Western Australia Electric Vehicle Owners

Behaviours, Attitudes, and Policy

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WESTERN AUSTRALIA

Executive Summary

Electric Vehicles (EVs) are a key pillar to meet the Western Australian (WA) Government's commitment to achieving net-zero greenhouse gas emissions by 2050 but are poised to significantly impact the energy landscape. Their unique usage patterns and requirements can be both a significant opportunity to soak up excess solar generation during the middle of the day and a threat to grid stability with the potential to exacerbate peak demand.

The electricity grid in WA is unique compared to those in the eastern states, it is geographically and electrically isolated, with no interconnections to other transmission systems, and has high solar penetration, a large low-density demand footprint and distinct rules and regulations.

Prior to this, the demographics, charging behaviours, and perceptions of WA's EV owners have not been studied. As the uptake of EVs increases in WA however, the need for dedicated research is becoming more crucial. In this study, we surveyed 1,253 Western Australians, including 461 EV owners and 792 non-EV owners to understand their demographics, purchasing decisions and motivations, charging behaviours and views on different mechanisms to manage EV charging.

We use these findings, as well as the insights from 8 interviews with energy and transport experts in the WA and Federal Governments and community advocacy groups and a review of global and Australian work in this space to form policy recommendations.

Key Findings

- EV owners in WA generally fit the early adopter profile that has been seen globally - they are predominantly male, 45-54 years of age, living in houses, full-time or retired, and have a high household income. This is not representative of the general public and therefore the charging patterns and perspectives will likely shift with increasing uptake.
- A fifth of EV owners in WA engage in daily EV charging habits, but many are only charging as needed every 2-3 days.
- WA EV owners, like other Australian and global EV owners, overwhelmingly reported that they charge at home (84%), with some charging at public charging stations (10%), and the remaining respondents charging at their workplace (6%).
- WA EV owners have a relatively high adoption of dedicated Level 2 chargers (55%) versus a basic cable charger (41%) compared to other global studies, the likelihood of which increases with income levels. Level 2 chargers (7kW-22kW) are essential as destination chargers to enable smart charging as Level 1 chargers (standard wall-plugs around 2.4kW) aren't fast enough to provide options to shift charging sessions outside of the peak.

- WA EV owners predominately begin charging during the day (57%) or overnight (27%). Charging during the day is strongly linked to solar PV ownership, with non-PV owners less focused on aligning charging with solar hours. This aligns with other Australian studies. WA EV owners are likely to also own solar PV – 75% of the EV owners in the survey had solar.
- WA EV owners are more likely to be under a TOU tariff than the general population, but still 57% of EV owners surveyed are under a flat rate tariff.
- Time of use (TOU) tariff users are more likely to charge outside peak periods compared to those under a flat rate. TOU tariff users distribute their charging more evenly between daytime and overnight charging than non-TOU tariff users.
- Over 70% of WA EV owners agreed or somewhat agreed with all the key mechanisms to manage EV charging, including automated charge management using smart chargers, TOU tariffs, direct messaging, and remote management by energy providers, while also being willing to change their behaviours in response to these mechanisms, such as shifting or reducing charging times, or investing in smart chargers.
- Experts most-cited recommendations to control/regulate EV charging behaviours included the implementation of TOU tariff policies, EV charging policy and regulatory frameworks, various forms of smart energy management systems and educational and awareness campaigns.

Recommendations

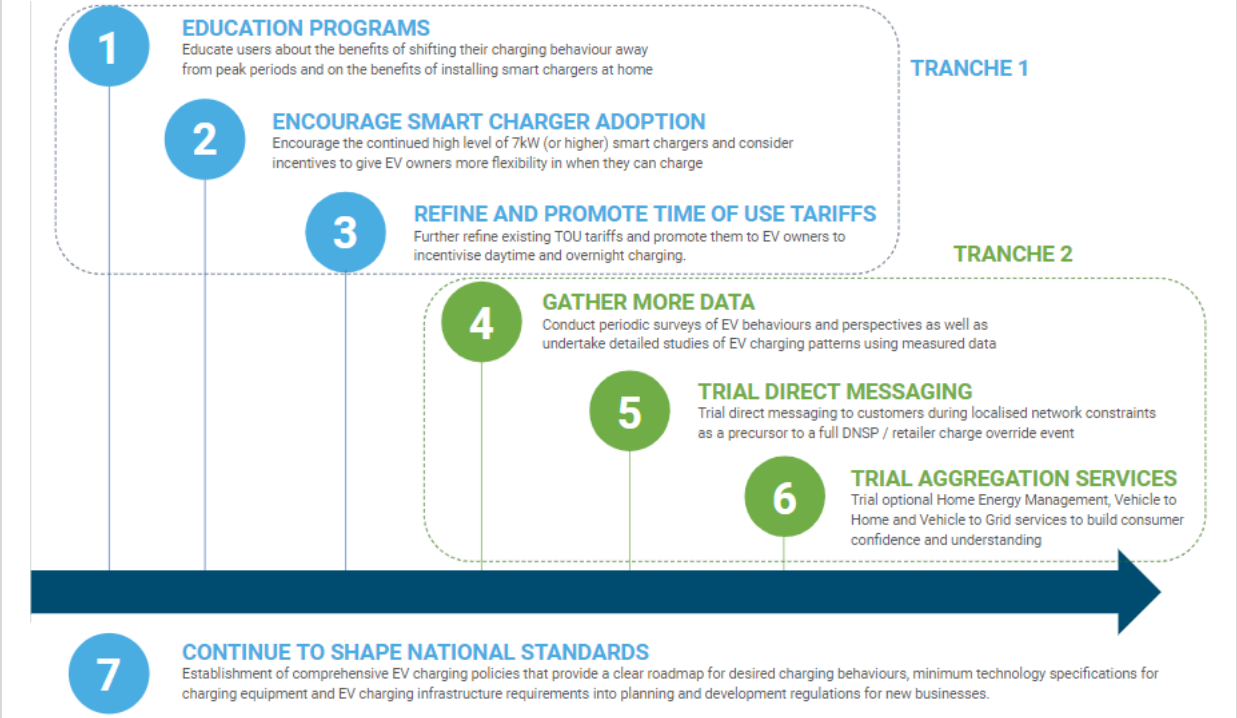
The charging behaviours and perspectives of WA early adopters are highly encouraging; however, it is not a given that this behaviour will continue if left unmanaged. The WA government has a role to play to shape and guide the purchasing decisions and behaviours of the current and next cohort of EV buyers to ensure efficient interactions with the electricity grid moving forward.

