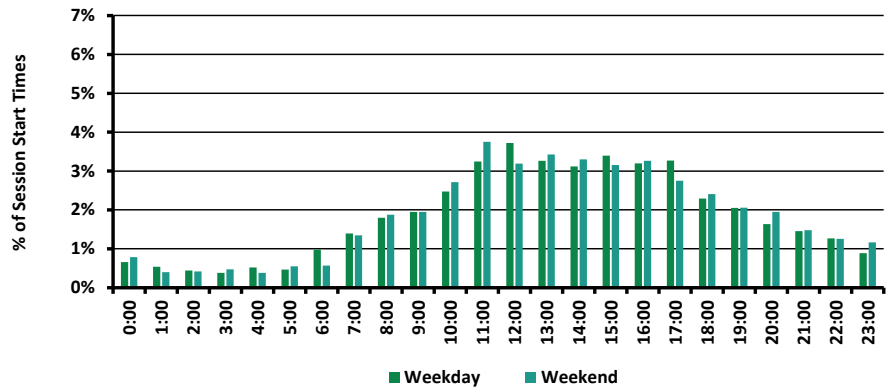
Source: ChargeFox, Evie, Energeia

- Though the favouring of regional charging sites is likely to be a reflection of the regional-dominant sample of charging station data received, the urban EV drivers do appear to be leaving the cities to use them
- It may also reflect the need for public charging to service long-haul driving, with urban residents able to charge at home when driving more locally

ENERGEIA

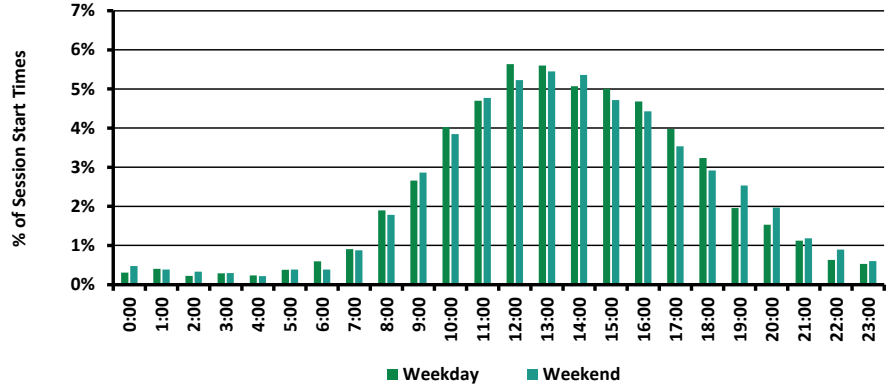
Site Usage by Site Location

User Frequency by Day Type for Urban Sites



Source: ChargeFox, Evie, Energeia

User Frequency by Day Type for Regional Sites



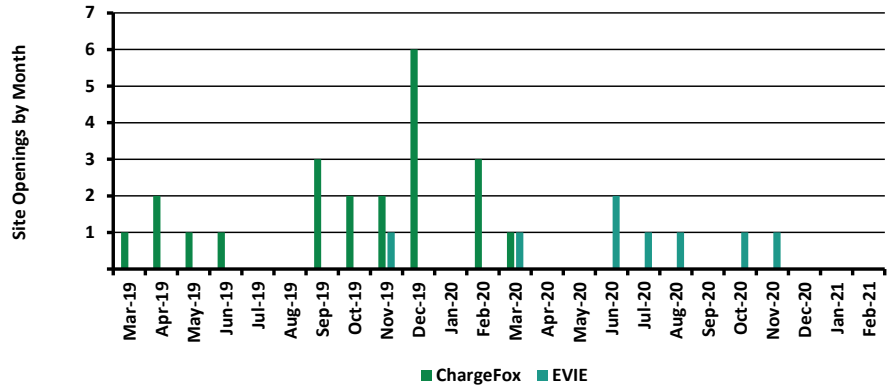
Source: ChargeFox, Evie, Energeia

- The urban charging station usage appears to be fairly spread out through the day, with charger usage remaining strong throughout the afternoon and early evening
- Regional charging stations are utilised much more during daylight hours

