WP1.2 Technical modelling of electrification of transport profiles Milestone Report: Vehicle-to-Building/Vehicle-to-Home analytical methodology and results

DISCLAIMER AND ACKNOWLEDGEMENT

Monash University Disclaimer:

Acknowledgement and Disclaimer:

This research is part of a program of fourteen projects, which have variously been funded and supported under C4NET's Enhanced System Planning collaborative research project. While conducted independently, the authors acknowledge the funding and in-kind support of C4NET, its members and supporters, and its ESP project partners.

MONASH TEAM
Jinhao Li, Leo Li, Chenghao Huang, Hao Wang (Lead)
Department of Data Science and AI
Monash University

Contact: Dr Hao Wang
Email: hao.wang2@monash.edu

EXECUTIVE SUMMARY

This report explores the integration of electric vehicles (EVs) into the energy grid through vehicle-to-building (V2B) or vehicle-to-home (V2B/V2H) technology, with a focus on its potential to enhance grid stability and reliability. As EV adoption increases globally, managing the interaction between EV charging demands and the electricity grid is becoming increasingly important. Observations from early adopters may suggest that EVs are charged during off-peak hours, especially at night, which helps to minimise their impact on peak grid demand. However, this approach does not fully leverage the potential of EVs to actively support the grid.

The evolution of V2B/V2H technology offers a transformative opportunity. Rather than solely consuming electricity, EVs will be able to discharge their stored energy back into the grid during peak demand period. This discharging capability transforms EVs into mobile energy storage units that can help alleviate stress on the grid, particularly during times of high electricity demand. Using EV batteries, V2B/V2H can help reduce peak load and balance supply and demand more effectively.

The report develops a framework to analyse the impact of V2B/V2H technology on the original meter load and EV charging load profiles. The report utilises the aggregated EV charging profiles based on different charging rates and customer distributions from previous report's efforts. aggregates these profiles, aiming to simulate real-world scenarios of V2B/V2H deployment.

To assess the effectiveness of V2B/V2H in shifting load and mitigating peak demand, the report analyses several load-shifting scenarios. It is worth noting that our simulation uses non-PV customers' meter load and aggregated EV charging profiles as case studies, because the derived EV charging profile for non-PV customers could be more reliable for the V2B/V2H analysis, compared to customers with PV installation. This is because the direct extraction of the EV charging profile for PV customers relies on both the smart meter data and PV generation data, while the PV generation data is currently unavailable. Specifically, it evaluates scenarios where 10%, 15%, and 20% of the load is shifted to non-peak periods, demonstrating how even modest levels of load shifting can contribute to peak load shaving. For example, a 20% load shift shows significant potential for reducing peak demand. Note that the simulation results only provide scenario analysis on possible V2B/V2H solutions, which may not reflect the actual V2B/V2H implementation in real-world applications. This analysis illustrates that V2B/V2H technology can play a critical role in shaping future energy systems, where EVs are not just consumers but active participants in maintaining grid balance.

The results of this study have important implications for utilities, policymakers, and stakeholders involved in the development of smart grid technologies. By highlighting the benefits and challenges of V2B/V2H systems, this report provides a roadmap for further exploration and deployment of these technologies at scale. It suggests that with proper planning and integration, V2B/V2H systems could significantly enhance grid flexibility, reduce operational costs, and support the transition to a cleaner, more sustainable energy future.

Through the detailed methodology and scenario analysis presented, this report emphasises the vital role that EVs can play in peak load management and grid reliability. It offers a vision of how the widespread adoption

of V2B/V2H technology could transform not only the transportation sector but also the energy landscape as a whole.

GLOSSARY OF TERMS/ABBREVIATIONS

EV	Electric vehicle
V2B/V2H	Vehicle-to-building/Vehicle-to-home
PDF	Probability density function

1. Introduction

The increasing adoption of electric vehicles (EVs) presents both challenges and opportunities for modern electricity grids. As the number of EVs on the road grows, so too does the demand for electricity to charge these vehicles. Observations from early adopters may suggest that EVs are charged during off-peak hours, particularly at night, when electricity demand is lower. While this practice helps prevent additional strain on the grid during peak hours, it fails to take full advantage of the potential for EVs to actively support the grid.

One promising solution is vehicle-to-building (V2B) or vehicle-to-home (V2H) technology, which allows EVs to do more than simply consume electricity. V2B/V2H enables EVs to discharge their remaining energy back into the grid during periods of high demand. This transforms EVs into mobile energy storage units that can contribute to grid stability by helping to reduce peak load demand. This capability is especially valuable in times of increasing grid stress, as more renewable energy sources are integrated and electricity consumption continues to rise.

V2B/V2H technology represents a shift in the way we think about energy management, turning EVs into distributed energy resources that can be strategically utilised to smooth out demand fluctuations. By discharging stored energy during peak hours, EVs can help reduce reliance on costly and polluting peaking plants, lower the need for additional grid infrastructure, and enhance overall grid resilience.

This report develops a framework for analysing the impact of V2B/V2H technology on meter load and EV charging load profiles. The methodology stems from the aggregated EV charging profiles aggregated based on different charging rates and the total number of customers (which have been analysed in previous reports), simulating various real-world scenarios for V2B/V2H deployment.

To explore the potential of V2B/V2H in shifting peak load, the report examines multiple scenarios, including 5%, 10%, and 15% load-shifting cases. The results illustrate how V2B/V2H technology can significantly reduce peak demand and improve grid stability, even with modest levels of load shifting. This analysis highlights the critical role that EVs can play in supporting a more flexible, reliable, and sustainable energy grid.

By focusing on the potential of EVs to contribute to peak load management, this report provides valuable insights for utilities, policymakers, and industry stakeholders. It lays out a pathway for integrating V2B/V2H systems into the energy grid and underscores the transformative potential of EVs as active participants in the energy ecosystem, capable of not only reducing emissions but also enhancing the reliability of the electricity grid.

