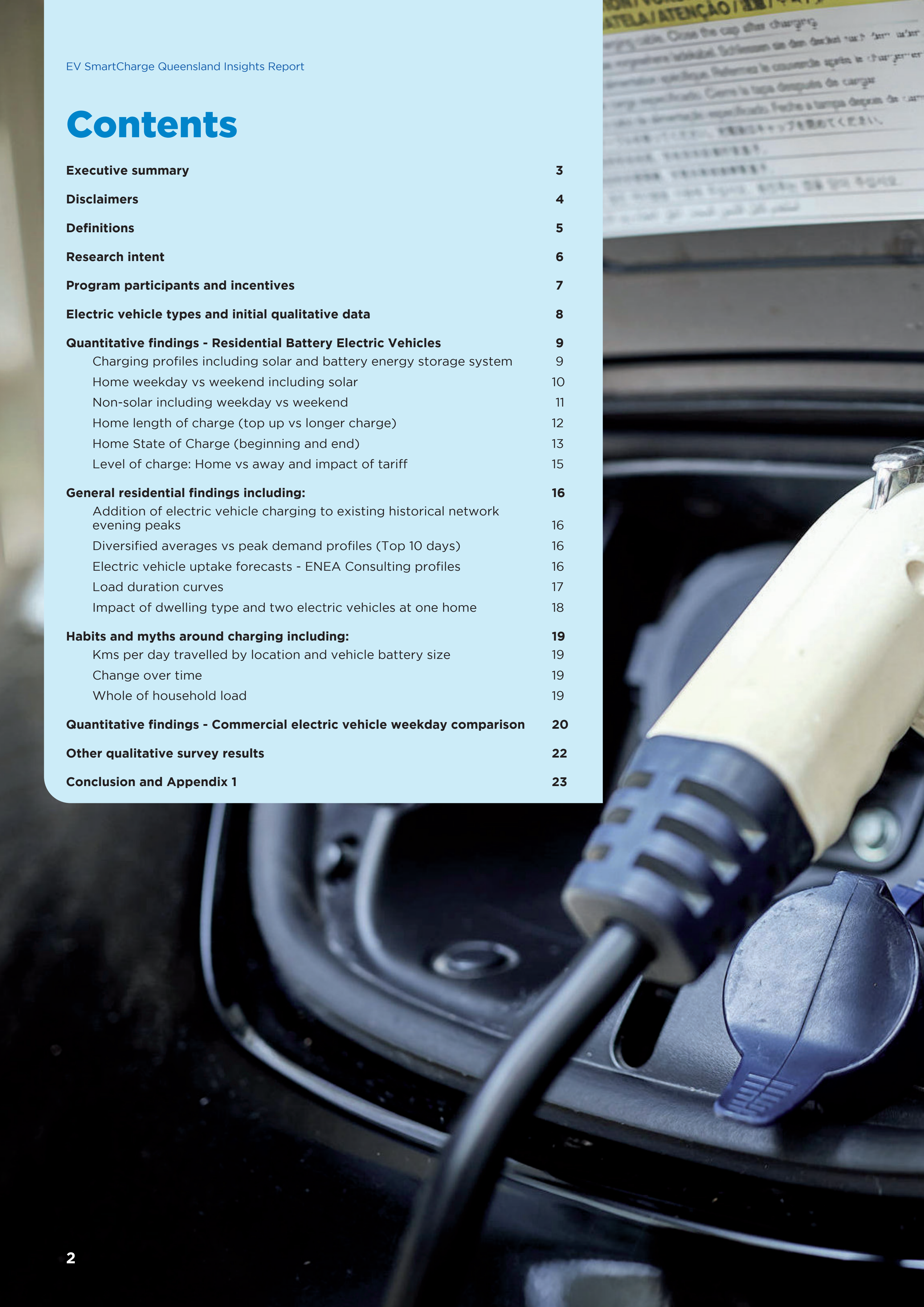
EV SmartCharge Queensland Insights Report

Contents



Executive summary

Electric vehicle (EV) adoption in Queensland, and Australia, has been slow but has the potential to follow the rapid adoption in other parts of the world that are witnessing the transition from internal combustion engine (ICE) vehicles to fully electric alternatives.

As at 31 January 2023 there were 18,704 EVs (excluding motorcycles) registered in Queensland; data supplied by the Department of Transport and Main Roads. When this transition accelerates, in Queensland, it will come with new challenges and new opportunities.

Commencing in May 2020, Ergon Energy Network and Energex Network (Networks), embarked on a research program to better understand EV charging profiles during the innovation phase of the adoption lifecycle and to understand how this may change and impact networks in the future.

EVs have the potential to double the electricity demand of a residential property whilst charging and add almost a half of the energy consumed by a typical household daily, based on recharging for an average daily commute. As more passenger EVs hit the road, the increased impact of additional load from EV charging may constrain localised parts of network infrastructure.

Integration of this flexible EV managed load with the grid has the potential to greatly assist in stabilising system level electricity demand and support increased utilisation of renewable energy within the grid at all levels.

Highlights

1. **Peak home charging occurred at 1am – high responsiveness to tariffs**
2. **Daytime charging at home illustrated the expected use of behind-the-meter solar generation**
3. **Charging contributed 0.75kW per vehicle during peak times, with the potential to be higher**
4. **Far less charging energy (kWh) was consumed at the EV owners' 'home base', than other research would suggest**
5. **EVs travelled 20% more on average than ICE equivalents, challenging range anxiety perceptions**
6. **EV charging is a very flexible load which can be managed for owner benefit**

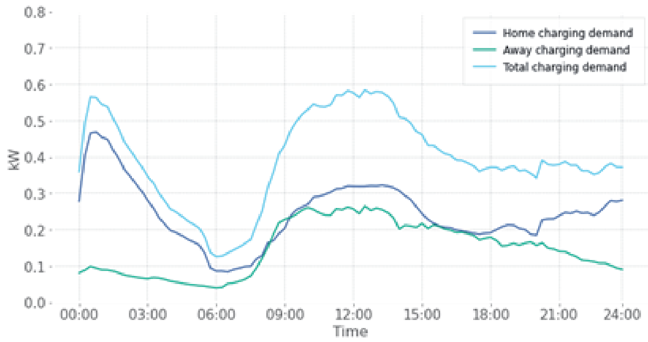


Figure 1. Residential vehicles - diversified profile, (n=119)

When owners manage their EV charging to take advantage of renewable solar generation, or a more dynamic tariff, the diversified daily charging profile is favourable to owners and networks alike. When a beneficial tariff or access to solar/ renewable generation is not available, convenience charging predominates into the evening with the potential for negative network impacts – particularly in home charging during historical network peak hours. This is shown in figure 1 above.

When analysing our EV SmartCharge Queensland participants, the diversified average of home charging was 0.25kW. However, when considering evening charging on the top 10 network peak days between 4-9pm, this baseline diversified average tripled to 0.75kW.

Conclusion

EV charging is a very flexible load for management – either by owners themselves or others. Owners are open to options as to how to manage their EV charging for their benefit; accessing advantageous pricing during the day, using the solar generation they may have in their home, use of their own active control mechanisms or having others manage the charging on their behalf.

This research illustrated customer charging behaviour that was both reasonable (based on access to retail tariffs and behind-the-meter generation) and responsive (able to be changed without a negative impact). This is also useful for networks. However, there is room for greater benefit for owners and networks through promotion of flexible EV charging options that minimise convenience charging at peak times and maximise daytime charging using renewable energy generation.

The research also uncovered some challenging charging behaviours that could cause network issues locally in the short-term (should EV ownership clusters evolve due to demographic influences on distribution transformers) and potentially significant medium to longer term network issues, unless managed.

Disclaimers

At the commencement of recruitment for participants to be involved in the EV SmartCharge program, there were approximately 3,400 EVs in Queensland. As such we clearly recognise that participants in the program represent innovators (first users) and should by no means be considered directly representative of the market of EV owners today, and especially not of mass-market EV owners in the future.

The program commenced during the early months of the COVID-19 pandemic, which most likely had an impact on some of the charging behaviour exhibited (perhaps more daytime charging than might have been otherwise seen in the pre-COVID era as people worked from home). However, with a potentially flexible ability to work from home when possible, following the COVID-19 pandemic, this “new order” could to some degree be seen to be reflective of residential EV charging in the future.

The primary focus of our study was on the charging behaviour and potential network impacts of fully electric vehicles (PHEVs are precluded from insights, unless otherwise stated).

We also recognise that our cohort size was relatively small and sub-segments consequently smaller. Inferred insights and findings should be read in this context.

Definitions

Geofence Identifier (ID)

Each participant was set up with their own Geofence ID, a unique latitude and longitude coordinate pinpointing the location where the vehicle was garaged and charged, around which a boundary existed - 200 metres in each direction of the coordinate. This created a box around this location. Any charging within the boundary was categorised as 'home' charging and anything outside the boundary deemed 'away from home' charging. If a participant charged within another participant's boundary, this too was deemed charging at 'home'; the boundary was not unique to that participant.

Diversity

In the context of the electrical system, diversity relates to the propensity of electrical loads to consume energy at different times and rates, resulting in a total diversified load that is substantially less than the sum of each load's maximum demand. This effect increases as the aggregation of loads grows.

Diversification of the EV population considers that not all vehicles are going to be charging at the same time, and that the rate of charging amongst vehicles charging simultaneously will differ.