Evenergi recommends seven key action items in two tranches, as per Figure 1.

The first tranche contains three policy mechanisms which together will largely drive EV charging behaviours into the periods of the day that will maximise the benefits that EVs can play in supporting the energy transition.

1. Education programs: EV owners seem happy to adopt smart charging behaviours and TOU tariffs when they understand the benefits this can provide to themselves and the energy transition. Educate future EV owners on the benefits of and how to use smart chargers and TOU tariffs.
2. Encourage smart charger adoption: larger 7kW (or higher) smart chargers enable the EV owner to focus charging into the times of day when it is most suitable to the grid, and also the cheapest times to charge - aligned to the solar window and overnight off-peak periods. The smart nature, including remote management capability, of these chargers also enables more advanced charging coordination at a grid scale as well as energy arbitration and potentially ancillary grid services in the fullness of time. Promoting the installation of dedicated smart chargers that meet minimum technological requirements allowing for future remote charging management enables a range of charging behaviours that assist the grid. Financial incentives should be considered for early adopters to mitigate the higher upfront costs of smart chargers as part of EV trials (see Tranche 2).
3. Refine and promote time of use tariffs: implementing TOU tariffs for educated EV owners was almost unanimously accepted. While material benefits exist for EV owners with TOU tariffs, the same benefits are not achievable without a large, flexible load such as an EV. This makes the purchasing of an EV, and installation of a smart charger the ideal time to encourage an energy user to convert to a TOU tariff. As there is a real benefit to the EV owner, we believe TOU tariff adoption could be a requirement of EV charging-related incentive schemes without material impact on EV adoption or sentiment of EV owners. The opportunity to opt-out after a trial arrangement may be more agreeable for new EV owners and likely to achieve a very similar outcome.

Figure 1: Policy recommendation staging



The second tranche contains three policy mechanisms which will drive knowledge gathering and inform future policy. More intelligent energy management systems including charging control, aggregation services and home energy management had widespread approval but there is a proportion of EV owners and expert stakeholders who were hesitant and therefore we recommend the following surveys and trials:

4. Gather more data: conduct periodic user surveys and in-depth charging pattern studies as EVs move into the mainstream population to refine policy strategies.
5. Trial direct messaging: to customers during localised network constraints to either stop or start charging to determine effectiveness. This was accepted by the EV owners surveyed, but they noted it might be an inconvenience or ineffective.
6. Trial aggregation services: to build consumer confidence and understanding and explore the potential benefits to the EV owner and the grid, including external EV charging management via smart chargers and bi-directional charging aggregation services.

The final and seventh recommendation is to:

7. Continue to shape national standards: continue to work with federal and state governments to shape national standards for EV charging infrastructure and grid policy.

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Glossary

Table 1: Glossary of terms	
AMI	Advanced metering infrastructure
BEV	Battery electric vehicle
DER	Distributed energy resources
DMIRS	Department of Mines, Industry Regulation and Safety
DNSP	Distribution network service provider
DOE	Dynamic operating envelope
EPWA	Energy Policy WA
EV	Electric vehicle
HEMS	Home energy management system
NEM	National electricity market
OCPP	Open charge point protocol
PHEV	Plug-in hybrid electric vehicle
PV	Photovoltaic (as it relates to solar panels)
TOU	Time of use tariffs
V2G	Vehicle-to-grid
VPP	Virtual power plant
WA	Western Australia
WEM	Wholesale electricity market

1 Introduction

Electric Vehicles (EVs) are poised to significantly impact the energy landscape. The electricity grid in Western Australia (WA) is unique compared to those in the eastern states, it is geographically and electrically isolated, with no interconnections to other transmission systems, and has high solar penetration, a large low-density demand footprint and distinct rules and regulations. This, coupled with the under-studied charging behaviours of WA's EV owners, creates a compelling need for dedicated research. The Western Australian (WA) Government is proactively assessing strategies to mitigate potential grid challenges posed by EV charging.