2. Recap of EV charging profile for non-PV customers

Using the correlated EV charging data extracted from our toolbox, we conducted a descriptive analysis focusing on charger type distribution, customer usage patterns, average weekly charging frequency, and weekly EV-related demand. The toolbox identified three types of chargers: 2.3 kW, 3.7 kW, and 7.4 kW. Fig. 1 illustrates the distribution of non-PV customers by charger type: 87.5% of customers use 2.3 kW chargers, 5.3% use 3.7 kW chargers, and 7.2% use 7.4 kW chargers, representing 232, 14, and 19 customers, respectively. The average EV charging consumption across all non-PV customers is 10.45 kWh per day. We would like to highlight that, such results may be affected by the COVID where lockdowns were imposed and it may not accurately reflect the practical post-COVID EV customer usage.

It is important to note that the current charger distribution, as derived from our disaggregation filter, may not reflect the actual charger mix in the original dataset. This discrepancy arises because the toolbox filters out some customers to ensure data consistency and integrity between 2022 and 2020.

As discussed in the EV charging disaggregation report, the majority of customers use 2.3 kW chargers for home EV charging, while a smaller number use 3.7 kW or 7.4 kW chargers. As a result, the disaggregated charging profiles for the 3.7 kW and 7.4 kW chargers may not fully capture typical charging patterns due to the limited sample size. Expanding the data collection for customers using these higher-powered chargers would improve the robustness of the findings.

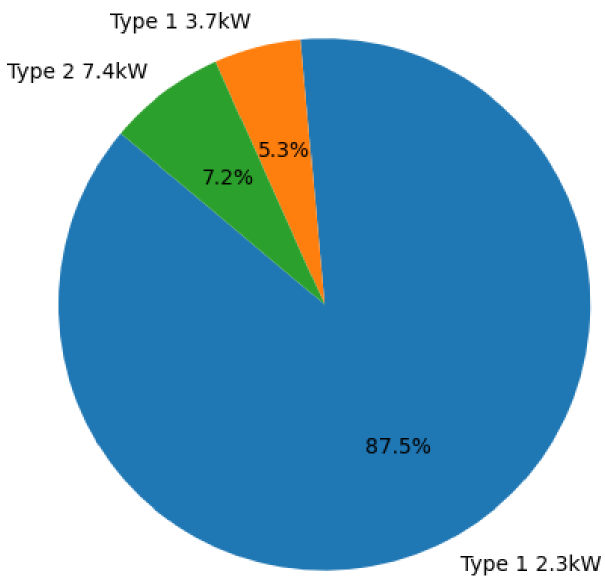

Figure 1 Distribution of EV customers without PV by their using types of chargers in the process dataset (Note that this mix does not necessarily reflect the actual mix in the real world as the processed data can be biased due to limited sample size.)

Different customers have varying preferences for charging times, making it crucial to analyse the distribution of charging periods for effective segmentation. We segmented the charging events and estimated the probability distributions for each segment. A session was defined as a single day, with multiple charging events possible within that session. For non-PV customers, charging events can occur in the morning (between 12am and 8am), noon (between 8am and 4pm), evening (between 4pm and 12am), or morning and evening.

This classification is a hard segmentation, which may result in some data loss, such as events spanning multiple segments. To address this, we adopted a soft classification method to better capture charging patterns. For instance, an event starting at 6 am and ending at 10 am is categorised under morning charging, ensuring no significant data is omitted.

After segmenting all sessions, we estimated the probability density function (PDF) for each charger type within each segmentation. For example, in the morning charging segmentation, the PDF for 2.3 kW chargers was estimated by counting the number of events per hour and dividing by the total events in a day. This process was repeated across all segmentations and charger types, allowing for a detailed understanding of customer charging behaviour throughout different times of the day.

Using this probability distribution approach, we aggregated the EV charging demand based on the observed charger mix: 232 customers with 2.3 kW chargers, 14 with 3.7 kW chargers, and 19 with 7.4 kW chargers. The respective proportions were 87.5% for 2.3 kW, 5.3% for 3.7 kW, and 7.2% for 7.4 kW. The aggregated demand was then averaged across the 265 non-PV customers over the year, with the results depicted in Fig. 2. Note that the results in Fig. 2 represent the average EV charging demand (in kW) per customer. Fig. 3 shows the aggregated meter load per customer, which is also averaged over the year. Both aggregated meter load and aggregated EV profiles facilitate our V2B/V2H analysis in the following sections.

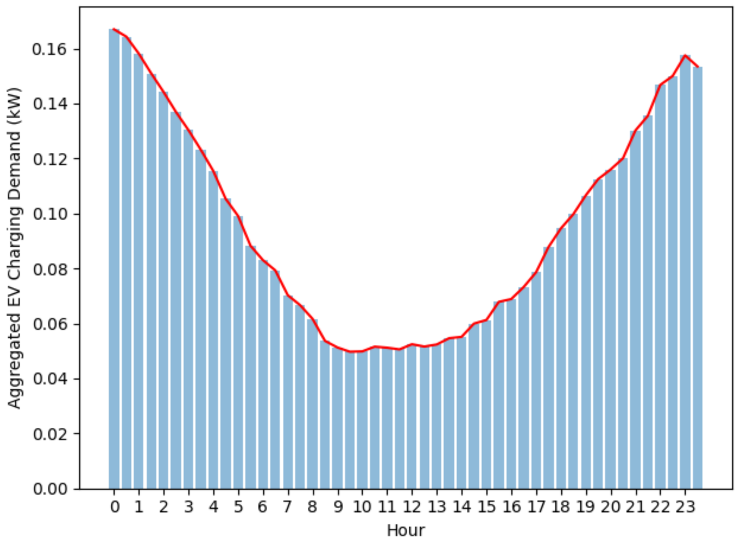

Figure 2 Aggregated EV charging demand per customer based on the current charger mix (2.3kW – 87.5%, 3.7kW – 5.3%, 7.4kW – 7.2%)