Charging levels

Level 1 charging – up to 15 Amp (approx. 3.6kW)

Level 2 charging – greater than 3.6kW and equal to or less than 22kW

Level 3 charging – greater than 22kW and equal to or less than 50kW

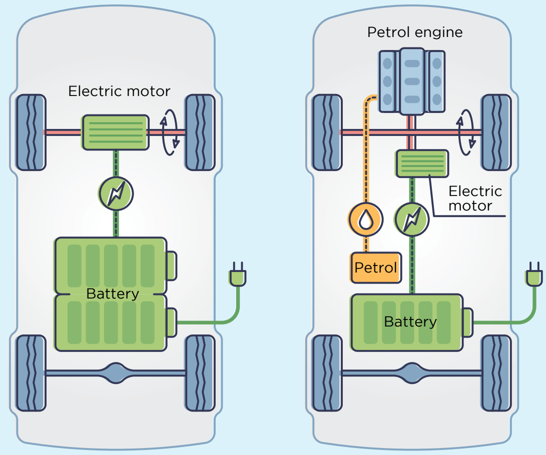
Level 4 charging – greater than 50kW

Level 1 and 2 charging is predominantly home charging, whilst Levels 3 and 4 is destination and highway (fast or ultra-fast DC public charging).

Vehicle Classification

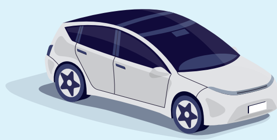
BEV
Battery electric vehicle

PHEV
Plug-in hybrid electric vehicle

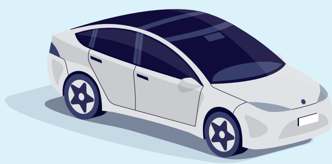


FUEL
100% electricity

FUEL
Petrol and/or electricity



Battery Electric Vehicle (BEV) Small:
Up to 50kWh battery



BEV Large:
>50kWh battery

PHEV:
Plug-in Hybrid Electric Vehicle (e.g., Mitsubishi Outlander, not Toyota Camry/Prius)

Research Intent

With minimal knowledge of how EVs impact the network currently and how this may differ in the future, we need to better understand the charging patterns of EVs to mitigate emerging challenges and maximise opportunities that EVs present.

Through understanding residential EV charging profiles and growing the acceptance of managed charging among owners, we, as network operators, will be able to assess the value of demand management within the EV market.

Understanding charging profiles and behaviours chosen by owners without network or external interference, and testing the control available to us, will further inform:

- How to fulfil owner needs for assurance of their EV charging requirements whilst effectively managing for network reliability and stability
- Communication and messaging to help educate and provide awareness of charging options for EV owners
- The value of EV load management for the network and customers in both a broad-based and targeted sense
- The approach for trialling flexible EV load control management and the establishment of value propositions that encourage either:
  - Behavioural and attitudinal changes to charging profiles that suit the network
  - Opportunities for third-party (aggregator) influence in managing charging profiles
  - Direct control by the Distribution Network Service Provider (DNSP) of charging profiles through load control tariffs
  - Scenario planning and forecasting within the Networks for future EV growth and support standards, policy issues and requirements regarding EV charge connections.

This understanding will provide the essential opportunity for our electricity planning and demand managers to gain access to additional flexible energy resources, which can be deployed to stabilise system-wide electricity demand, increase utilisation of baseline grid-supplied or sustainable renewable generation, and mitigate the risk of EV charging on transmission and distribution networks down to the low voltage (LV) network level.

The EV SmartCharge Queensland program was launched by the Networks in May 2020 and over 19 months we collected raw charging and trip data from 167 passenger vehicle owners throughout Queensland.

The program was funded as part of Energex's Demand Management Innovation Allowance funding allocation during the regulatory control period 2020-25.

It was provisionally planned for three years, with a planned two years of data capture and a total planned budget of $745,942.

Project expenditure amounted to $472,525 with approximately half the costs being associated with hardware and two years of data licensing, and the other half attributable to project management and associated internal labour allocations.

At program commencement, to the best of our knowledge, there had been no primary research undertaken in Australia to deliver actual charging profiles of residential EVs across a wide model range and network geographic topography. Additionally, no prior study focused on demographic differences, nor investigation of potential charging capacity impacts, and the availability and integration of renewables at home.

The SmartCharge data collection period was for 19 months. Using a data collection device in each EV (connected to the OBDII port), collection of actual charging data helped to confirm assumptions and discover behaviours around charging of an EV.

Program participants and incentives

A successful recruitment phase attracted 197 participants. COVID-19 disruptions extended the recruitment phase to seven months.

Several channels were approached and were extremely supportive of promoting to their member groups to be involved. These channels included:

- The Electric Vehicle Council
- Network social media
- Membership clubs including Australian Electric Vehicle Association and Tesla Owners Club Qld
- Queensland Department of Transport and Main Roads
- RACQ
- Universities and academic contacts
- EV publications, i.e. The Driven
- Dealerships and EV charge installers
- Retailers.

Participants were initially paid after being onboarded and some were also paid to be involved in qualitative research and/or involvement during a behavioural study.

All participants had access to their own charging and trip data via their SmartCharge dashboard.

The recording devices gathered data from the individual EVs in 15-minute intervals, including metrics such as:

- Start time and duration of charge session (hours and minutes)
- Maximum rate of charging session (kilowatts - kW)
- Battery state of charge (SOC) at the start and end of each charging session (%)
- Electricity delivered to the car, plus energy losses (kilowatt hours – kWh)
- Charge location (GPS coordinates)
- Trip duration (hours and minutes)
- In the case of PHEVs, electric distance travelled (kilometres), and non-electric distance (kilometres).

At the end of the program there were 167 participants from which the findings and insights were compiled into this report. Included in the analysis was data on those participants who had at least 15 months of active data over the full 19-month collection period. At the end of the program there were also seven households with two EVs enrolled.

Reasons for the removal of participant data due to not meeting the active 15 months of data requirement included:

- Lifestyle changes, other EV trial participation and unwillingness to continue in the EV SmartCharge program
- Sale of vehicle and new owner not wishing to continue in program or too much time elapsed from sale to notification
- Damage resulting from a natural disaster or accidents and the consequent time delay for replacement parts
- Effects of COVID-19 disruption - participants not regularly driving vehicles
- Car warranty concerns over installation of the data collection device
- Problematic device installation with other existing telematic devices already installed in vehicle
- Device removed for servicing (the OBDII port being used for servicing diagnostics) and not reinstalled by service agent
- 3G network connectivity issues.

Participant locations were as follows:

- South-East Queensland 84.4%
- Regional 11.4%
- Rural 4.2%

It was not surprising that the cohort were also early adopters of other energy technologies, with 77% of participants indicating they had a solar PV system, compared to the penetration of residential solar PV of 33.3% in Queensland. Additionally, 19% also had a battery energy storage system (BESS), compared to reported data from the Distributed Energy Resources register of 0.49% of residential premises in Queensland. All the BESS owners were also solar PV owners.

83% of participants lived in a detached house and the remainder lived in either an apartment/unit or townhouse.

Approximately 34% were 'EV only' households, with 66% owning both an EV and an ICE vehicle.

Almost 60% of participants indicated they had purchased a dedicated EV home charger.

Greater than 80% of the group either worked full time (more than 30 hours per week) or indicated they were self-employed.

Electric vehicle types

- 64% of the vehicles in the program were defined as 'BEV Large' with a battery capacity >50kWh. This included all Tesla models (X, S and 3) as well as the Jaguar I-PACE and Hyundai Kona
- 23% were defined as 'BEV Small' with a battery capacity <=50 kWh, including the Nissan Leaf, BMW i3, Hyundai IONIQe and Mitsubishi iMiEV
- The remaining 13% were PHEVs and included the BMW i3P, Hyundai IONIQ, Mitsubishi Outlander and Holden Volt.

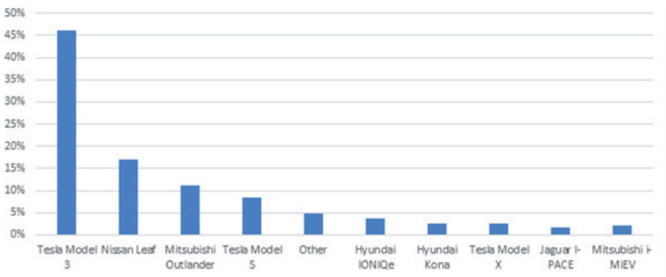


Figure 2. SmartCharge program makes and models

Thirteen different EV models (as illustrated in figure 2) were owned by participants in the program. The 'other' category above comprised BMW i3 and I3P (PHEV), Hyundai IONIQ and Holden Volt.

Qualitative data gathered

Throughout the program a range of qualitative data was captured from willing participants including:

- Initial demographic and related data during recruitment
- In depth interviews as part of customer journey mapping experience research (page 22)
- A further subset of 60 participants who were involved in an EV charging behavioural change study (page 22).

Recruitment phase

Whilst the focus of the qualitative data capture was to understand how EV owners charge their EVs in terms of frequency, rate, location, tariff and charging arrangement, we also wanted to obtain views and initial perceptions from participants on how they thought they behaved so we could understand how to best manage EV charging for everyone's benefit. After they'd registered, participants revealed:

- 55% had fixed EV Supply Equipment (EVSE) (a dedicated charger) at home
- 75% indicated they charged (via EVSE or a power point) on a continuous supply, flat-rate tariff
- 80% was the most common claimed maximum recharge level
- 17% claimed their typical charging behaviour was to do a substantial recharge most of the time, allowing the battery charge to significantly decrease, then recharge, while 43% said they top up whenever they can and 40% said they do a combination of both top up and full charge
- Surprisingly, 68% of respondents suggested their charging behaviour had not really changed at all since first purchasing their EV, and 32% indicated it had changed considerably. (The initial hypothesis was that as users became more comfortable with the EVs performance and reduced range anxiety that it would influence charging behaviour.)