ENERGEIA

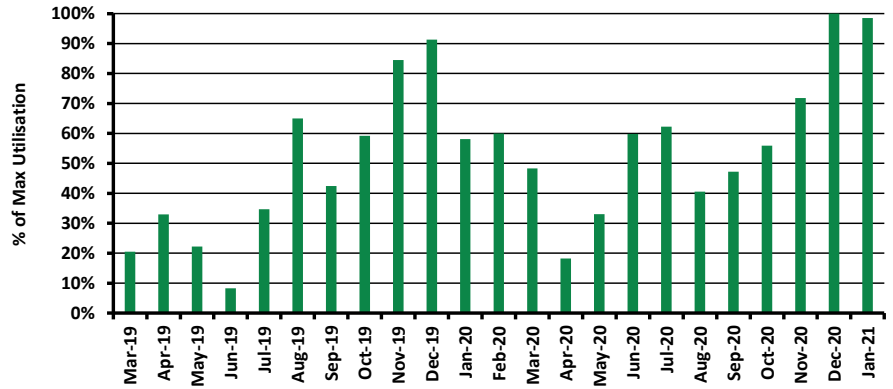
Site Usage Over Time

Site Openings



Source: ChargeFox and EVIE, Note: X-axis denotes cumulative months of operation by site

User Frequency Over Time

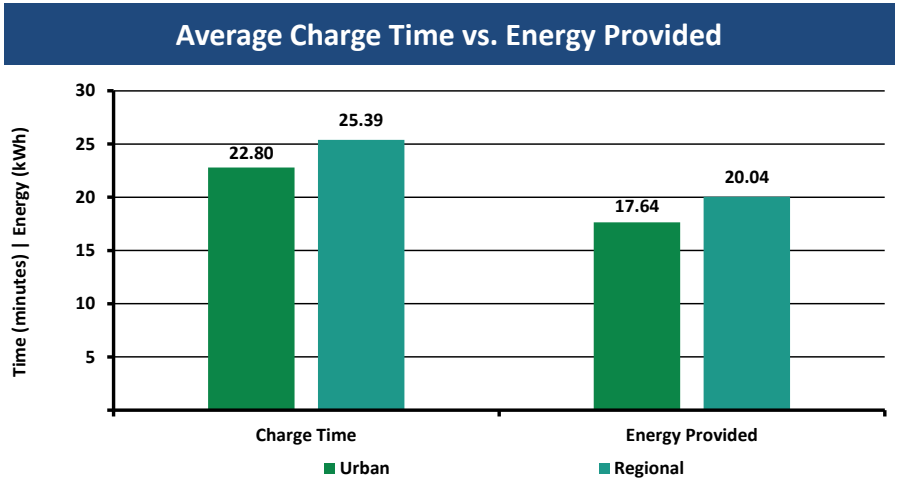


Source: ChargeFox and Evie, Note: Opening date of Evie sites not available. First available bill date used as an approximation

- Utilisation increases to 2x pre-2020 COVID lockdown levels by early 2021
- Utilisation at the system level is increasing over time, mainly in last 3 observed months
- Utilisation at the site level is increasing overall over time
- High utilisation for first Evie charging install potentially due to promotional free charging during the first month of opening and siting on a major highway

ENERGEIA

Session Duration Breakdown



Source: ChargeFox, Evie

- Regional charging sessions lasted longer on average and delivered more energy
- Drivers typically don't leave their EVs in the charging spot for much longer than they need to