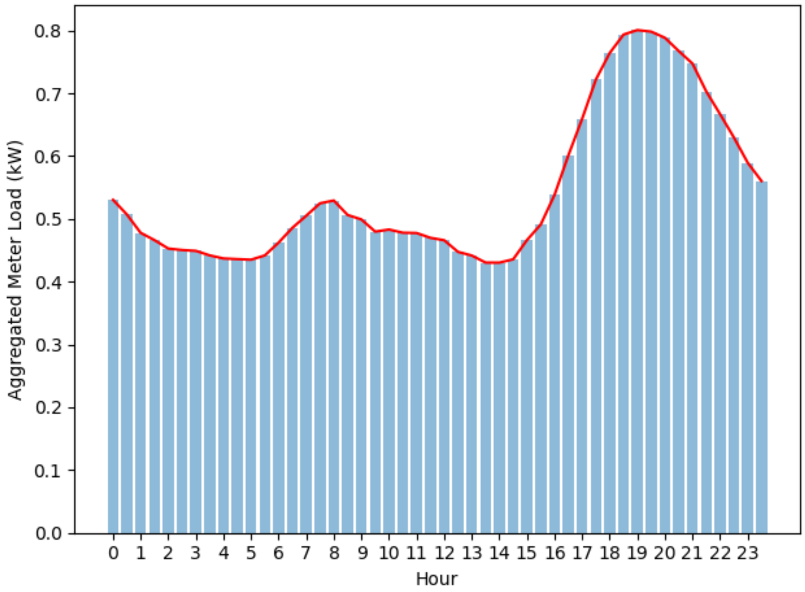

Figure 3 Aggregated meter load per customer based on the current charger mix (2.3kW – 87.5%, 3.7kW – 5.3%, 7.4kW – 7.2%)

3. Motivation of V2B/V2H technology

The rapid adoption of EVs is reshaping the energy landscape, presenting both challenges and opportunities for modern electricity grids. V2B/V2H technologies are emerging as pivotal solutions to enhance grid stability, reduce carbon emissions, and optimise energy management [2]. These technologies enable bidirectional energy flow, allowing EVs not only to consume electricity but also to discharge stored energy back into homes, buildings, or the grid during peak demand periods. This section outlines the key motivations driving the development of V2B/V2H methodology in this report, supported by relevant literature.

Enhancing Grid Stability and Flexibility: One of the primary motivations for V2B/V2H technologies is their potential to enhance grid stability and flexibility. As renewable energy sources like wind and solar become more prevalent, managing their intermittency becomes critical [3]. V2B/V2H systems provide a valuable buffer by storing excess renewable energy during low-demand periods and discharging it during peak times, thereby smoothing out fluctuations in energy supply and demand. Studies, such as [3]-[4], have shown that V2B implementations, which aggregate multiple EV batteries within a building or community, can significantly increase the renewable energy auto-consumption ratio, improving energy independence and reducing grid reliance.

Reducing Peak Demand and Enhancing Energy Efficiency: Another major driver for V2B/V2H technologies is their ability to mitigate peak demand [5]. Peak periods often require grid operators to activate costly and polluting peaking plants to meet high electricity demand. V2B/V2H systems allow EVs to discharge energy during these peak times, effectively shaving peak loads and reducing the need for additional generation capacity. This not only lowers operational costs for utilities but also contributes to a cleaner energy mix by minimising reliance on fossil fuel-based generation [6].

Economic and Environmental Benefits: V2B/V2H technologies also offer significant economic and environmental benefits [7]. By participating in demand response programs, EV owners can earn financial incentives for providing power back to the grid or their homes during high-demand periods. This creates an additional revenue stream for EV owners while supporting grid stability. Furthermore, these technologies contribute to carbon reduction efforts by optimising the use of renewable energy and minimising greenhouse gas emissions from conventional power sources.

Supporting Energy Decarbonisation Goals: The global push towards decarbonization has made the integration of renewable energy and smart grid technologies a priority [8]. According to the International Energy Agency, the electrification of the transportation sector is expected to grow rapidly, contributing to significant shifts in energy demand patterns V2B/V2H technologies align with these decarbonisation goals by maximising the utilisation of renewable energy, thus reducing the carbon footprint of buildings and communities.

Addressing Challenges in Real-World Deployment: While the potential benefits of V2B/V2H technologies are well recognised, their real-world implementation faces challenges such as the need for advanced energy management systems and smart, bidirectional charging infrastructure [9]-[10]. The integration of these systems requires robust communication and control technologies to manage the flow of energy between EVs, buildings, and the grid. Moreover, the scarcity of real-world data on the operation of these technologies poses a significant barrier to their widespread adoption. This highlights the need for further research and pilot programs that utilise real-world data to refine models and validate the effectiveness of V2H and V2B systems.

The motivation for V2B/V2H technologies is rooted in their ability to transform EVs into active energy resources that can support the grid, reduce emissions, and improve energy efficiency. By leveraging the bi-directional energy flow capabilities of EV batteries, these technologies provide a critical tool for managing the complexities of modern energy systems. As research and development efforts continue, V2B/V2H technologies hold the potential to play a significant role in the transition towards a sustainable, low-carbon energy future.

The above motivation factors drive our report to develop the V2B/V2H methodology using the real-world customer data to investigate the positive impacts of EV adoption on shaving the grid demand and enhancing the grid reliability and stability, which are detailed in the following section. Regarding the aggregated EV charging profiles and aggregated meter load (as shown in Fig. 2 and 3, respectively), we would like to highlight that the aggregated EV charging patterns per customer stem from the inherent charger mix of the provided dataset. Due to the limited sample size of the dataset, the current charger mix may not reflect the actual charger mix. Therefore, the aggregated EV charging profiles, as well as the subsequent V2B/V2H analysis, may be biased to some extent and should be applied cautiously in other scenarios.

4. V2B/V2H methodology

This methodology outlines a systematic approach for implementing vehicle-to-home (V2B/V2H) technology, with the goal of reducing peak load demand on the grid by strategically discharging stored EV energy during peak hours and shifting EV charging to off-peak periods. The methodology involves several key steps, as shown in Fig. 4, and can be described in two phases: Preparations and Execution (which includes Peak Load Reduction and EV Charging Shifting).