1.1 Context

The electrification of transport is a key pillar to meet the Western Australian Government's commitment to achieve net-zero greenhouse gas emissions by 2050, as outlined in the *Western Australian Climate Policy* [1]. To achieve this, the Western Australian Government's approach to the electrification of transport is outlined in The *State Electric Vehicle Strategy* (EV Strategy) [2]. Electric vehicles interact with both the transport and power sectors and therefore need to be understood in the context of the energy transformation underway in Western Australia.

The *Distributed Energy Resources (DER) Roadmap* [3] highlights the clear and present challenge posed by the rapid uptake of rooftop solar photovoltaics (PV) and other forms of DER (including EVs), and outlines a future where DER is effectively and efficiently integrated into the power system, and the actions required to achieve this. Notably, the WA DER market is aiming to start in late 2025.

The subsequent Electric Vehicle Action Plan [4] was developed to fulfil Action 16 of the DER Roadmap and presents an integrated set of actions designed to deliver a future where EVs contribute to a safe, reliable, and efficient electricity system while playing a role in accelerating Western Australia's transition to a low-carbon future. Action 25 of the *EV Action Plan* identified the need to understand consumer preferences and behaviours regarding use of EVs.

The context of the WA electricity grid is vital to consider when designing EV policy. EVs in the SWIS will be operating in a non-contestable environment, where the uptake rates of time of use (TOU) tariffs have been historically quite low at approximately 3% of the general population[1]. Additionally, EVs will strongly interact with solar PV which will influence the EV owner's charging decisions as well as their baseline knowledge level about the electricity grid

[1] As at October 2023, there are around 32,000 residential customers under a Synergy TOU tariff compared to approximately 1.1 million residential customers in the SWIS. There are 8,500 customers under currently offered products, with uptake accelerating recently.

and energy management. As WA has a high level of rooftop solar PV uptake, adding approximately 190 MW of generation capacity in 2021 [5], the behavioural differences in EV owners with and without PV needs to be understood and incorporated into any policy considerations.

1.1.1 Key concerns of EVs for the WEM

EVs are a unique form of DER that warrant special consideration due to their scale (in terms of energy consumption and storage) and mobility. Additionally, the anticipated flexibility and smart functionality of EVs mean there are opportunities to provide network benefits when utilised as a dispatchable, controllable load.

At a network level, electrifying transport is expected to total electricity consumption by 40% once complete according to the Electric Vehicle Council (2023 presentation). The key is how much impact will they have on peak demand in the low and medium voltage networks in the SWIS. Western Power used its 'Grid Transformation Engine' ('GTEng') Modelling Tool to understand these impacts and associated costs. Initial findings from GTEng modelling suggests that medium voltage network substations and feeders will require augmentation to accommodate the increased load, particularly if large portions of the vehicle fleet charge coincident with the peak or one another.

Western Power modelling shows that substantial benefits may exist from diversifying EV charging behaviour, determining that priority should be given to:

1. shifting charging patterns to the middle of the day (when system load is low and output from rooftop solar is plentiful);
2. prioritising charging outside the 3pm-9pm system peak demand period; and
3. minimising the creation of additional coincident peak charging periods that result in localised network constraints.

As EVs are a form of customer-owned DER, there is additional work required to understand the relationship between EV owners and the power system. EV customers vary in their levels of knowledge and engagement, preferences, and ability to respond to incentives. As such, it will be important to understand these in designing a regulatory framework and incentives to promote the most efficient use of the existing network, as well as in preparing for greater participation of EVs in the future.

1.1.2 Synergy residential tariffs

EV owners who charge at home in the WEM will likely be non-contestable customers serviced by Synergy and have the choice of three currently offered electricity tariffs in Table 2: one flat rate tariff and two time-of-use (TOU) tariffs. [2] Most residential customers are under a flat rate tariff compared to a TOU tariff (3%), however our surveyed showed a high proportion (57%) of EV owners are under a TOU tariff.

Compared to the Home Plan which has the same rate of 30.812c/kWh across the entire day, the Midday Saver and Electric Vehicle Add On plans offer lower rates overnight and during the day and higher tariffs during the peak periods in the late afternoon-evening. EV owners under the EV TOU tariff will therefore be incentivised to charge in the following order:

1. during the day from 9am to 3pm (super off-peak)
2. overnight from 11pm-6am
3. during the off-peak periods between 6am-9am, and 9pm-11pm
4. during the peak periods between 3pm-9pm.

Despite the high incentive to charge during the day in the super off-peak period, EV owners under the EV Add On tariff are still incentivised to charge overnight if they cannot charge during the middle of the day or if not convenient. The overnight rate is still lower than other times of the day and lower than the flat rate under the Home Plan. Therefore, we would expect to see a blend of charging behaviours incentivised by this tariff.

EV owners with PV systems are expected to still have the same incentives - ideally charge during the day using their own surplus solar or super off-peak rates, but when this is not available then charge overnight and not in the peak grid periods.

[2] There are around 32,000 residential customers under a Synergy TOU tariff compared to approximately 1.1 million residential customers in the SWIS. Around 70 per cent are currently on legacy TOU tariffs which are no longer offered. Synergy is reviewing these products and intends to migrate these grandfathered customers to the currently offered TOU tariffs.