Quantitative findings - Residential

Electric vehicle charging profiles

Residential BEV profile

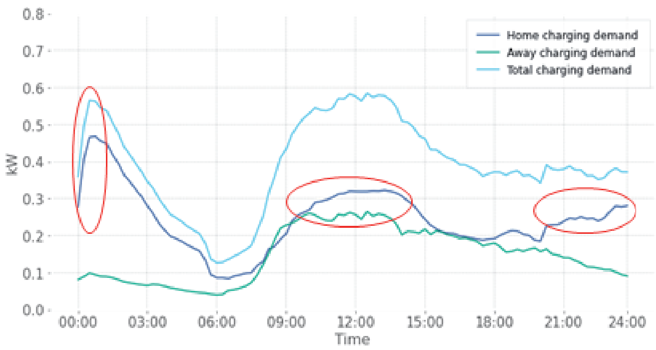


Figure 3. Residential vehicles - diversified profile, (n=119)

The diversified residential BEV profile shows some clearly separate, identifiable behaviours (circled in red) that can logically explain different residential behaviour patterns. This is shown in figure 3 above. Noting that a diversified profile combines total load averaged across all the vehicles in that cohort (including those not charging at the time).

There was clearly an identifiable peak in the middle of the night from around 1am which tapers off through to around 6am. This was the first evidence of the impact a retail tariff could have on influencing charging behaviour. At least one retailer offering provides a cheap, or significantly discounted rate compared to daytime throughout this period. The early-morning peak illustrated the impact of only 22 participants in the program, a disproportionate peak for such a small cohort. Noting if they weren't charging at this time, other peaks during the day would become more accentuated.

The second unique characteristic was the middle of the day heightened curve which extended from 9am until around 3pm. This was made up by a combination of home and away charging, the emphasis on home charging was driven through the desire to self-consume solar generation, rather than exporting to the network. Figure 8 (non-solar owners) demonstrates the difference in charging profile for users without solar PV.

The third significant aspect to recognise, was that the home charging curve demonstrates an upward trend from 6pm through until midnight. This is considered "convenience charging". Convenience charging can be defined as a behaviour of owners arriving at a destination (typically home from work) and immediately charging their EV, aiming to ensure a full battery or at least enough for the planned daily commute.

To achieve a deeper insight into the diversified profile and its constituent parts, the data obtained whilst investing participants to the program has allowed for significant exploration into generating homogenous groupings of EV owners and their charging activity.

Residential BEV Solar

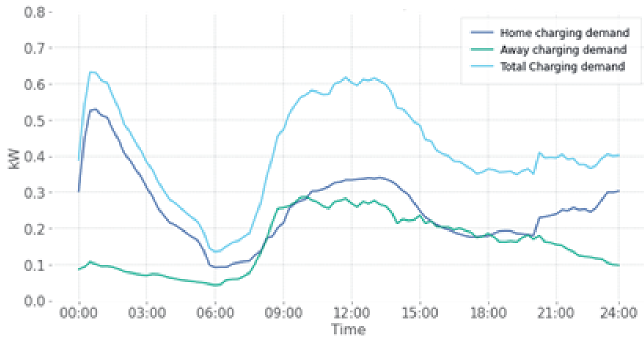


Figure 4. Homes with PV – diversified profile, (n=97)

With 77% of the cohort indicating they had a Solar PV array at home, a comparable graph is generated when focusing on just the residential subsegment (as illustrated in figure 4). Daytime charging at home illustrates the sensible use of solar generation. The tariff induced early morning peak was also significant.

Residential BEV Solar and BESS

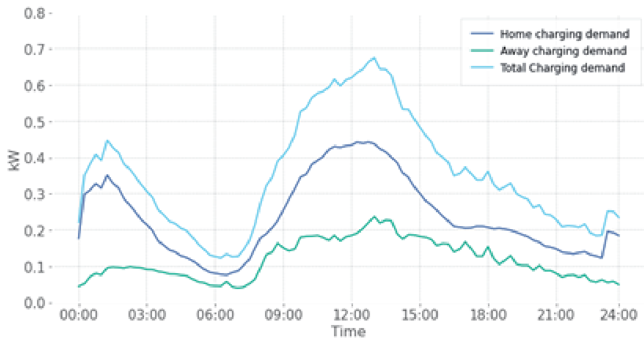
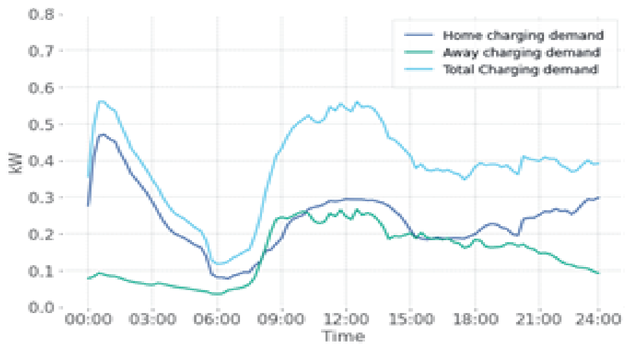


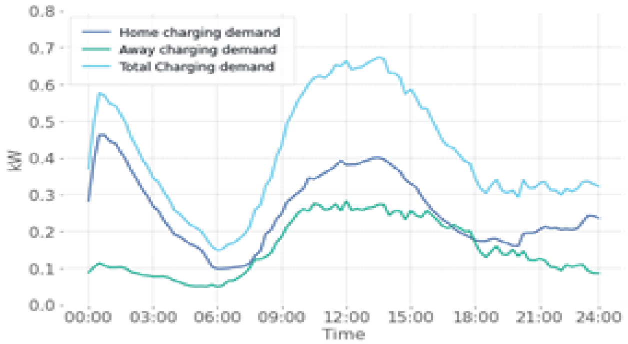
Figure 5. Homes with PV and BESS – diversified profile, (n=25)

Whilst the sample size was smaller, the discernible difference to highlight when BEV solar and BESS owners are compared to those BEV solar only owners, is the approximate 28% higher middle of the day home charging peak and the downward curve during evening convenience charging. This is shown in figure 5 above. It would appear this cohort were using solar generation as much as possible during the day to charge their EV and then orchestrating their battery storage for use during the evening period rather than sourcing energy from the grid. The return of load after 10.30pm and peaking at approximately 2am is the impact of those solar PV/BESS owners on a Time of Use (ToU) tariff taking advantage of the cheap tariff rate to add any necessary charge to their EV, albeit at lower levels than those who do not have BESS. Additionally, the 'away from home' EV charging for BESS owners was also less than those with just solar.

Residential BEV - Home weekday vs weekend



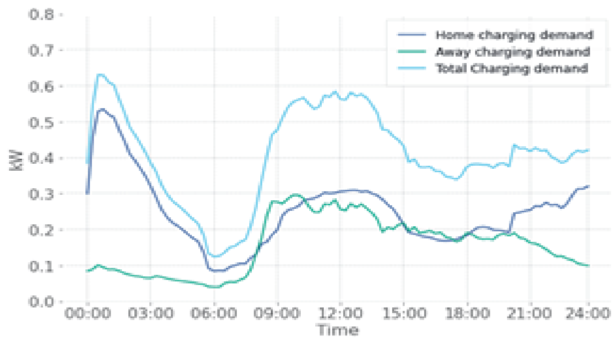
Diversified weekday profile, (n=119)



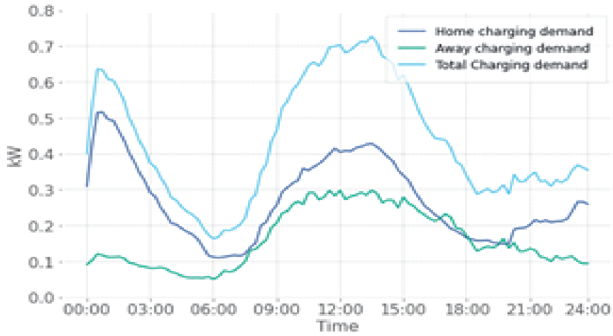
Diversified weekend profile, (n=119)

Figure 6. Residential vehicles weekday/weekend

Residential BEV with Solar - Home weekday vs weekend



Diversified weekday profile, (n=97)



Diversified weekend profile, (n=97)

Figure 7. Homes with PV weekday/weekend

The diversified daily profiles for those vehicles charging on weekdays compared to the weekend was broadly consistent (as shown in figure 6 above).

For both weekdays and weekend days, the graphs highlight the significant peak of charging at around 1am, the minimal charging between 5.30-7.30am, and considerable middle-of-the-day charging between 9am and 3pm.

Charging demand during the middle of the day was approximately 20% higher on weekend days compared to weekdays. This is understandable as EVs are not at home as often during weekday daytime and weekends tend to provide greater time for charging.

There is still a growth in weekday evening charging (from 6pm onwards), which could be problematic to networks, as this falls in the network peak demand time of 4-9pm. To a lesser extent weekends also see this rise.

The charging profile of the wider BEV cohort reflects that of solar owners above (as shown in figure 7) with no demonstrable differences (this is logical given they form the majority of this cohort).