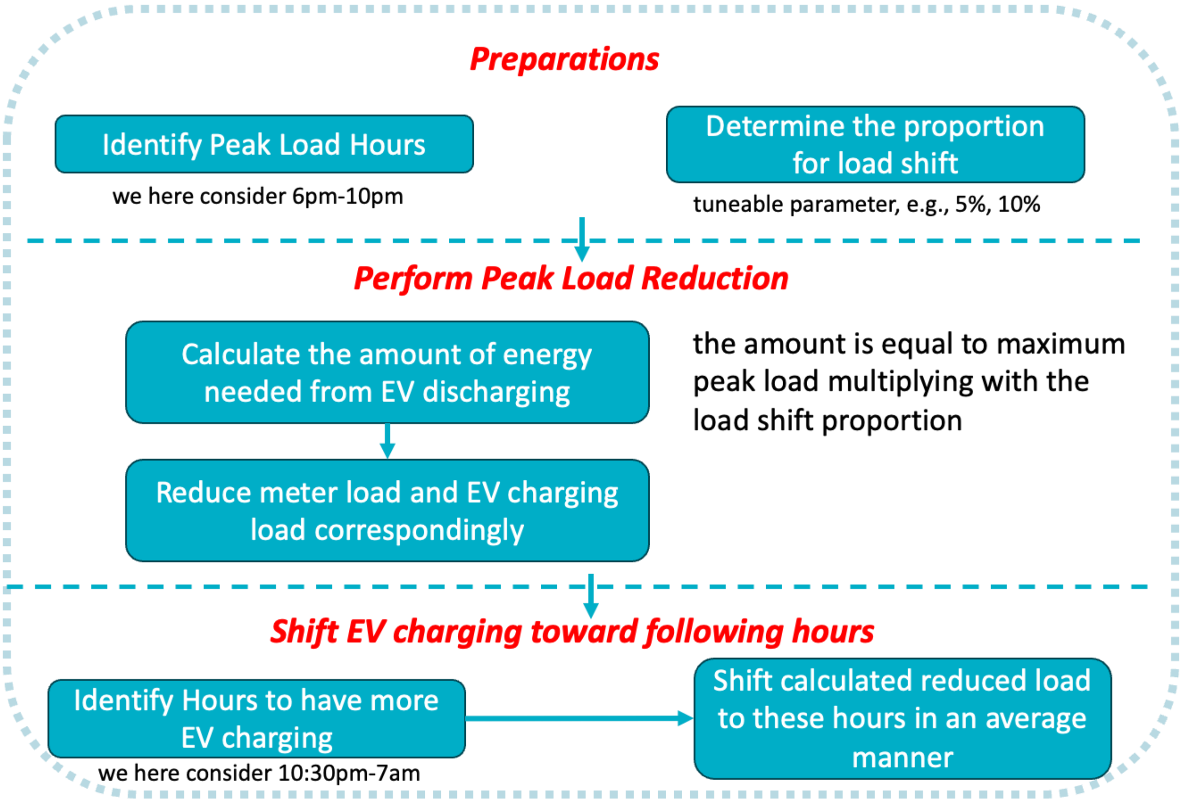

Figure 4 Aggregated meter load per customer based on the current charger mix (2.3kW – 87.5%, 3.7kW – 5.3%, 7.4kW – 7.2%)

4.1. Preparation of peak load shaving

The first step in the preparation phase involves identifying the time period during which the grid experiences its highest demand, commonly referred to as peak load hours. In this methodology, the peak load hours are defined as 6 pm to 10 pm, a period when household and business energy usage typically spikes due to high activity levels. These peak hours represent the target window for deploying V2B/V2H energy to relieve the grid.

The next step involves selecting a tunable parameter for the proportion of the peak load that will be reduced via EV discharging. This parameter can be adjusted depending on the scenario being analysed, with typical values being 5%, 10%, or 15%. This load shift proportion represents the fraction of the peak load that will be alleviated by discharging stored energy from EVs back into the grid.

We would like to **highlight** that we have taken a simplified generic approach here, rather than one which would be specifically aligned to conditions where the market price of generation is higher than a set threshold, which would be reflective of when peaking plants are scheduled on and where the benefits of V2B/V2H are most relevant.

4.2. Peak load shaving

Once the load shift proportion is determined, the amount of energy that needs to be discharged from EVs to reduce the peak load is calculated. This is done by multiplying the maximum peak load during the identified peak load hours (e.g., 6 pm to 10 pm) by the chosen load shift proportion. The resulting value is the energy requirement to be supplied by the V2B/V2H system. This calculation ensures that the reduction in load corresponds exactly to the planned shift, helping to stabilise the grid during critical demand periods.

After determining the energy needed from EVs, the next step is to adjust the load profiles accordingly. The meter load (household or business electricity consumption) and EV charging loads are reduced during the peak load hours based on the calculated discharge amount. This step effectively reshapes the load curve by lowering demand during peak times, supported by the energy discharged from EVs. By implementing this reduction, the grid experiences less strain, contributing to overall grid stability.

4.3. EV charging shift toward non-peak hours

Once peak load reduction has been implemented, the focus shifts to recharging the EVs that discharge their stored energy. The methodology identifies the optimal time window for increased EV charging during off-peak periods when grid demand is lower. In this case, the hours chosen for more EV charging are 10:30 pm to 7 am. This off-peak period typically sees less energy consumption, providing a favourable environment for EVs to recharge without adding significant load to the grid.

It is worth mentioning that an alternative to this period would be during the peak solar PV generation period, when energy market prices are low (also being an off-peak period), even though these customers do not have their own solar PV systems, which brings a wider energy system benefit.

The final step involves distributing the reduced load (the energy shifted out of peak hours) evenly across the identified off-peak hours. This ensures that EVs are recharged in a balanced manner during the off-peak window. By averaging the load shift across these hours, the methodology avoids creating new demand spikes in the grid, further supporting overall system stability. The system stability is related to peak load management and active operational network management. The former focuses on handling extreme, short-term events where the demand on the grid exceeds normal levels. The latter, on the other hand, is a continuous and real-time process that involves balancing supply and demand under normal operating conditions. In summary, peak load management is reactive and event-driven, whereas active operational network management is proactive and ongoing. Both are essential for grid stability.

In summary, this methodology provides a structured framework for using V2B/V2H technology to smooth out demand fluctuations and support grid stability. By identifying peak and off-peak periods, determining a load shift proportion, and carefully calculating energy requirements, this approach allows for targeted peak load reduction through EV discharging. In turn, EV charging is shifted to more favourable off-peak hours in a controlled and averaged manner, ensuring that the grid remains balanced and efficient. The design is flexible, allowing for different load shift scenarios (e.g., 5%, 10%, 15% as analysed in the following section), and can be tailored to specific grid needs or conditions.