Table 2: Current Synergy residential tariffs (cents / kWh) as of 10 October 2023			
Time period	Home Plan (A1 tariff) (Flat Rate) (c/kWh)	Midday Saver (TOU) (c/kWh)	Electric Vehicle Add On (TOU) (c/kWh)
Super Off Peak (9am to 3pm)	30.812	8.20	8.20
Peak (3pm to 9pm)		51.25	51.25
Overnight (11pm to 6am)			18.45
Off Peak (9pm to 9am)		22.55	
Off Peak (6am to 9am / 9pm to 11pm)			22.55

1.1.3 Understanding Western Australian EV Owners

There have been previous studies, trials, and reviews of EV owner's behaviours and perspectives focussed on customers in the National Electricity Market (NEM). However, to date, there has been no empirical research undertaken to validate if these findings apply to Western Australian EV owners.

EV uptake in Western Australia is still in its early stages, accounting for only 2.8% of new vehicle sales in 2022 [6]. While current WA EV owners may not be representative of the future fleet once uptake reaches mainstream adoption, it is important to understand their charging behaviours and perspectives for the development of future policy and messaging which promote efficient use of the network, while ensuring customer needs are met.

1.2 Purpose of this project

This project aims to garner insights on Western Australian EV owners' local charging practices, attitudes towards charging management mechanisms, and to identify effective policy mechanisms to prepare and secure the power grid from other states and international markets. The effectiveness of these mechanisms is gauged by their success in modifying charging behaviours to avoid peak electricity demand periods.

The objectives of this project are to:

1. Obtain an understanding of actual charging behaviour and attitudes towards different charge management mechanisms in WA via direct surveys
2. Review research from interstate and overseas to understand similarities in behaviours and identify successful policy mechanisms and strategies that have been used elsewhere that would be relevant for consideration in WA
3. Provide insights on the challenges and opportunities evident in WA for the SWIS and recommendations based on best practices on the best ways to tackle challenges and leverage opportunities.

Based on the prior research and analysis, this report will help form policy recommendations in support of efficient use of the power system for residential EV charging, consistent with the Western Australian State Government's commitment to reach net zero greenhouse gas emissions by 2050 and Western Australia's Energy Transformation Strategy activities, including:

1. Distributed Energy Resources (DER) Roadmap;
2. DER orchestration: Roles and Responsibilities framework; and
3. Electric Vehicle Action Plan: Preparing Western Australia's electricity system for EVs.

This report provides an overview of the insights from the two previous reports as well as recommendations on optimal charging policies and strategies best suited to the WA context. It also provides insights into how these policy recommendations might align with current policies and initiatives and inform policy in the future.

1.3 Study methodology

This report provides a summary of two previous internal reports: a rapid literature review of global EV charging behaviours and policy, and a research report containing a survey of the charging behaviours and perspectives of 1,253 Western Australians.

The literature review combined the learnings of over 100 papers relating to Electric Vehicle (EV) technologies, uptake rates, user charging behaviours, and government policies to guide charging behaviours that are more favourable to the grid.

The research report was completed in two parts:

1. An online survey of 1,253 Western Australians on their behaviours and perspectives including 461 EV owners and 792 non-EV owners, between 6 May 2023 and 6 June 2023.

2. 8 structured interviews with energy and transport experts from WA and Federal Government and community advocacy groups investigating their main concerns about EVs and their recommendations to control and/or regulate their charging.

1.4 Structure

Section 2 discusses the key findings from the literature review. The survey results are presented in Section 3 and compared to findings from the literature review. Then the results from the interviews of key stakeholders are summarised in Section 4. Finally, key policy recommendations are given in Section 5.

2 Global and Australian EV charging behaviours and policies

In the first stage of this project, over 100 papers were reviewed relating to EV technologies, uptake rates, user charging behaviours, and government policies to guide charging behaviours that are more favourable to the grid. These papers were combined with prior experience of Evenergi to answer these three key research questions:

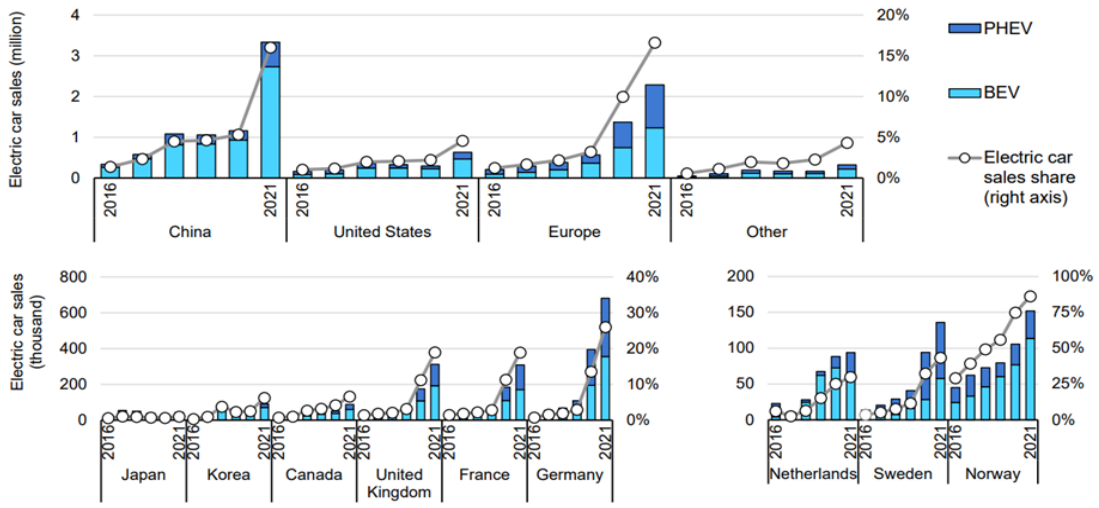
1. What are the typical charging behaviours in markets with large EV uptake? How does this compare to Australian charging behaviours?
2. What policy positions are governments taking in the more mature EV markets and in Australia?
3. What policies or services are found to change EV charging behaviours to align with grid needs?