Residential BEV, non-solar

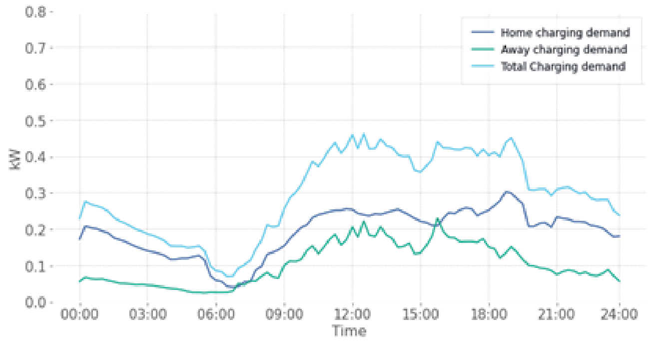
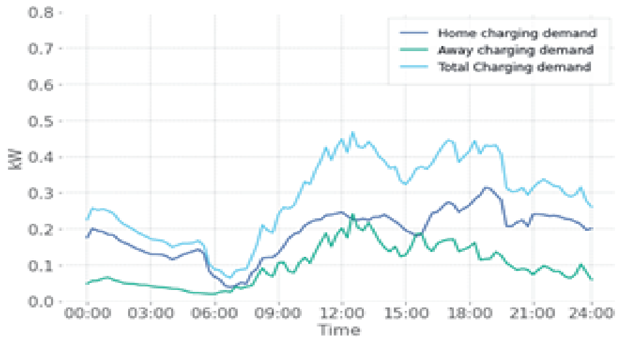


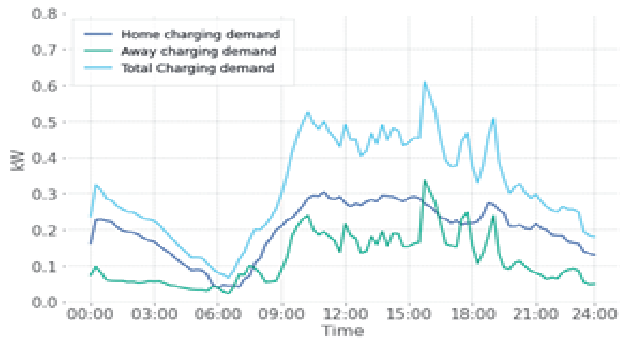
Figure 8. Homes without PV - diversified profile, (n=22)

The charging profile of non-solar BEV owners was much less variable than solar owners, and the charge rate (as shown in figure 8 above) was considerably lower across the full 24 hours of the day with no obvious preference for middle of the day charging, like those participants with solar. The difference is potentially due to the percentage of Small BEV in this group. Small BEV comprise 26% of this group, whereas they only form 20% of the owners with solar. Of significant importance was that from midday to 6pm the consistent load remains quite high, but the peak between 6-8pm is of primary interest.

Residential BEV, non-solar weekday vs weekend, and prominent charging days



Diversified weekday profile, (n=22)



Diversified weekend profile, (n=22)

Figure 9. Homes without PV weekday/weekend

When breaking down the weekday/weekend data (as illustrated in figure 9), weekends again demonstrated a greater opportunity to charge during daylight hours. It also highlighted that the "convenience charging" peak between 4-7pm was a predominantly weekday phenomenon, which is of interest, especially if presenting on network peak-demand days. Further peak day analysis and the associated impact is undertaken in figure 20.

The charging profile on any given day of the week was generally consistent, however weekend days in aggregate (home and away charging combined) did appear to indicate a higher likelihood of charging compared to a weekday.

In addition, Thursdays and Fridays did show a higher propensity to charge at home during the middle of the day compared to other weekday days, suggesting planning ahead for weekend journeys.

The 'average daily charging' profile of participants on public holidays (including any adjacent weekend days) was approximately 7% less compared to that of normal days (remaining periods exclusive of public holidays). There was no discernible difference in charging behaviour pre or post, in the lead up to public holiday periods compared to non-public holiday periods.

Home length of charge
(top up frequently vs infrequent longer charge)

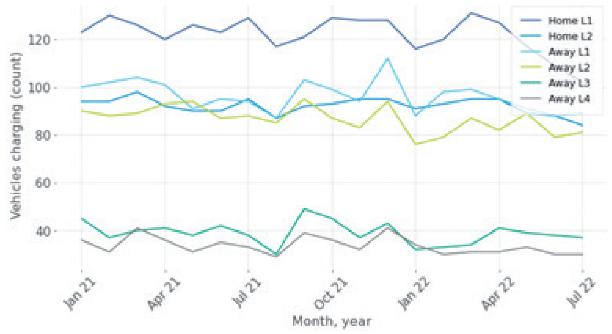


Figure 10. Count of all vehicles using each level of charging per month, (n=167)

With Level 1 and 2 charging being predominantly slow AC charging (2-22kW), it was not a surprise to see these dominating the home and away private charging activity (as shown in figure 10 above). With Level 3 and 4 charging considered as AC Fast (50kW) to DC ultra-fast charging (350kW) we saw approximately 24% of EVs using this charging option each month. Interestingly, approximately 12% of the cohort did not use a fast charger during the analysis period. The downward trend in home L1 charging since April 2022 was investigated, but no single cause was identified.

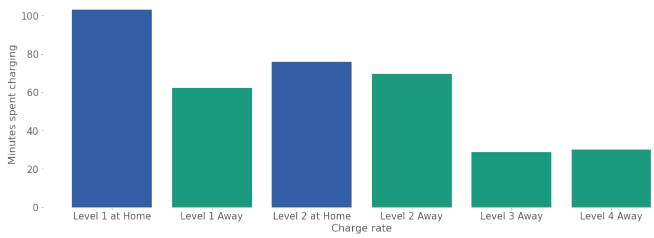


Figure 11. Charging duration by charging type

The charging level (home v away) also reasonably corresponded to expectations of average length of time spent charging (as shown in figure 11 above). On average, owners tended to charge for shorter periods away from home on Level 1 and 2 charging. With Level 3 and 4 charging being faster, the time for charging was demonstrably shorter.

Home SOC (beginning and end)

In reviewing the data for battery SOC at the commencement and end of charging sessions, we tested the hypothesis that charging behaviour was altering as EV owners became more confident with the range provided by their battery; the more confident owners become, the less often they charge and the SOC at the beginning of a charge session will be less over time. The aggregate use (all vehicle types included) of the data provides the level of insight required for this activity.

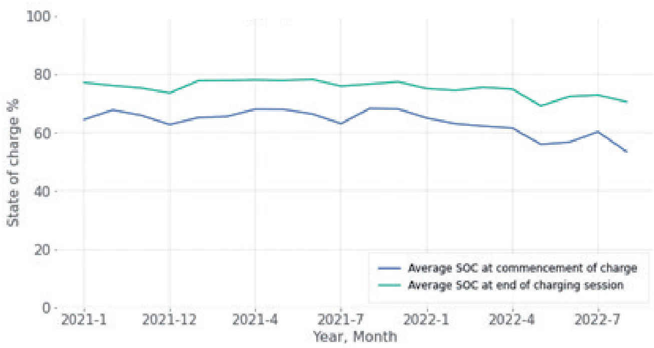


Figure 12. Charging behaviour over time

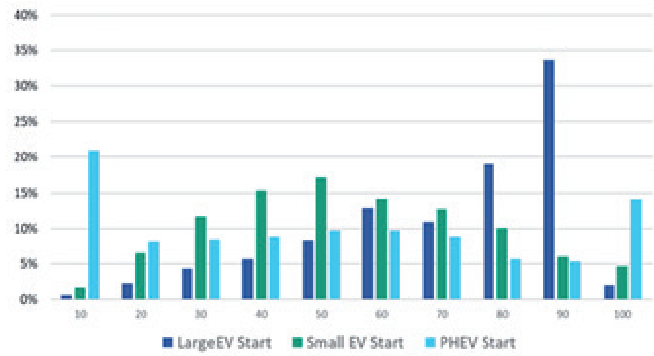


Figure 13. SOC at start of charging sessions

Figure 12 illustrates a stable trend with both SOC at beginning and end of charging sessions, but from September 2021, there is a trending decline in the SOC at the start of a charging session. It also suggests a gentle trending decline in the end SOC too. The gap between the two lines representing the average amount of charge being put into each vehicle, which appears to widen over time.

Most (90) of the original cohort had purchased their EV since 2019, with 28 purchasing between 2014 and 2018 and 15 prior to that. Those newest EV owners are more numerous and have shown the greater propensity to change their charging behaviour as they become more comfortable with their EV range. This is compared to those who have owned their EVs for longer and therefore have already settled into a habitual charging pattern prior to the SmartCharge program commencing.

SOC charge data by vehicle type (as shown in figure 13) shows definitive patterns emerging – the magnitude of the sessions on the Y axis are dominated by the BEV Large cohort; the spread of SOC that is the significant measure. BEV Small show the greatest variation in SOC at the beginning of charging sessions. Having smaller batteries, they will tend to use a greater percentage of their capacity prior to charging than a BEV Large if covering the same distances (for example the daily commute). If a BEV Large and BEV Small owner have the same charging behaviours, the BEV Large will show a higher percentage SOC to that of a BEV Small owner. PHEV owners show a disproportionate tendency to have a beginning SOC of under 10% as the battery storage is so small that the average daily commute will consume almost all its capacity.