5. V2B/V2H results: scenario analysis

In this section, we examine the impacts of V2B/V2H on the meter load profiles and EV charging profiles. We would like to highlight that the meter load profiles used represent a “pre-electrification of space heating/cooling” position, and that these load profiles are likely to change, in many cases materially, because of the move away from gas to electricity. Hence, the analysis may not be reflective of actual future conditions.

Before applying our V2B/V2H methodology, in Fig. 5, we firstly present the aggregated EV charging profile and meter load profile during the whole week, weekday, and weekend (in black, blue, and red lines, respectively), based on the filtered non-PV customer dataset with a charger mix of 87.5% 2.3kW charger, 5.3% 3.7kW charger, and 7.2% 7.4kW charger. Note that all aggregated EV charging consumption and meter load are averaged over the year. For the EV charging profile in Fig. 5, the demand is lower in the early morning hours (0 to 6 AM) and then gradually increases throughout the day, peaking in the late evening around 9 to 11 PM. During the weekends, the charging demand appears to be lower in the early morning but higher in the evening compared to weekdays. Weekdays show a more consistent and slightly higher demand throughout the day compared to weekends. For the meter load profile, the overall meter load is relatively low during the night (midnight to early morning). It is noteworthy that domestic electric hot water heating loads have typically been during the night time/early morning periods. The smart meter dataset used in this instance may not be reflective of these types of customers. However, it might be considered in the future analysis as this may affects the load profile. The meter load begins to increase around 6 AM, peaking twice: once in the late morning around 9 to 10 AM, and again in the evening around 6 to 9 PM. The weekend profile shows a more pronounced peak in the evening, and the load is generally higher during the late morning and early afternoon compared to weekdays. Weekdays exhibit a double peak pattern, with a significant increase in load in the morning and another in the evening. The variations between the weekday and weekend profiles suggest differences in customer behaviour and load usage patterns, with weekend EV charging and meter loads peaking at different times compared to weekdays.

As discussed in the disaggregation report for non-PV customers, we here would like to acknowledge that this charger mix does not necessarily reflect the actual mix in the real world as the processed data can be biased due to limited sample size.

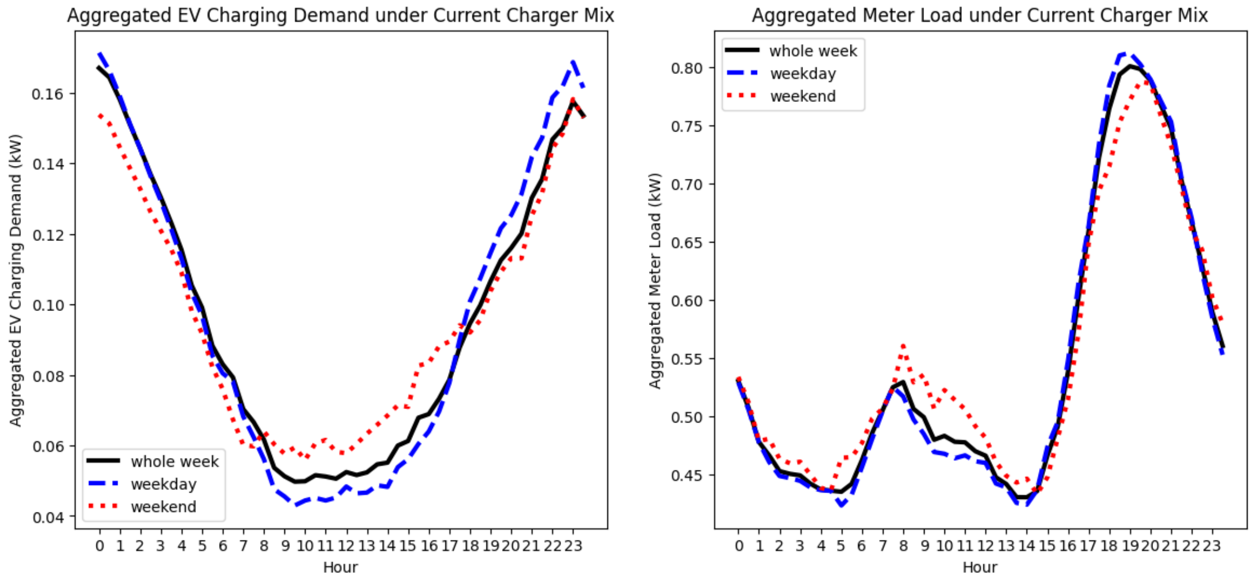

Figure 5 Aggregated EV charging demand per customer and aggregated meter load per customer based on the current charger mix

According to the report released by the Ausgrid [11], the daily maximum value of EV charging demand (i.e., the value of the Y-axis in the left figure of Fig. 5) is normally between 0.3 kW and 0.5kW. We found that, as more non-PV customers update their 2.3kW chargers to high-powered chargers, e.g., 3.7kW and 7.4kW chargers, the scale of both the aggregated EV charging demand and the meter load per customer increase as depicted in Fig. 6, where the charger mix is changed to – 0% of 2.3kW charger, 50% of 3.7kW charger, and 50% of 7.4kW charger. Compared to Fig. 5, both EV charging demand and meter load increase more sharply during peak hours, reflecting the higher charging power of the chargers in this mix. While the original charger mix in Fig. 5 results in a smoother demand profile, this shaper evening peak may pose challenges for grid stability if not managed properly.