ENERGEIA

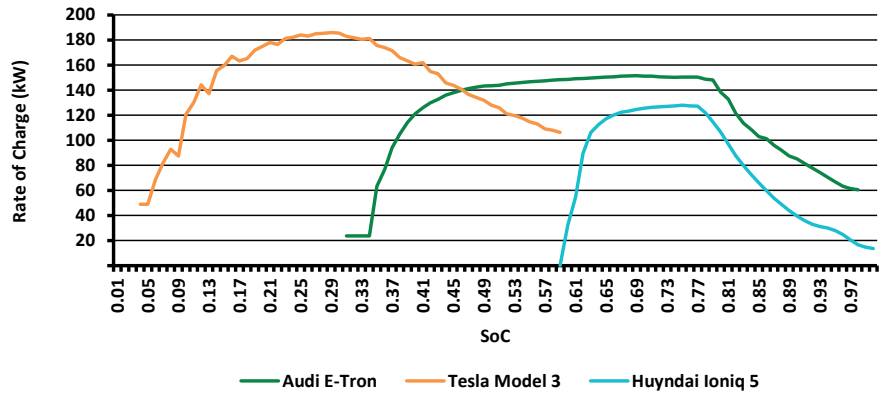
Preliminary Insights

Public Charging Electricity Infrastructure Impacts

ENERGEIA

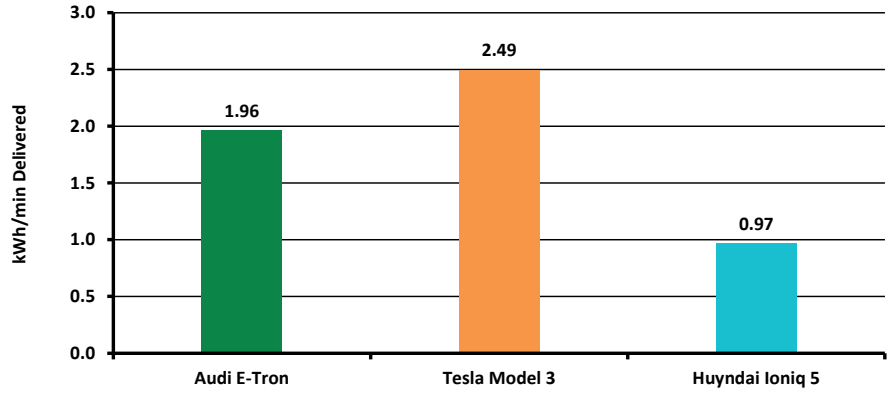
Power Curve Analysis

Power Delivered Curves by Vehicle Model



Source: ChargeFox, Energeia, Note: Each model started at a different SoC

Average Energy Delivered per Minute

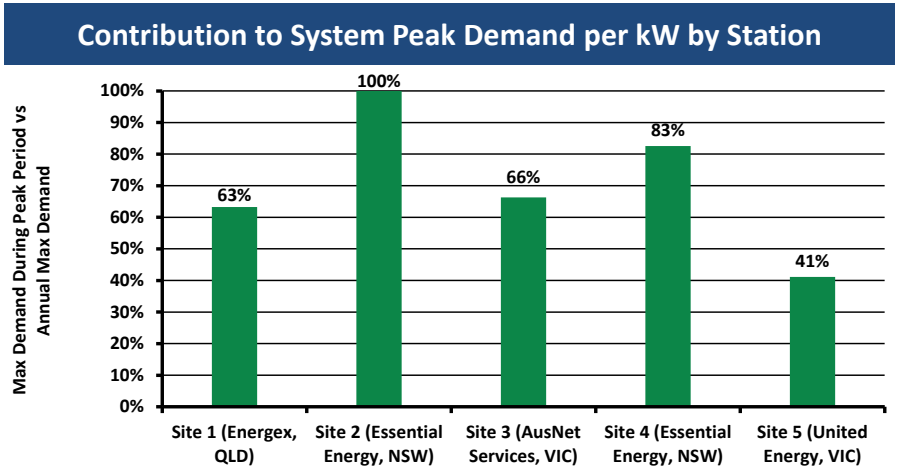


Source: ChargeFox, Energeia

- Charging ramps up rapidly, then tails off as session nears conclusion
- Charging power and speed is a reflection of the EV's battery state of charge and health and the max power input the vehicle's system can handle

ENERGEIA

Electricity System Impacts



Source: Evie Meter Data

- Public charging has the potential to drive significant upstream network upgrades if not managed correctly
- 1 out of the 5 stations observed peaked during the peak network time, assumed to be 3-9pm on summer weeknights as a simplification

ENERGEIA

Load and PV Congestion Timing (Illustration)