The following sections highlight the key findings from this literature review.

2.1 EV uptake and early adopters

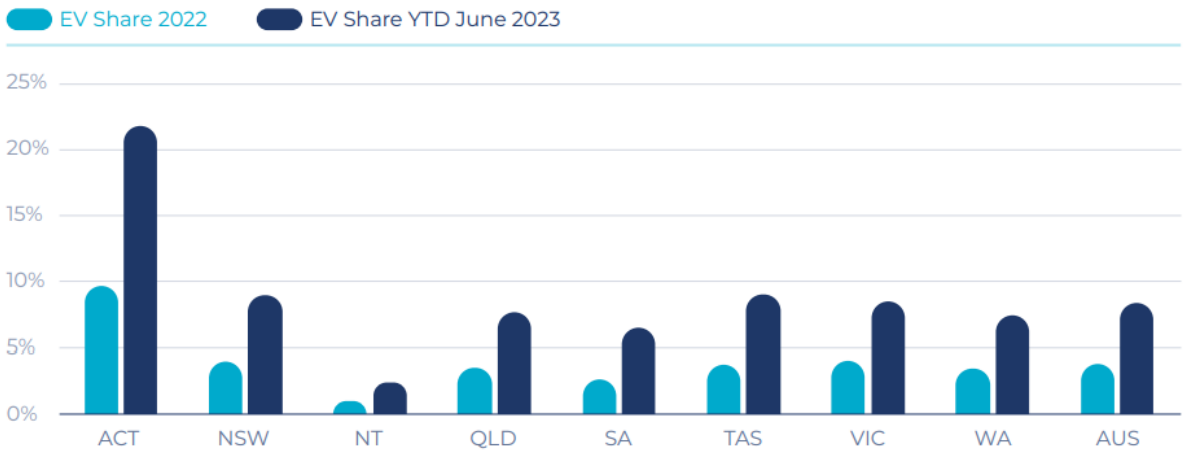
The global electric car stock has been increasing rapidly over the past 10 years. There were over 26 million electric cars in 2022, compared to just 10 million in 2020 [7]. The rate of EV adoption across each country radically differs, as shown in Figure 2. Norway has long been the world leader in EV uptake. In 2022, 79.3% of all new passenger vehicles sold were EVs, according to the Norwegian Road Federation [8]. Other large EV markets include Germany, China, and the United States (particularly California).

Figure 2: Electric car registrations and sales share of the largest EV markets *(Source:* [9]*)*



Australia has had a low adoption rate compared to these countries at 3.8% of new vehicle sales in 2022 [10], and Western Australia slightly lower than the Australian average, as shown in Figure 3.

Figure 3: New EV sales share in Australia by state as at July 2023 *(Source:* [10]*)*



Australian EV uptake is, however, growing rapidly, already lifting to 8% of new sales in April 2023 [11]. With the recent introduction of state and federal EV targets and plans like the National EV Strategy [12], the State Electric Vehicle Strategy for Western Australia [2] and subsequent EV Action Plan [4], and the ongoing consultation on national fuel efficiency standards [13], EV manufacturers are expected to have more certainty and therefore bring more EV models to Australia, further increasing uptake.

Despite the rapid uptake of EVs, they still account for a relatively small proportion of the overall vehicle market. This is particularly true in Australia. Consequently, the bulk of research conducted on EV behaviours primarily represents the patterns and practices of early adopters or owners belonging to the early majority.

Early adopters are defined as the first consumers of new technologies, and they typically have distinct demographics and motivations for using the new technology compared to the general population. Globally EV early adopters tend to be predominantly highly educated, affluent, male, and often retired [14]. A similar demographic trend can be observed in studies of current EV owners in Australia [15]–[17], implying that the Australian research predominantly captures the behaviours of early adopters, rather than the broader population.

This demographic concentration highlights a crucial point for policy consideration. While it is necessary to formulate policy that caters to the needs and behaviours of current owners, policymakers should be aware that these behaviours are likely to evolve over time. As EV technology becomes increasingly mainstream and penetrates broader demographics, user behaviours and requirements may shift substantially. Therefore, policy design must account for the current landscape but remain adaptable, anticipating the inevitable changes that will occur as EVs transition from the domain of early adopters to become the dominant technology in the vehicle market.

Current EV owners in WA are early adopters and therefore any user behaviour trends may change considerably as EV technology reaches the mainstream.