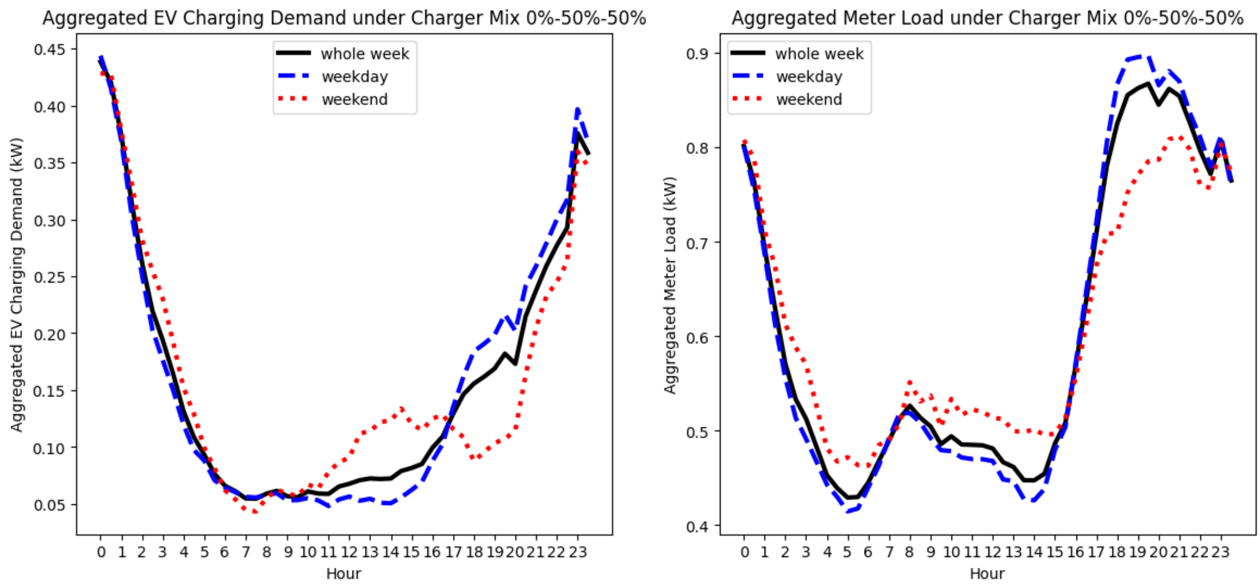

Figure 6 Aggregated EV charging demand per customer and aggregated meter load per customer based on the charger mix of 0% of 2.3kW charger, 50% of 3.7kW charger, and 50% of 7.4kW charger.

Therefore, in the following analysis, we apply our V2B/V2H methodology to perform peak load shifting with the help of EV discharging, with the aim of investigating how EVs contribute to shaping the load profile under varying charger mixes. Three load shift scenarios are synthesised – 10%, 15%, and 20% load shifts. Moreover, given that EV customers may have more opportunities to charge their EVs during daytime at weekends compared to weekdays, we thus extend the duration of EV charging shift for weekend – from 10:30 pm to 12 am, while keeping the same duration for weekday, i.e., from 10:30pm to 7am. The aggregated EV charging and meter load profiles before and after load shift for all three scenarios are shown from Fig. 7 to Fig. 9. Specifically, for each figure, the solid orange and solid green lines represent the demand profiles before load shift for weekday and weekend, respectively, and the dotted orange and dotted green lines represent the profiles after load shift for weekday and weekend, respectively.

For the 10% peak load shift scenario, i.e., Fig. 7, the shift from peak to off-peak hours shows a noticeable reduction in the charging demand during peak times, with a corresponding increase in demand during the compensatory charging period. The reduction is moderate, reflecting the 10% shift, which provides some alleviation of peak demand without drastically altering the overall load profile. Similarly, the aggregated meter load shows a reduction during peak hours, with a slight increase during the compensatory charging period. The change is subtle, maintaining a relatively stable load curve with less pronounced peaks and troughs.

The 15% shift results in Fig. 8 in a more significant reduction in EV charging demand during peak hours compared to the 10% scenario. The compensatory charging demand during off-peak hours, particularly between 10:30 pm and 7 am, shows a more pronounced increase, reflecting the higher shift percentage. The meter load reduction during peak hours is more substantial in this scenario. The increase in load during the off-peak compensatory period is also more pronounced, indicating that the 15% shift introduces a more aggressive load redistribution, smoothing the peak more effectively.

The most aggressive shift, at 20% in Fig. 9, results in a significant reduction in charging demand during peak hours. The compensatory charging period sees the largest increase in demand, with the load curve showing a distinct rise during off-peak hours, particularly late at night and early in the morning. The 20% shift produces the most substantial reduction in meter load during peak hours, with the corresponding increase during off-peak hours being the most pronounced among the three scenarios. This shift effectively flattens the peak load, creating a more even distribution of energy demand throughout the day.

Comparing the three scenarios, we summarise the following insights:

- Peak load reduction: As the peak load shift percentage increases from 10% to 20%, the impact on both the EV charging demand and meter load during peak hours becomes progressively more significant. The 10% shift provides a modest reduction, which is suitable for scenarios where grid stability is of concern but does not require drastic intervention. The 15% and 20% shifts, on the other hand, offer more substantial peak load reductions, which could be more beneficial in high-demand situations or where grid capacity is limited.

- Redistribution of off-peak hours: With each increase in the peak load shift percentage, there is a corresponding increase in demand during off-peak hours. The 20% scenario, in particular, introduces a significant load into the off-peak period, particularly during the late-night hours. While this helps to flatten the peak, it may require careful management to avoid creating new demand spikes during these off-peak times.

- Weekday vs. weekend: The results show that the EV charging demand and meter load profiles for weekdays and weekends behave similarly under each shift scenario, though the absolute values differ due to differences in typical daily routines. The additional charging period provided on weekends (10:30 pm to 12 am) helps to accommodate the altered usage patterns, ensuring that EVs are adequately charged while still contributing to peak load reduction.

In summary, increasing the peak load shift percentage from 10% to 20% progressively enhances the effectiveness of V2H in reducing peak demand. However, higher shift percentages also require more strategic management of the compensatory load during off-peak hours to maintain overall grid balance. The selection of the appropriate shift percentage should therefore be based on the specific grid conditions and the overall objectives of the load management strategy.