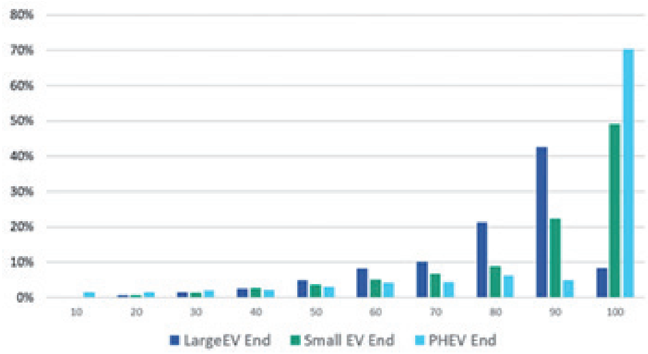


Figure 14. SOC at end of charging sessions

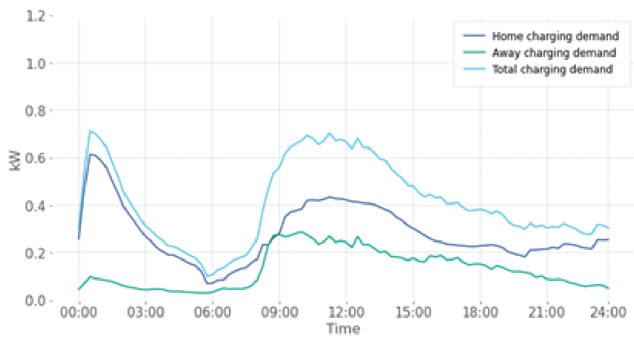


Figure 16. Regular top ups - diversified profile, (n=48)

Whilst PHEVs commence a charge with mostly 60% or less charge, they predominantly fully charge – this is not unreasonable, as illustrated in figure 14. Having very small batteries that are quick to charge, this energy can be easily used in the next trip. It also demonstrates that smaller batteries are more often depleted to low levels. BEV Small also had a reasonable spread of SOC when commencing a charge, but also tended to reach a 90-100% full charge. BEV Large had a different profile altogether with a higher propensity having a larger commencing SOC. This is simply a factor of the size of battery in the vehicles and that the daily average use will have far less impact on the SOC than that of a BEV Small. Whilst it is acknowledged that not going past an 80% charge is good battery management in preserving the longevity of the battery's effective charging life, and many individuals follow that guideline, both BEV Large and Small owners are seemingly prepared to move into the 90% end SOC. For BEV Large, those charging to 100% could be explained as planned charging for specific use on a longer trip.

When looking to group owners who are more inclined to frequently top up versus those who discharge more deeply prior to charging, an interesting difference is seen in their charging profile.

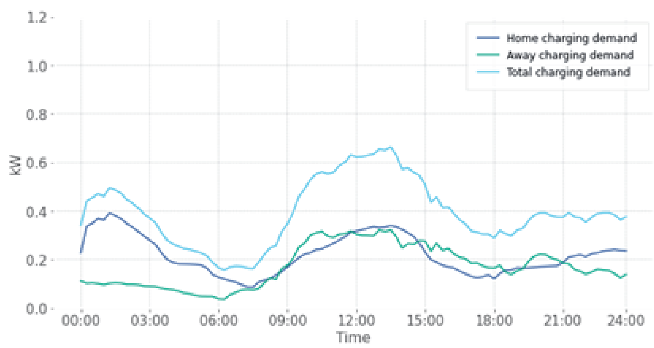


Figure 15. Daily chargers - diversified profile, (n=32)

As shown in figure 15, those who did charge daily (self-reported as "a combination of both top up and full charging") had a profile that similarly follows the average residential daily charging profile. On average, their annual EV energy needs are 3,449kWh.

Those who reported regularly topping up, had a charging profile that shows a propensity to follow a tariff value proposition as well as solar charging. This is shown in figure 16 above. On average, their annual EV energy needs are 3,617kWh.

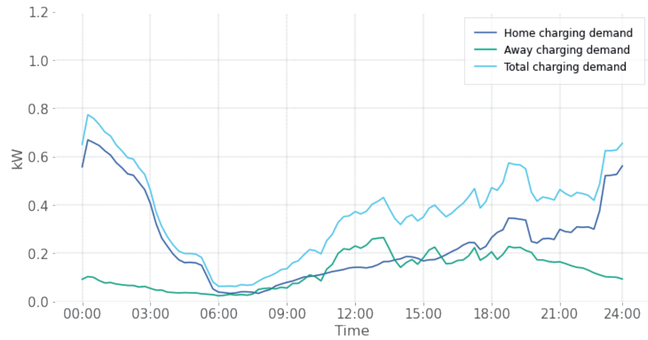


Figure 17. Deep chargers - diversified profile, (n=15)

When looking at those who advised that they typically did a "deep charge", the charging profile becomes significantly different, as depicted in figure 17 above. They are heavily influenced by tariffs, but also seem more likely to charge during network evening peak times. This would certainly be the case if they do not have access to faster "home" charging (i.e. Level 2 charging up to 22kW AC). On average their annual EV energy needs are 3,250kWh.

Should owners move towards more deep charging (as figures 23 and 24 SOC graphs are indicating), so the propensity for EV charging to creep into network evening peaks grows. This would indicate that in lieu of any direct charging management, a time-of-use tariff to encourage best charging behaviour is the first line of defence to keep charging out of historical network peak times. However, another way of doing this would be to encourage faster charging at home, which could be facilitated with managed EVSE charging. EVSE charging would be present with active management. In this regard, the best outcome for owners and networks to address fast EV charging at home would be suitable tariffs and an EVSE with active management.

Level of charge: Home vs away

On average 62% of charging energy (kWh) was consumed at the EV owner's 'home base'. The total energy cosumed by vehicle type is shown in figure 18 below.

Home charging typically being Level 1 and 2, and Level 3 and 4 charging being fast or ultra-fast public charging away from the home. A reasonable quantity of Level 1 and 2 charging is also found away from home. The graphs in figure 18 show the home and away consumer energy percentages for different sized vehicles.

To be noted, not every charge is from empty to full, not all charging rates are the same and 64% of the cohort were categorised as BEV large vehicles. It was found that Level 2 chargers are more common for BEV Large vehicles, enabling quicker and more convenient charging at home. Also, after long trips, a larger battery may have sufficient range to allow the vehicle to return to home to recharge.

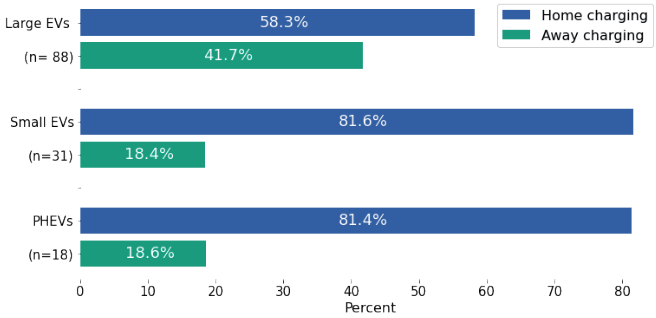


Figure 18.: Level of charge by vehicle type

Tariff

In reviewing those owners who were responding to a ToU tariff for EV charging, there was a specific tariff offering that generated a significant peak in the very early morning hours, by 13% of the cohort (circled in red in figure 19 below).

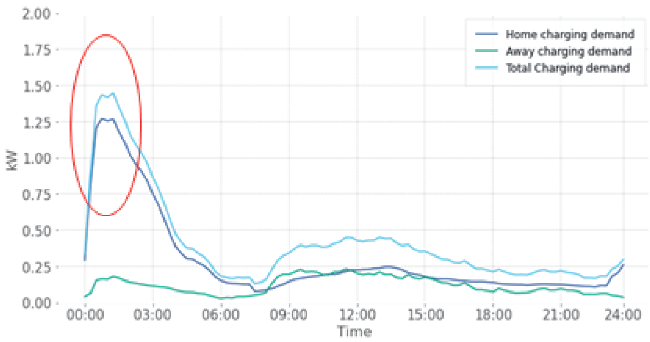


Figure 19. Overnight charging profile, (n=22)

Considering this peak is demonstrable within the whole cohort, this indicates the potential power of a tariff in influencing owner charging behaviour. In this regard it also demonstrates the perverse impact of generating a network demand peak outcome from what can be a high demand and energy load. For example, should a tariff reflect a rate drop at a certain hour of the day (i.e. 9pm) the potential is to set EV chargers to begin charging just after 9pm, with the potential for a new network evening peak of coincidental charging. Compared to a flat-rate tariff this is very significant.

General residential findings

Addition of EV charging to existing historical network evening peaks

Whilst the total residential BEV diversified demand profile (figure 3) presently indicates an average evening addition to loads of approximately 250-280W for the EV SmartCharge cohort, this does not show the full story.

When analysing the diversified data of the EV cohort on the top 10 peak charging days (between 4-9pm), the picture is significantly different. The diversified additional load to the network peak gets as high as 0.75kW (see figure 20). This is significant as it represents one of the highest energy consuming appliances in a home; managing diversified loads of this size has been the backbone for the networks' load control activity for over 50 years. A forecasting perspective is that this peak could be up to 1.5kW in the future.

Diversified averages vs peak demand profiles (Top 10 days)

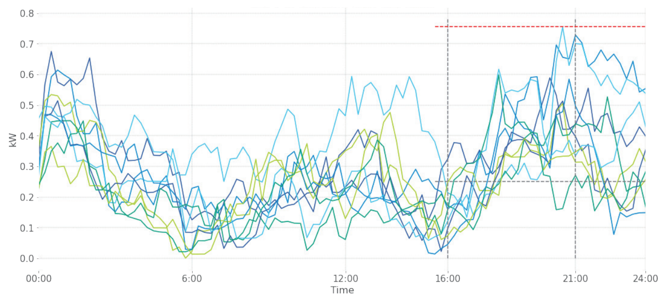


Figure 20. Top ten 4-9pm peaks (n=167)

Whilst some areas of network may be under stress during a normal network peak demand day, the addition of coincidental convenience EV charging would not be beneficial. Should EV sales universally take off or, as a minimum, congregate in demographic pockets it may easily trigger LV network augmentation which is why networks are utilising demand management strategies including batteries and tariffs to manage network expenditure sustainably.

EV Uptake Forecasts – ENEA

The Networks engaged ENEA Consulting (ENEA) to deliver an independent Distributed Energy Resources forecast for the Queensland distribution networks through to 2035.