2.2 Charging locations for private vehicles

Across many mature markets, EV owners charge predominantly at home [18], [19] with the rest charging at the workplace, destinations, and public fast chargers. This is true of European studies. In Norway, 95% of charging sessions are completed at home [18], in Austria, 88% [19] as well as the US (55%) [19], while China had 38% of charging sessions completed at home, followed by 31% at work [19].

Studies in Australia support this finding. A Queensland survey of EV owners in 2021 (n = 104) found that almost 60% charge at home at least 3 times a week, with 85% of the participants using public chargers 'at least occasionally', and 91% able to charge their cars at work [17]. Similarly, 80% of Australian EV owners in a 2022 study (n = 741) reported charging at home at least twice per week [20] (drivers were mainly from New South Wales, Victoria, and Queensland). From the literature, it is currently unclear whether WA EV drivers will also predominantly charge at home as there has been insufficient research carried out, but it seems likely that they will follow Australian trends.

If WA EV Owners are like Australian and global drivers, they will prioritise charging at home when possible.

2.3 Residential charging infrastructure

EV owners have access to two main options to charge their vehicle at home:

1. Level 1 charging: where the EV is plugged into a portable charger via a standard residential wall plug
2. Level 2 charging: where the EV uses a fixed EV charger that requires dedicated wiring and must be installed by a licensed electrician.

Level 1 charging is the lowest cost option as no additional charging infrastructure is required. Because of this, however, it can only offer slow charge rates around 2.4 kW if using single phase power, which would take circa 27 hours to fully charge a modern passenger EV with a 65kWh battery. This leaves no room for managing the charging time to avoid grid peaks or to take advantage of spikes in renewable energy supply.

Some owners therefore opt for installing dedicated Level 2 charging infrastructure at their residence that provides faster charge rates (between 7 kW single phase, up to 22kW if they use 3-phase power) which can fully charge a modern passenger EV in the overnight off-peak window. The charger is sometimes bundled in the purchase price of the EV but is more often an additional cost between $2,000 - $3,000 including installation.

Many, but not all, of the Level 2 chargers are considered 'smart' as they can visualise EV energy consumption, support charge scheduling, and can take remote instructions via the open charge point protocol (OCPP). This allows the vehicle's charging to be managed in both the short term by the scheduling feature in a 'set and forget' fashion, controlled by the EV owner, and in the long term remotely by an aggregator via the OCPP to dynamically adapt charging to the availability of cheap power and the needs of the grid.

This allows the EV owner to participate in third party applications like home energy management solutions (HEMS) in the future, where the charging of the EV is done in alignment with total household loads and generation. HEMS devices are expected to become increasingly more prevalent in residential settings as loads become smarter.

This makes encouraging adoption of a Level 2 charger by a high proportion of EV owners an important point for the WA Government to consider when thinking about what it could do to enable smart charging behaviours.

Residential/destination Level 2 EV chargers with smart charging capabilities are essential to enable charging which supports a high renewable energy system.

The proportion of EV owners who install dedicated Level 2 chargers varies globally between 40-80%, even in studies with high proportions of home ownership. A Norwegian survey conducted in 2016 (n = 8,000) found that only 37% of private home chargers were dedicated Level 2 chargers [18], while in the 2022 EV Smart Chargepoint Survey in the UK (n = 1,000) [21], the majority of BEV drivers (66%) primarily used a dedicated charge point at home, arguably due to the UK's Office of Zero Emission Vehicles (OZEV) smart charger grant scheme which will be discussed in Section 2.6.2. This seems to be consistent with Australian studies. A survey of 104 EV drivers in 2021 found that 61% of the sample had Level 2 chargers installed [17]. As 87% of the drivers resided in their own dwellings and therefore had the opportunity to install chargers, it is clear there is a subset of the population who are not sufficiently incentivised to purchase a dedicated Level 2 charger. WA EV owners also are currently showing a high adoption rate (57%) of Level 2 chargers.

The additional cost to install a Level 2 charger may be a prohibitive factor for future EV owners. In the previously mentioned 2022 UK study, 44% of the BEV and PHEV owners who did not have a dedicated chargepoint at home (n = 287) listed the price of the charger as a prohibitive factor [21]. Additionally, of the EV owners with a Level 2 charger, many received it for free when they purchased the vehicle (31%) or participated in the government grant scheme to purchase it (75%).

Without incentives, it's unclear whether future WA EV owners will opt for Level 1 or Level 2 chargers once the mainstream population starts purchasing EVs.