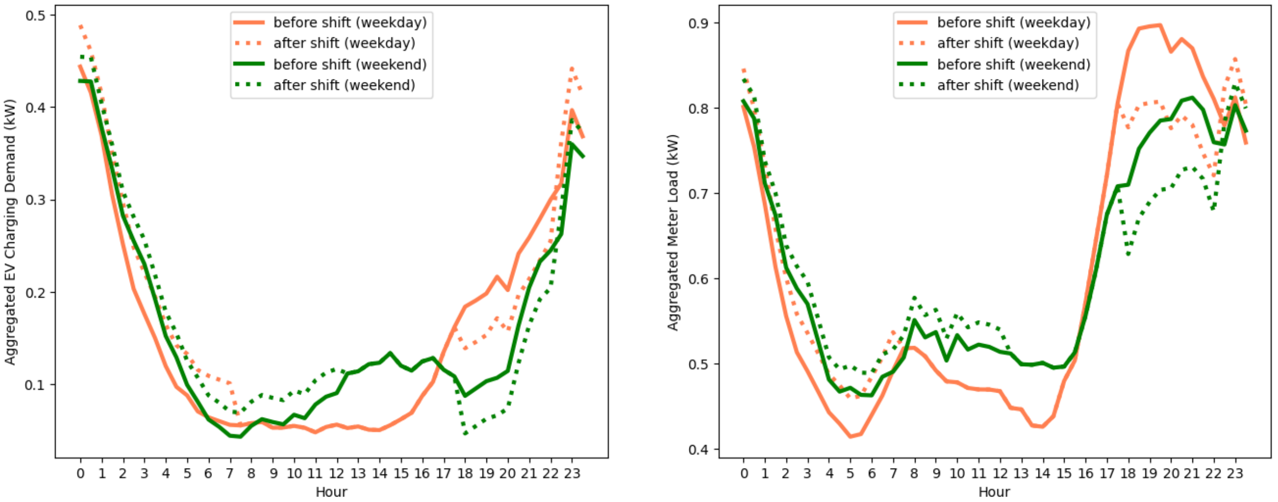

Figure 7 Aggregate demand profiles before and after 10% peak load shift via EV discharging

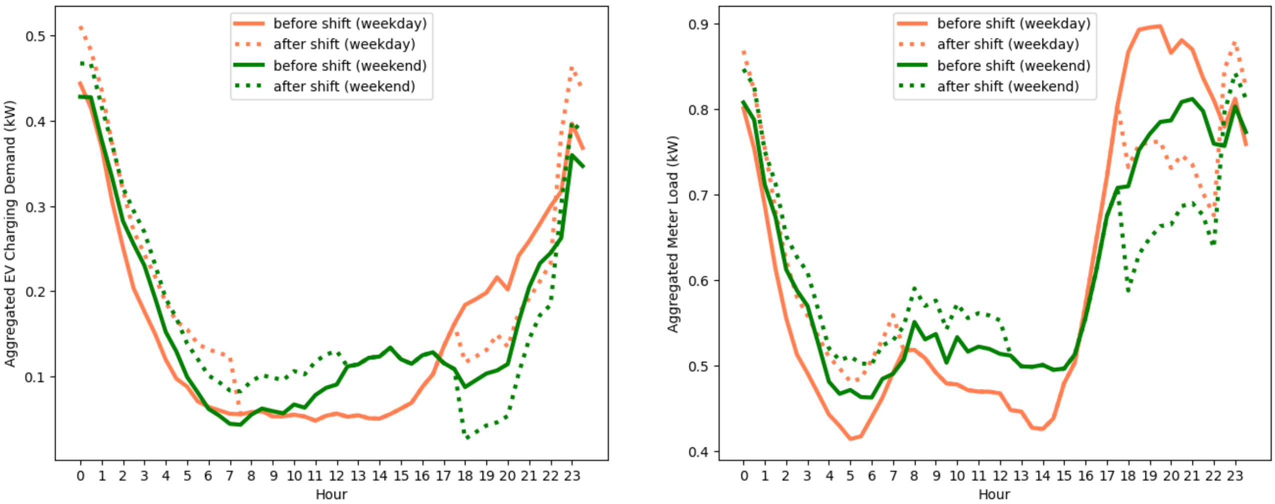

Figure 8 Aggregate demand profiles before and after 15% peak load shift via EV discharging

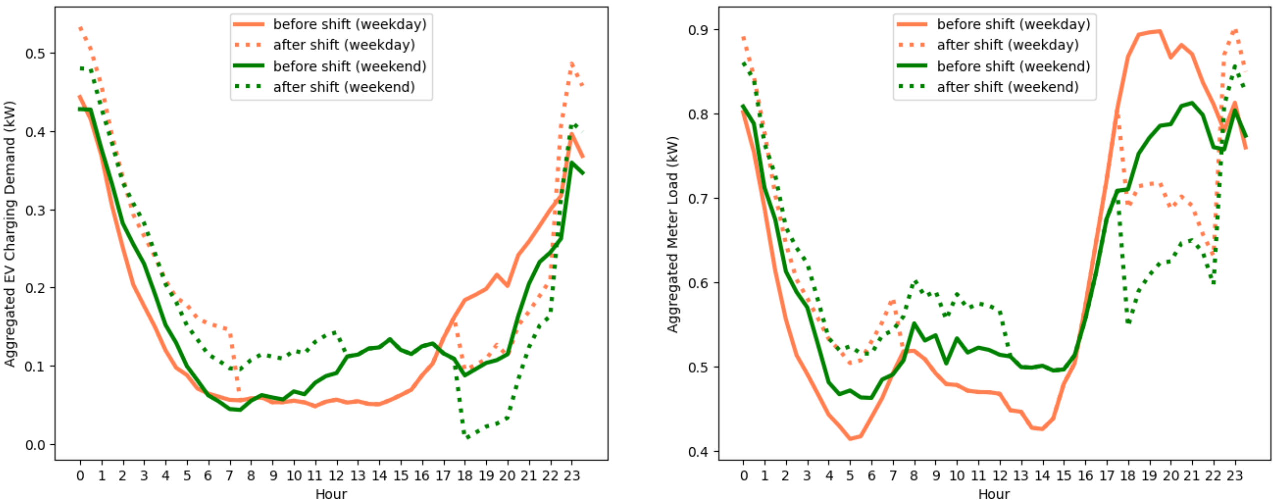

Figure 9 Aggregate demand profiles before and after 20% peak load shift via EV discharging

Conclusion

This report underscores the transformative potential of vehicle-to-building/vehicle-to-home (V2B/V2H) technology in modern energy grids. As electric vehicles (EVs) continue to proliferate, their role in not only consuming but also supplying energy is becoming increasingly vital. By enabling EVs to discharge their stored energy during periods of peak demand, V2B/V2H technology provides a promising solution to one of the key challenges faced by today's energy systems: maintaining grid stability in the face of rising electricity consumption and greater reliance on intermittent renewable energy sources.