EV uptake forecasts cover three different scenarios – slow, medium, and fast update of EV's as depicted in figure 21 below.

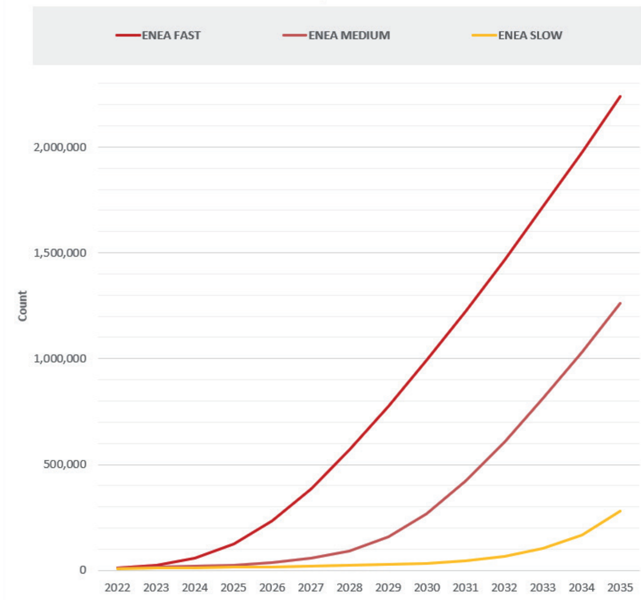


Figure 21. EV uptake forecast

It was assumed owners typically adopt one of two charging behaviours:

- **Convenience charging** - Vehicle owners charge based on their individual preferences and convenience, with no – or limited – cost-reflective tariffs and pricing signals incentivising when they charge. Convenience charging typically indicates a preference for charging during the evening peak after returning from work or other daytime activities
- **Collaborative charging** - Vehicle owners are encouraged to charge within specific windows of time, with price signals in place to incentivise 'good' charging behaviour from a network perspective. It is assumed that the incentives and technology to manage charging will exist, to enable an increasing share of collaborative charging over time.

The SmartCharge program findings are matched to that of the forecast modelling that when price or access to solar/ renewable generation is not available (collaborative charging tendency), coincidental convenience charging dominates with the ensuing potential for negative network impacts – particularly in home charging during historical network evening peak hours. The forecast modelling estimated a co-incidental evening peak averaging 1.5kW per EV.

Load duration curves

The following load duration curves are plots between load and time, illustrating the relationship between demand and the proportion of time that demand is being utilised.

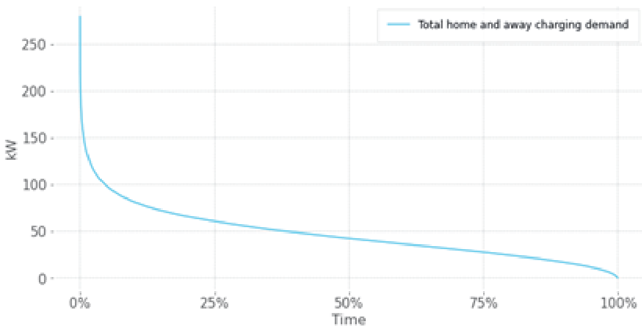


Figure 22. Residential vehicles 19 month profile, (n=119)

Residential Total (home and away combined) has around 260kW peak (i.e. ~2kW per vehicle) as depicted in figure 22 above. This most appropriately reflects the maximum impact of EVs on the network.

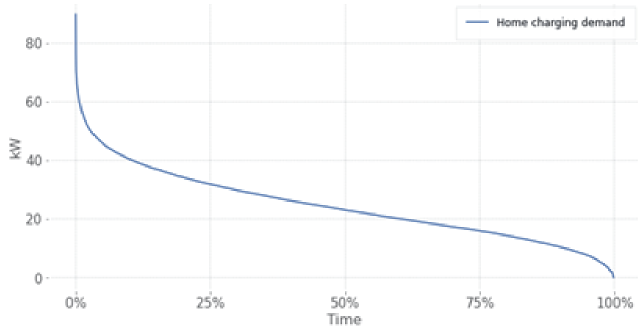


Figure 23. Duration curve for demand between 4-9pm, (n=119)

Residential home only charging between 4-9pm (historical network peak demand period). This is illustrated in figure 23 above. This is the impact at a LV network level with a diversified peak around 0.75kW per vehicle.

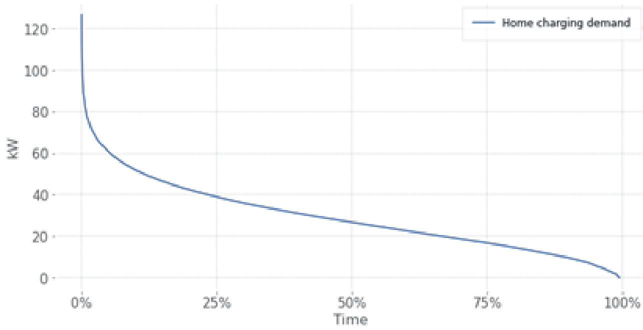
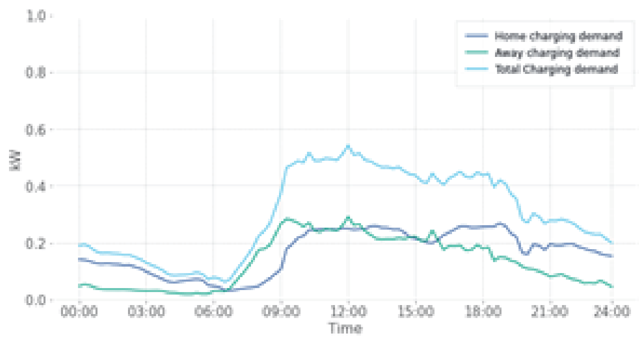


Figure 24. Residential vehicles 19 month profile, (n=119)

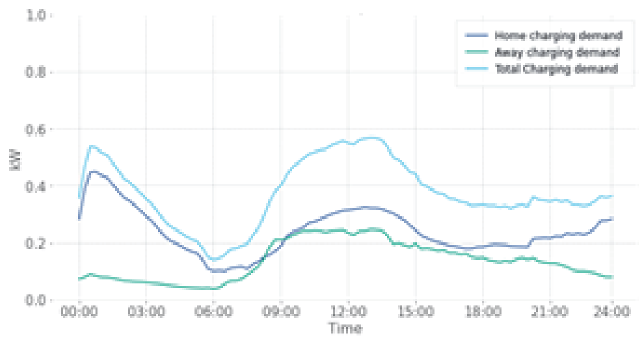
Residential home only charging was just over 120kW peak for 119 vehicles, as shown in figure 24 above. This is the impact at a LV network level with a diversified peak around 1kW per vehicle. With a smaller group of EV owners on a small rural feeder this contribution could be much greater. If this potential peak happened during network peak days (rather than the 0.75kW that was experienced on the top 10 peak days across the data collection period) a significant impact on local distribution transformers would be experienced. It is very important to note, the 1kW per EV demonstrates the maximum of coincidental home charging of the behaviour we see today. Forecasts of an average up to 1.5kW if coincidental charging prevails over the forecast period to 2035, creating an even worse outcome with which networks need to contend.

Impact of dwelling type

Houses vs townhouses and units



Unit/townhouse/other - diversified profile, (n=28)



House - diversified profile, (n=124)

Figure 25. Houses versus townhouses and units

EV owners who resided in units or townhouses clearly didn't take advantage of any cheaper overnight retailer tariff, as shown in figure 25. Even though solar installations at these premises were less prevalent (only 28%), there remained a tendency to charge EVs at home and away during daylight hours. There was a higher propensity for townhouse and unit dwellers to also convenience charge with the charging profile remaining high during hours around 6pm (when coming from work and plugging in to charge).

Two EVs at one home

Note: This reflects seven (7) premises, 14 EVs:

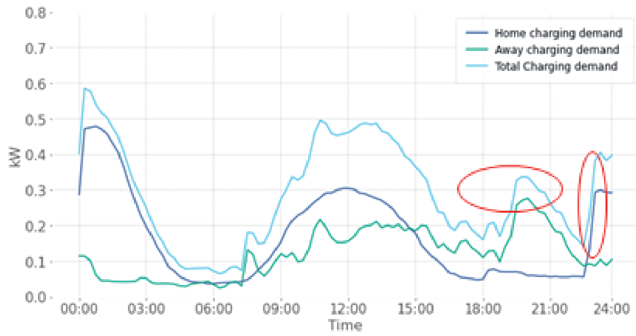
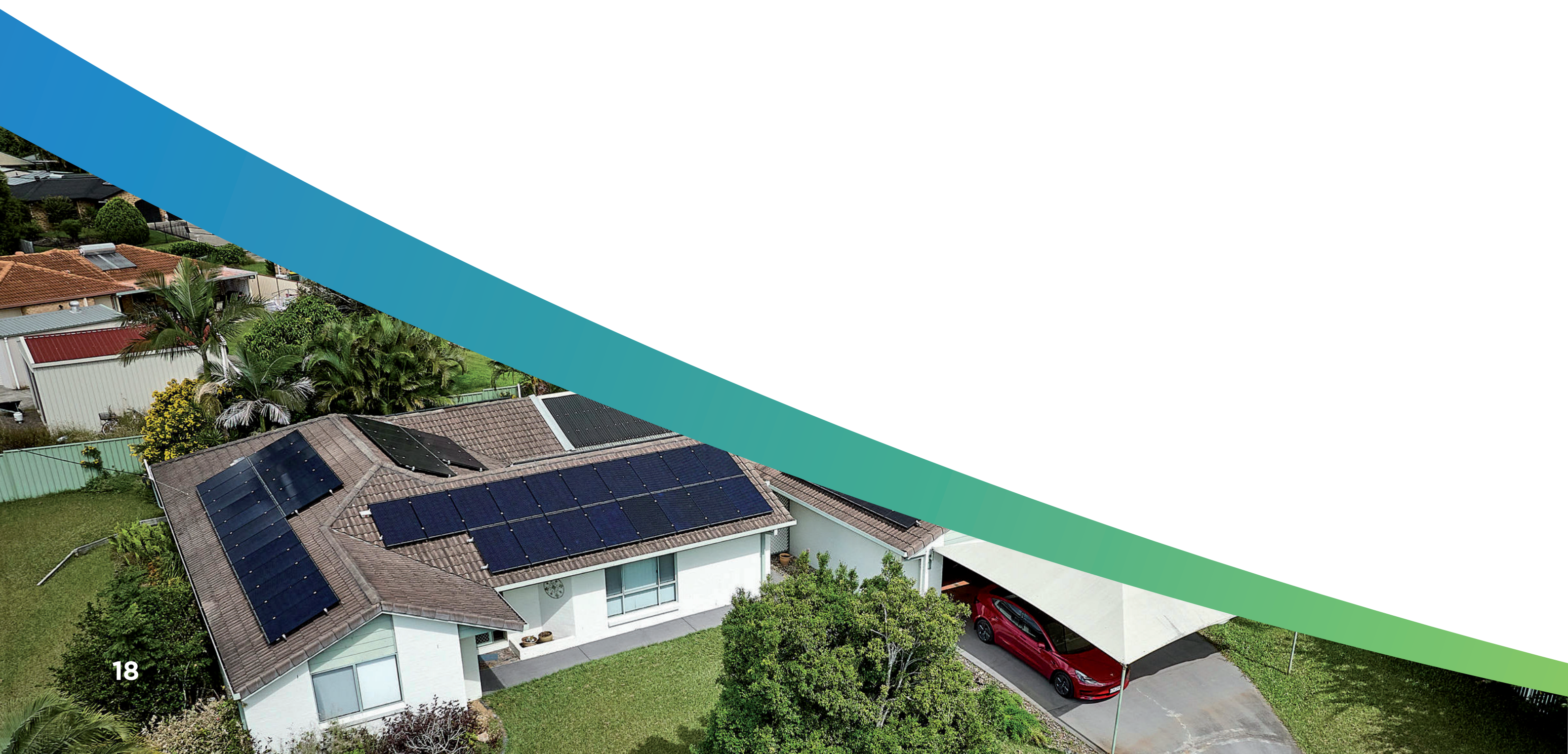


Figure 26. Multiple EVs at one premises, diversified demand profile, (n=14)

As shown in figure 26 above, the diversified demand profile of seven homes with two EVs was generally the same as that of a single-owned EV charging profile from midnight, with a similar overnight peak and middle of the day peak of charging at home, but differs markedly during the evening period.

There was a distinctive 'away from home' peak between 7-10pm (circled in red). In some respects, this can be attributed to three of the 14 vehicles being 'commercial' (including one location with two commercial EVs). There was also a pattern of more 'away' charging given commercial vehicles have less discretion in their charging options and will charge when required to perform their required use.

The other significant influence of two EVs in one household was a much lower at home kW load after 4pm and an earlier spike at 11pm in the evening (circled in red). This increased late-night charging and increased solar consumption suggests these households are more likely to seek off-peak charging options (ToU tariff and solar) that can reduce charging costs.



Habits and myths around charging

kms per day travelled by location and vehicle battery size – therefore daily requirement of kWh

According to a 2019/20, Australian Bureau of Statistics survey of motor vehicle use, the average Australian and Queensland vehicle drives approximately 33 km/day equating to 12,100km a year.

From our program:

- In South-east Queensland EV participants travelled 42.5km/day (15% more than Queensland ICE vehicles), with a corresponding 9.36kWh in daily consumption (this does not include regenerative charging) as shown in figure 27
- Regional participants' daily average, by comparison, was in line with that of Queensland ICE vehicles at 36km/day, with corresponding 9.26kWh in daily consumption (this does not include regenerative charging)

  Whilst there was a distinct difference in average daily distance travelled, a range of possible causes were investigated, to provide reason why the daily consumption was similar for participants in south-east Queensland compared to regional Queensland, but no single explanation was identified.
- BEV large vehicles travelled on average 50% more than BEV small vehicles and twice that of PHEVs (excluding petrol kms), clearly demonstrating that battery size and distance travelled are correlated, as shown in figure 28 and
- BEV large vehicles will continue to have the most significant charging requirements for the grid to enable, with annualised consumption on average of 3,990kWh per vehicle.

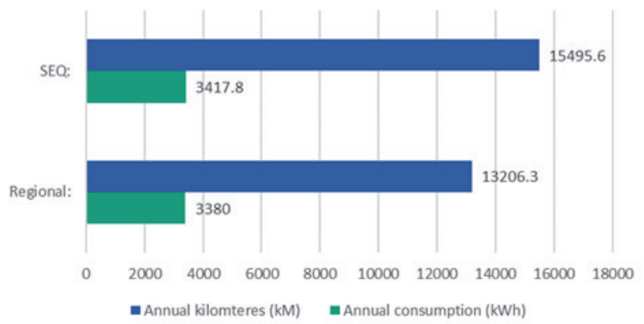


Figure 27. Annualised distance and consumption

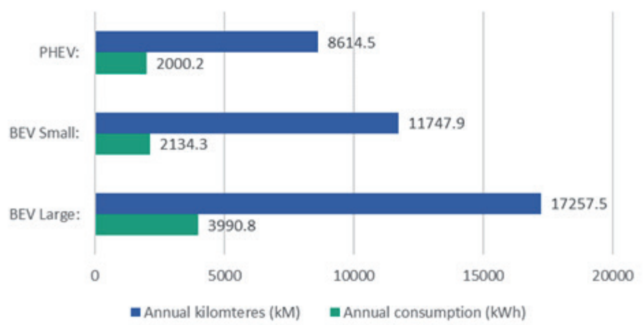


Figure 28. Annualised distance and consumption

Change over time

Commencement of program and end of program	In Jan Mar 2021	In May July 2022
Total kWh consumed	885	860
Total km travelled	3,965	3,903
Efficiency (km/kWh)	4.48	4.53
Start SOC (%)	65.1	57.7
End SOC (%)	77.5	71.4
Average kWh per charge	6.9	7.5

Figure 29. Change over time

In assessing activity from the beginning of the program to the end of the program, the data illustrates as shown in figure 29 above that marginally shorter distance was travelled on average between the first summer period and final winter period, whilst the overall efficiency km/kWh was marginally improved. Of significance was that the average starting SOC was markedly lower at the end of the program. This is a strong indicator that over the period of the research, confidence in the EV range had grown and owners were more confident to let their battery discharge more before they recharge.

Age of vehicle

Older vs newer vehicles	Older vehicles (2018 and prior)	Newer vehicles (2019+)
Total kWh consumed	4,536.3 (19 months)	5,774.8
Total km travelled	1,9735.4	2,6627.3
Efficiency (km/kWh)	4.35	4.61
Start SOC (%)	68.6	62.4
End SOC (%)	80.7	73.1
% gain per charge	12.1	10.7
Average kWh per charge	4.9	7.0

Figure 30. Age of vehicle

Those with newer EVs are travelling further on average than their counterparts with older EVs as illustrated in figure 30 above. The increasing range of newer EVs does have an impact on this finding, but we are also seeing net efficiency gains in km/kWh of newer vehicles.

Whole of household load

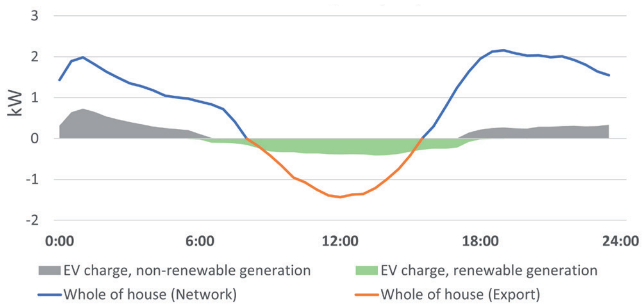
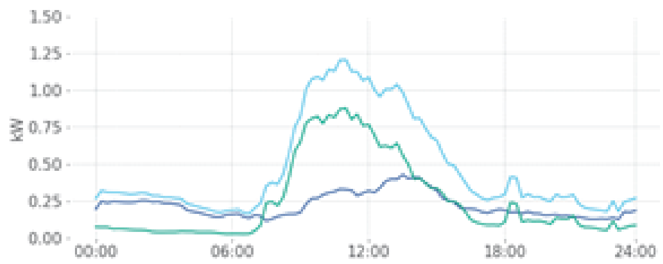


Figure 31. Whole of home profile (n=39)

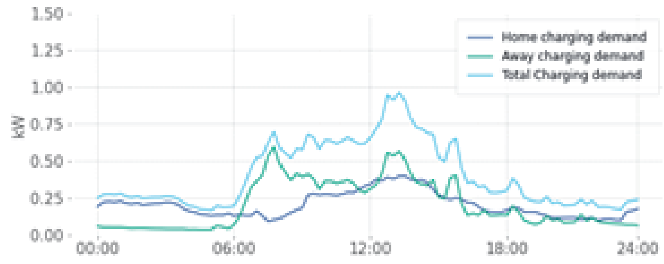
A subset of 39 participants' homes on the EV SmartCharge program trial also had 30-minute interval meter data available, which enabled plotting of their personal EV home-charging profile with their "whole-of-home" energy usage profile. This is shown in figure 31 above. Some of these users may have the flexibility to park at home and charge during times when their solar PV is generating excess energy, whereas others do not. This has a net result of energy being exported by some households during the day whilst others self-consume. Households who are unable to capture PV energy into their vehicle during the day have a higher propensity for EV charging profile at night. Tariffs can also provide alternate motivation to charge this way.