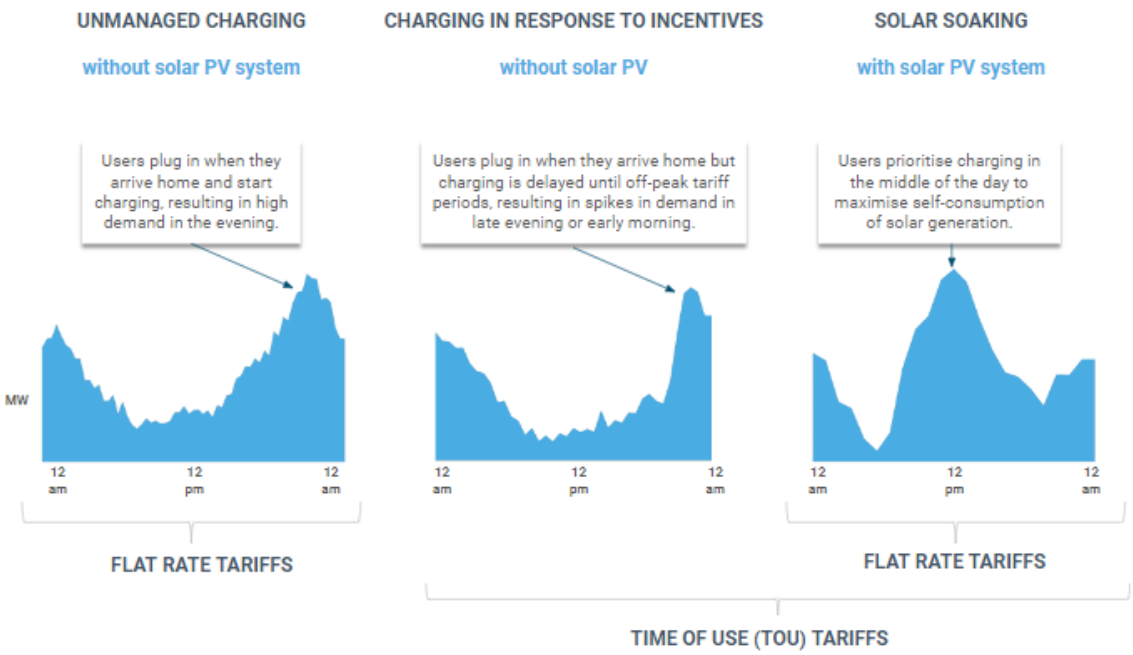
2.4 Charging profiles

There has long been a concern that electric vehicles will exacerbate high existing peak demand periods in the evening when EV uptake is higher, a fear that is shared by the WA policymakers surveyed in this study. Three daily charging behaviours have emerged in the literature:

1) Unmanaged charging, where EV owners arrive home after work, plug in and immediately start charging around 5-6 PM,
2) Delaying charging until late at night or early morning, usually in response to some form of incentive like a time of use (TOU) tariff, and
3) Solar soaking, where EVs charge to maximise consumption during times of high solar generation.

These three core profiles are summarised in Figure 4.

Figure 4: Dominant EV charging profiles found globally for passenger vehicles



2.4.1 Unmanaged charging

The first charging behaviour, unmanaged charging, has been found across all markets, particularly when there is little education on ideal charging times, little access to incentives to charge at certain times, or little access to programmable smart chargers. It is characterised with EV owners arriving home after work, plugging in and immediately commencing charging around 5-6 PM [22]–[25].

As many of these measures have been introduced in large EV markets in the past decade, unmanaged charging is particularly prevalent in early EV surveys. The findings were so ubiquitous that many future EV projections used in future electricity planning reports assume that unmanaged charging will be the dominant charging behaviour in the absence of incentives. However, as TOU tariffs and smart chargers have been introduced to mitigate unmanaged charging, more recent studies are not showing that unmanaged charging is such a problem, and instead other patterns are emerging.

2.4.2 Charging in response to incentives

Many regions which have introduced charging behaviour incentives like time-of-use (TOU) tariffs have reported a significant change in the charging profile as compared to no incentives. Two predominant features occur in this charging profile:

1. A reduction in peak electrical demand during the evening peak period (locally dependent, but generally within the region of 5-8 PM), and
2. A higher peak than the baseline profile once the TOU peak demand period ends.

The latter feature is often referred to as the 'second peak' or the 'avalanche effect' whereby the charging which was once diversified through arrival times is now concentrated at one time when the high tariff periods end. This has been found in several Australian studies including the EV SmartCharge Queensland study in 2023 (peak around 1 AM) [26] and the AGL EV Orchestration trial in 2022 (peak around 9 PM) [16], [27]. Smart charging equipment which is compliant with OCPP provides an option for start and end time randomisation (in the minute scale) to help smooth these secondary peaks.

2.4.3 Solar soaking

The final dominant EV charging behaviour is where owners tend to concentrate charging during the middle of the day. It is also called 'solar soaking' as the rationale for this behaviour is to either maximise self-consumption of rooftop solar photovoltaics (PV) generation, or to respond to TOU tariffs that account for the glut of solar generation in the middle of the day across their network, such as Synergy's EV Add On TOU tariff which offers 8.2 c/kWh rates during the day between 9 – 3 PM [28], the lowest of any time period.

While there are some global examples of this, in particular in the UK [29], Australia is leading in this space, perhaps unsurprisingly as Australia has one of the highest uptake rates of rooftop solar PV globally. This behaviour was observed in Australian EV charging behaviour studies, including the University of Queensland study in 2022 [30] and the Electric Vehicle Council study in 2022 [20].

2.5 Australian EV behaviour research & smart charging incentives

There have been a few surveys of Australian EV owners' behaviours to date. Table 3 provides an overview of influential Australian studies and trials conducted on EV owners. The surveys present two prevailing charging patterns: predominantly charging during the day [30], predominantly charging overnight [15], [27], and sometimes both [31].