% of ZS >= 90% of Peak Demand by Period (Ausgrid)

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
0:00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.56%	0.00%	0.00%	0.00%
1:00	0.00%	0.00%	0.56%	0.00%	0.00%	0.56%	0.00%	0.00%	0.56%	0.00%	0.00%	0.00%
2:00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.56%	0.00%	0.00%	0.00%
3:00	0.00%	0.00%	0.56%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4:00	0.00%	0.00%	0.56%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5:00	0.00%	0.00%	0.56%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
6:00	0.00%	0.00%	0.56%	0.00%	0.00%	0.00%	0.00%	0.00%	0.56%	0.00%	0.00%	0.00%
7:00	0.00%	0.00%	0.00%	0.00%	0.00%	0.56%	0.00%	0.00%	1.13%	0.00%	0.00%	0.56%
8:00	1.69%	1.69%	0.00%	0.00%	0.00%	0.56%	0.00%	0.56%	1.13%	0.00%	0.56%	3.95%
9:00	2.82%	1.13%	0.00%	0.00%	0.00%	1.69%	14.12%	6.21%	1.13%	0.00%	0.56%	4.52%
10:00	2.26%	1.13%	0.00%	0.00%	0.56%	4.52%	26.55%	14.12%	0.56%	0.00%	0.00%	2.82%
11:00	1.69%	1.13%	0.56%	0.00%	1.69%	6.21%	32.77%	16.95%	1.13%	0.00%	0.00%	2.82%
12:00	0.56%	1.13%	0.56%	0.00%	2.26%	8.47%	38.42%	25.99%	1.69%	0.00%	0.00%	2.26%
13:00	0.56%	0.56%	0.56%	0.00%	2.82%	8.47%	44.63%	32.77%	4.52%	0.00%	0.56%	2.26%
14:00	0.56%	0.56%	0.00%	0.00%	2.26%	11.30%	52.54%	37.85%	6.21%	0.00%	0.56%	1.69%
15:00	0.56%	0.56%	0.00%	0.00%	1.69%	9.04%	51.98%	47.46%	5.65%	0.00%	0.00%	1.13%
16:00	0.56%	0.56%	0.00%	0.00%	1.13%	10.73%	54.24%	55.37%	3.39%	0.00%	0.00%	1.69%
17:00	1.69%	0.56%	0.00%	0.00%	0.00%	6.21%	51.41%	68.93%	1.69%	0.00%	0.00%	7.34%
18:00	11.86%	4.52%	0.00%	0.00%	0.56%	5.65%	47.46%	58.76%	0.56%	0.00%	1.69%	23.16%
19:00	18.64%	5.65%	0.56%	0.00%	0.00%	3.39%	40.11%	48.02%	0.56%	0.00%	1.69%	23.73%
20:00	10.73%	1.69%	0.56%	0.00%	0.00%	1.69%	31.07%	21.47%	1.13%	0.00%	1.13%	19.21%
21:00	0.56%	0.56%	0.56%	0.00%	0.00%	1.13%	12.99%	6.21%	1.13%	0.00%	0.00%	5.65%
22:00	0.56%	0.56%	0.00%	0.00%	0.00%	0.56%	1.13%	0.56%	0.56%	0.00%	0.00%	0.56%
23:00	0.56%	0.56%	0.00%	0.00%	0.00%	0.56%	0.00%	0.56%	0.56%	0.00%	0.00%	0.56%

Source: Energeia Analysis, Ausgrid

% of ZS <= 90% of Min Demand by Period (SAPN)