The analysis in this report demonstrates that modest levels of load shifting, such as 5%, 10%, and 15%, can reduce peak load demand. It is important to note that the other primary benefit of V2B/V2H lies in its ability to support system stability, such as frequency regulation during short-term events, which could be a potential research direction in the future.

By redistributing EV charging to off-peak hours, V2B/V2H systems offer a flexible and dynamic tool for balancing supply and demand in real time. We acknowledge that, in this report, our analysis does not consider shifting EV charging into the peak solar generation hours, where there may be wider system benefits compared to overnight charging, which could also be future research directions.

This study also highlights the importance of carefully crafted methodologies for simulating V2B/V2H deployments. By using non-PV customers' meter load and aggregated EV charging profiles, this report has developed a framework that can simulate realistic V2B/V2H scenarios and provide valuable insights into the benefits and challenges of implementing these systems at scale. While the simulations in this report offer a theoretical exploration of V2B/V2H potential, they provide a critical foundation for future research and real-world deployment.

The findings of this report have important implications for a range of stakeholders, from utilities and policymakers to industry leaders and rely on the willingness and capability of customers to participate. As the energy landscape continues to evolve, the integration of V2B/V2H technology can provide significant advantages in terms of grid reliability, cost reduction, and sustainability. However, to fully realise these benefits, careful planning and strategic deployment will be essential. As the framework presented in this report demonstrates, V2B/V2H systems can be a key component of a more flexible and resilient energy future—one in which EVs serve not only as modes of transportation but as active participants in the management and stabilisation of the grid.

In conclusion, the widespread adoption of V2B/V2H technology represents a significant opportunity to reshape the way we think about energy management and transportation. By transforming EVs into mobile energy storage units capable of both consuming and supplying electricity, V2B/V2H systems can help create a more sustainable, reliable, and efficient energy grid for the future.

References

[1] Mumtahina, Umme, Sanath Alahakoon, Peter Wolfs, and Jiannan Liu. 2024. "Constructing Australian Residential Electricity Load Profile for Supporting Future Network Studies" Energies 17, no. 12: 2908. https://doi.org/10.3390/en17122908
[2] David Borge-Diez, Daniel Icaza, Emin Açıkkalp, Hortensia Amaris, Combined vehicle to building (V2B) and vehicle to home (V2H) strategy to increase electric vehicle market share, Energy, Volume 237, 2021, 121608, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2021.121608. https://www.sciencedirect.com/science/article/pii/S0360544221018569.
[3] Zhanwei He, Javad Khazaei, James D. Freihaut, Optimal integration of Vehicle to Building (V2B) and Building to Vehicle (B2V) technologies for commercial buildings, Sustainable Energy, Grids and Networks, Volume 32, 2022, 100921, ISSN 2352-4677, https://doi.org/10.1016/j.segan.2022.100921. https://www.sciencedirect.com/science/article/pii/S2352467722001667.
[4] Villante C. A Novel SW Tool for the Evaluation of Expected Benefits of V2H Charging Devices Utilization in V2B Building Contexts. Energies. 2023; 16(7):2969. https://doi.org/10.3390/en16072969.
[5] Kai-Yun Lo, Jian Hern Yeoh, I-Yun Lisa Hsieh, Towards Nearly Zero-Energy Buildings: Smart Energy Management of Vehicle-to-Building (V2B) Strategy and Renewable Energy Sources, Sustainable Cities and Society, Volume 99, 2023, 104941, ISSN 2210-6707, https://doi.org/10.1016/j.scs.2023.104941. https://www.sciencedirect.com/science/article/pii/S2210670723005528.
[6] M. J. Aparicio and S. Grijalva, "Economic Assessment of V2B and V2G for an Office Building," 2020 52nd North American Power Symposium (NAPS), Tempe, AZ, USA, 2021, pp. 1-6, doi: 10.1109/NAPS50074.2021.9449799.
[7] Nathaniel S. Pearre, Hajo Ribberink, Review of research on V2X technologies, strategies, and operations, Renewable and Sustainable Energy Reviews, Volume 105, 2019, Pages 61-70, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2019.01.047. https://www.sciencedirect.com/science/article/pii/S1364032119300516.
[8] Muhammad Abdul Rehman, Muhammad Numan, Hassaan Tahir, Usama Rahman, Muhammad Waseem Khan, Muhammad Zubair Iftikhar, A comprehensive overview of vehicle to everything (V2X) technology for sustainable EV adoption, Journal of Energy Storage, Volume 74, Part A, 2023, 109304, ISSN 2352-152X, https://doi.org/10.1016/j.est.2023.109304. https://www.sciencedirect.com/science/article/pii/S2352152X23027020.
[9] Bassam Zafar, Sami Abdullah Ben Slama, PV-EV integrated home energy management using vehicle-to-home (V2H) technology and household occupant behaviors, Energy Strategy Reviews, Volume 44, 2022, 101001, ISSN 2211-467X, https://doi.org/10.1016/j.esr.2022.101001. https://www.sciencedirect.com/science/article/pii/S2211467X2200195X.
[10] Mahdi Ghafoori, Moatassem Abdallah, Serena Kim, Electricity peak shaving for commercial buildings using machine learning and vehicle to building (V2B) system, Applied Energy, Volume 340, 2023, 121052, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2023.121052. https://www.sciencedirect.com/science/article/pii/S0306261923004166.
[11] Ausgrid - Revised proposal - EVenergi - Att. 5.7.5 - EV owner demographics and behaviours - 30 Nov 2023. https://www.aer.gov.au/documents/ausgrid-revised-proposal-evenergi-att-575-ev-owner-demographics-and-behaviours-30-nov-2023.

Faculty of XXXXX
Monash University
Wellington Road
Clayton, Victoria 3800
Australia

T: +61 3 XXXX XXXX