Figure 31 shows a diversified profile of energy from those 39 households, inclusive of all loads including EV charging, with the EV charging energy source coloured based on PV generation available from these houses at the time of their charging profile. This shows that there is still significant scope to increase the utilisation and self-consumption of renewable generation – by shifting of the grey shaded profile into times of PV generation (between 8am – 4pm).

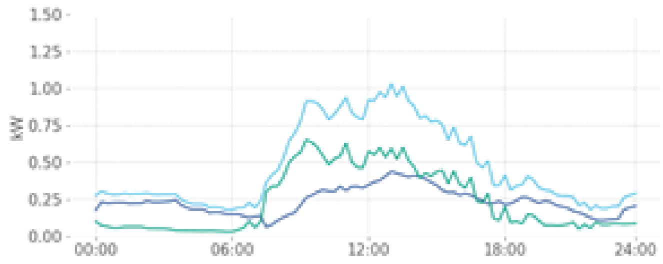
Quantitative Findings - Commercial



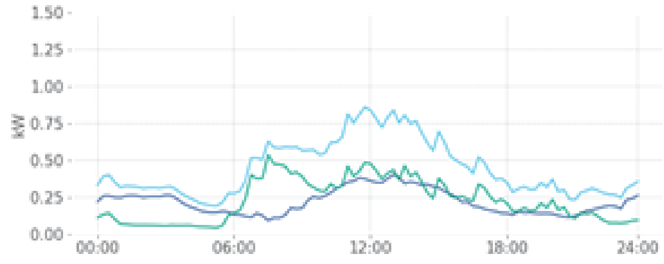
Monday



Tuesday



Wednesday



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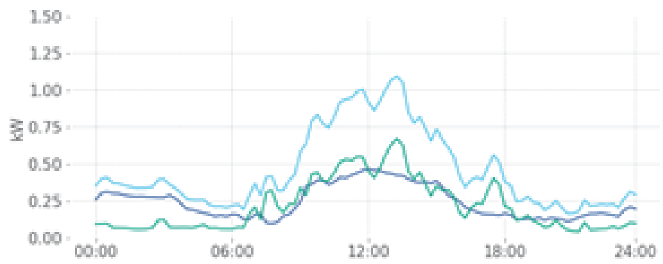
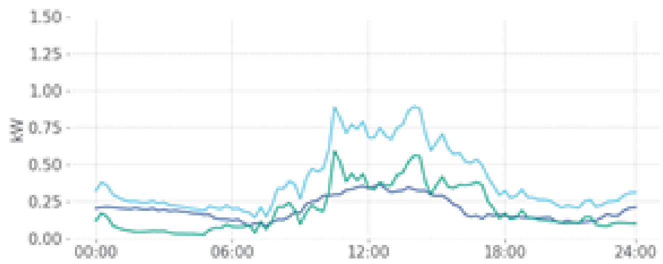
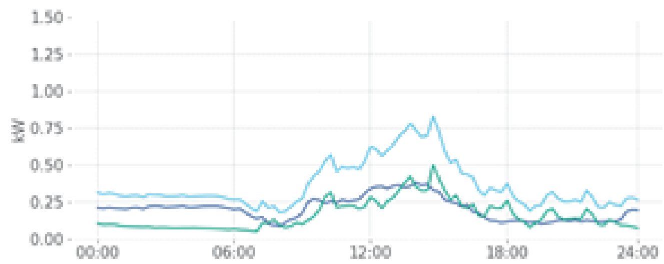


Friday



Saturday



Sunday

Figure 32. BEV Commercial comparison (24hour aggregated daily profiles) (n=27)

Commercial-use EVs (whilst still passenger vehicles) had a distinctively different demand curve due to their typical hours of operation, and purpose, as illustrated in figure 32 above). Whilst some overnight charging was evident, the evening period from 4–9pm and the overnight/early morning peak base load from 11pm – 5am is approximately half that of residential charging. The commercial EVs within the program had a 'home' geofence but the mix of charging inside and outside the 'home' area greatly differed when compared to residential vehicles. It is understood that some 'home' locations could be set as the participant's work address and so some evening charging (at an employee's home for example) may appear as away charging, or vice versa.

On average, commercial vehicles had a higher demand curve at away locations than they did at their home locations. Further analysis of the data indicates commercial "away" charging did exhibit a higher average charging session count of Level 4 charging than residential participants in any one month, to January 2022. From February 2022 to the end of the data capture, this has fallen to reflect the residential monthly sessions for Level 4 charging.

The need for ongoing recharge in the daytime for commercial use throughout the day was very apparent, especially at the beginning of the working week on a Monday.

Other qualitative survey results

In depth interviews

We completed some additional in-depth research with some participants in the SmartCharge program as well as EV owners outside of the program.

The primary focus was to understand the customer experience from consideration of buying an EV through to how EV owners manage their EVs through charging.

Some highlights included:

- Confirmation that price was the key barrier to purchasing an EV
- Charging EVs became part of the total home energy management routine for those who had a home battery and solar PV
- A clear preference to avoid using the grid and leverage solar power to charge EVs and home batteries
- EVSE home charging requirements were typically an afterthought to the electric vehicle purchase itself
- A common charging behaviour of 'topping-up' the EV battery to meet travel requirements for the next day, with an allowance of additional kilometres as a 'safety buffer'.

Read the full research report in [EV Customer Experience Journey Mapping]

Behavioural Charging study

A behavioural study was also undertaken in March/April 2022 to understand the opportunity to encourage participants to change their charging behaviour around peak times between 4-9pm and during the day to assist with solar soak. A total of 14 events were conducted, consisting of instructions to either 'charge your EV' or 'do not charge your EV' during specific times. Participants could opt out of any individual event called.

60 participants participated and events were called at different times of the week and weekend with different notification lead times, durations, and incentive amounts. This tested if there was any major difference in willingness or ability to take part or opt out and to explore different behaviour compared to a control group.

Incentives when offered ranged between $10 - $30, were provided for most events, with a capped threshold of $150 in total per participant available.

Participants were highly responsive and willing to change their charging behaviour with incentives provided. Greater than 90% of participants reached the capped threshold demonstrating extremely high participation in almost all events by all participants.

With the majority of events, participants overwhelmingly responded by being more involved compared to the non-involved control group on average 11% more. Participants were more likely to respond to those events where we requested they 'charge their EV'.

Importantly, participation was easy, and they indicated the event requests did not interrupt their day-to-day lifestyle. Whilst being recognised as an innovator cohort, this highlights the potential for managed charging going forward. The key will be the extent to which managed charging can extend to the mass market.

Conclusion

Owners today are exercising prerogative control of their EV charging - it works for them. They are also willing to have their EV charging managed, so long as there is a benefit to them (i.e. a ToU tariff can impact charging behaviours) and their amenity of the EV is not compromised.

In reviewing the original objectives of the research, we have generated a greater understanding of EV charging profiles and the potential for influencing network demand and energy use. As EV owners become more familiar with their EVs, their charging profiles altered with fewer deeper charging sessions and the starting SOC becoming lesser over time. Depending on the type of EV there was the propensity to drive more than their ICE counterparts, but when comparing energy use and distances travelled across the EV cohort there was no significant difference over time.

We have seen that EV charging is a very flexible load for management. Flexibility provides the ability to actively maximise diversity in energy use and demand, for both owner and network benefit. This allows for the creation of many charging options for EV owners that will also be network friendly.

EV charging does not appear to be a consideration in the decision-making process of purchasing an EV. In this regard more information needs to be made available to increase awareness of charging expectations and options available for EV purchasers.

Our findings from the research cohort illustrate an overall charging behaviour that is reasonable and responsible but can show further improvement with greater benefit for owners and networks. As an overall, diversified charging profile, residential EV charging today works for both the owner and networks. However, the research has uncovered some challenging charging behaviours that could cause network issues locally in the short-term (should EV ownership clusters evolve due to demographic influences on distribution transformers) and potentially significant medium to longer term network issues, unless managed. This was evident as:

(i) Coincidental, convenience-home charging in the normal network residential evening peaks. The profile had been observed to some degree in all owner groupings that have been generated (with greater propensity amongst PHEV owners and those without direct access to their own solar generation)

(ii) The impact of a highly valuable pricing discount that caused disproportionally large early morning peak in EV charging from approximately 13% of the participants.

Appendix 1 - Glossary

A = Amperes

BESS = Battery Energy Storage System (static)

BEV = Battery Electric Vehicle

DNSP = Distribution Network Service Provider

EV = Electric Vehicle

EV charging station = stationary part of EV supply equipment connected to the supply network

EV charging system = complete system including the EV supply equipment and the EV functions that are required to supply electric energy to an EV for the purpose of charging

EVSE = Electric Vehicle Supply Equipment providing dedicated, potentially faster AC or DC charging functions typically from a fixed electrical installation or supply network to an EV for the purpose of charging

ICE = internal combustion engine

kW = kilowatt is a unit of power

kWh = kilowatt hour is a measure of how much energy is used in an hour

LV = low voltage network supplying electricity directly to customer premises

Networks = Ergon Energy Network and Energex Network

OBDII = on-board diagnostic port

PHEV = Plug-in hybrid electric vehicle

PV = photovoltaic

SOC = state of charge, how much charge is left in the battery at a given time

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