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
0:00	3.82%	4.46%	12.10%	8.92%	8.92%	10.83%	8.28%	7.64%	10.19%	9.55%	5.10%	3.18%
1:00	7.64%	7.01%	15.92%	10.83%	20.38%	14.65%	9.55%	9.55%	9.55%	17.20%	13.38%	5.73%
2:00	14.01%	12.74%	23.57%	17.20%	18.47%	26.11%	19.75%	15.29%	16.56%	20.38%	14.65%	10.19%
3:00	15.29%	14.65%	25.48%	19.11%	17.83%	28.66%	21.02%	15.92%	19.75%	22.29%	16.56%	12.74%
4:00	15.29%	12.10%	26.11%	17.83%	17.83%	30.57%	21.02%	15.92%	20.38%	24.84%	17.20%	13.38%
5:00	10.83%	8.92%	21.66%	16.56%	13.38%	28.03%	20.38%	14.01%	19.11%	22.29%	15.92%	9.55%
6:00	2.55%	1.91%	13.38%	7.01%	7.64%	29.30%	17.20%	5.73%	16.56%	17.83%	12.74%	6.37%
7:00	2.55%	0.64%	7.64%	1.27%	1.27%	24.20%	12.74%	0.64%	9.55%	14.65%	5.73%	2.55%
8:00	3.18%	0.64%	6.37%	1.91%	1.27%	21.02%	12.10%	0.64%	6.37%	19.11%	4.46%	1.27%
9:00	2.55%	1.27%	8.28%	6.37%	7.01%	33.12%	18.47%	3.18%	4.46%	29.94%	2.55%	1.91%
10:00	2.55%	8.28%	27.39%	31.21%	33.76%	55.41%	38.85%	12.74%	12.10%	49.68%	10.83%	2.55%
11:00	3.82%	22.29%	48.41%	49.68%	51.59%	67.52%	58.60%	39.49%	31.85%	65.61%	29.30%	10.19%
12:00	7.01%	24.84%	48.41%	52.87%	53.50%	71.34%	60.51%	46.50%	42.68%	64.33%	36.31%	9.55%
13:00	5.73%	30.57%	52.23%	54.14%	52.23%	71.97%	61.15%	46.50%	47.13%	67.52%	39.49%	12.74%
14:00	5.10%	22.93%	46.50%	56.05%	50.96%	68.79%	61.15%	48.41%	43.95%	60.51%	30.57%	11.46%
15:00	5.10%	8.28%	25.48%	50.96%	49.68%	64.97%	56.05%	43.95%	42.68%	37.58%	14.01%	4.46%
16:00	0.64%	2.55%	21.02%	35.03%	36.94%	52.87%	33.76%	28.66%	19.11%	10.83%	5.10%	2.55%
17:00	0.64%	0.64%	14.65%	5.10%	3.82%	10.83%	7.01%	3.18%	5.10%	4.46%	2.55%	2.55%
18:00	0.64%	0.64%	14.65%	1.91%	1.27%	5.10%	2.55%	1.27%	1.91%	4.46%	1.91%	1.27%
19:00	0.64%	0.64%	12.74%	1.27%	2.55%	5.10%	1.27%	0.64%	1.91%	3.82%	2.55%	3.18%
20:00	1.91%	0.64%	13.38%	1.91%	1.91%	5.10%	1.27%	0.64%	1.91%	3.82%	3.18%	3.18%
21:00	2.55%	1.27%	12.74%	2.55%	2.55%	3.82%	1.91%	0.64%	3.18%	5.10%	4.46%	3.82%
22:00	1.91%	1.91%	12.10%	3.18%	3.82%	5.10%	2.55%	3.18%	4.46%	7.01%	5.73%	3.82%
23:00	3.18%	2.55%	14.01%	6.37%	7.01%	10.19%	3.18%	7.01%	7.64%	8.28%	5.73%	5.10%

Source: Energeia Analysis, SAPN

- Energeia's analysis of network load profiles found that peak congestion is likely to occur on a summer evening, as indicated by the heat maps
- Early indication is that many public charging sites will not have a significant impact on peak demand if charging load is at its highest in the early afternoon
- Public EV charging patterns could provide a solution to min demand caused by solar PV
- The SAPN network, in which 40% of residential customer have PV installed, now experiences min demand in the middle of the day, when public charging utilisation is observed to be at its highest

Source: Energeia Analysis

Thank You

ENERGEIA

Energeia Pty Ltd
Suite 2, Level 9
171 Clarence Street
Sydney NSW 2000
Australia

P +61 (0)2 8097 0070
energeia@energeia.com.au

energeia.com.au