Importantly, several of these studies (notably AGL and Origin) investigated Australian perspectives on charging behaviour policies like TOU tariffs and external charge control via smart chargers through trials. Participants responded strongly to both of these signal types (as measured by empirical data) and seemed to be largely open to these policies.

Australian EV early adopters are either predominantly charging overnight or during the day. They are much more likely to charge during the day than seen in other countries.

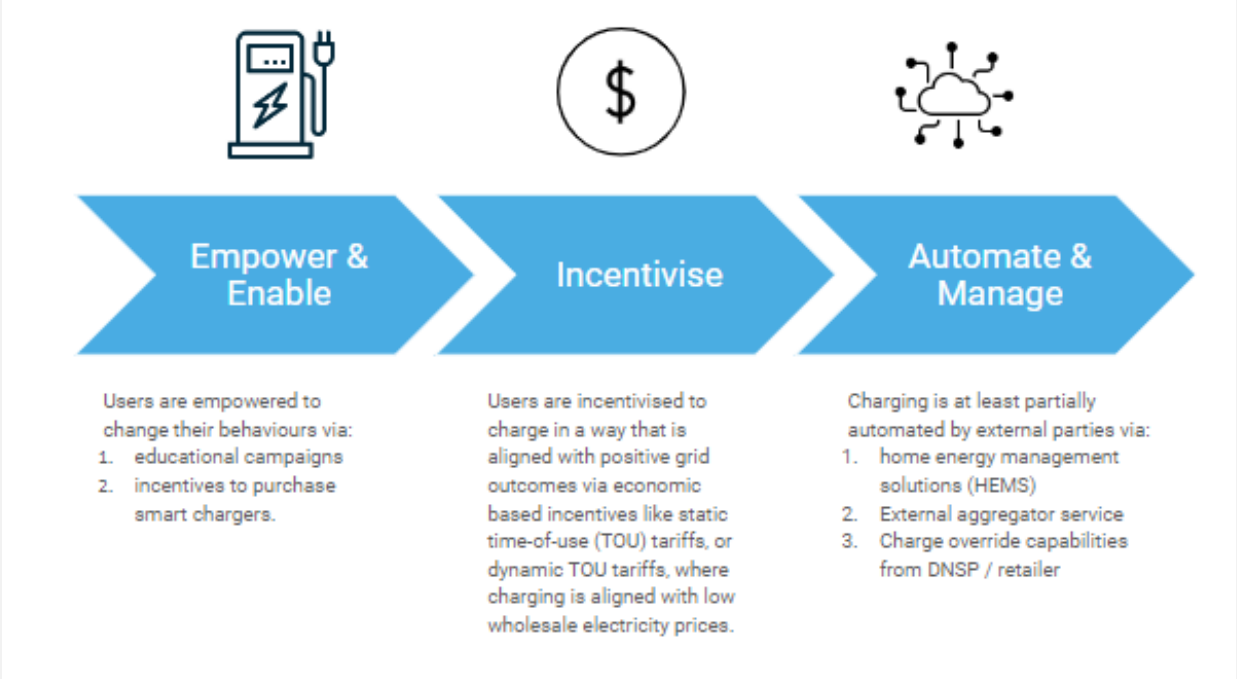
Table 3: Summary of Australian EV charging behaviour studies and trials					
Category	Group	Region	Date range	Sample Size	Findings
Behavioural survey	Griffith University	QLD	2020	348	EV charging mostly occurred overnight from 9 PM - 6 AM (65%), followed by during the afternoon between midday to 6 PM (16%), and finally from 6 AM to midday (11%) [15].
Behavioural survey*	University of Queensland	QLD	2021-2022	239	Drivers were predominantly charging in the middle of the day. The report concludes that EV owners are likely self-managing their charging times to take advantage of off-peak rates for TOU tariffs [30].
Behavioural survey*	Ergon Energy and Energex	QLD	2020-2021	167	Peak home charging occurred at 1 AM in response to TOU tariffs, but daytime charging was also seen (77% of participants had solar PV). 75% indicated that they charged under a flat-rate tariff. The authors note that despite the small amounts of the cohort on a TOU tariff, they had a disproportionately large impact on the total charging profile. Far less charging was done at home than expected (62% of total charging energy) [26]
Behavioural survey	Electric Vehicle Council	AUS wide	2022	741	Only 15% of owners routinely charged during the evening peak periods, EV owners with solar predominantly charged during the day with shorter charge sessions around midnight, while owners without solar mostly charged overnight between 1-2 AM [20].
TOU and Smart charger control trial*	AGL	AUS wide	2021	100	A large proportion of the non-controlled TOU population self-managed their charging to off-peak periods. Customers under a fixed-time charge schedule (constructed to avoid charging during peak demand periods and during TOU tariff rate changes around 11 PM) successfully changed the charging profiles compared to the non-controlled profile with low opt-out rates [16], [27].
TOU and Smart charger control trial*	Origin Energy	AUS wide	2022	150	Baseline charging included both overnight charging and sunshine charging. Trial participants responded strongly to a reward of 10 c/kWh for charging outside of peak periods, where the proportion of participants charging outside of peak periods increased from 70% to 90%. Participants mostly shifted from peak periods to overnight charging. Participants also tested external control between 3 PM and 9 PM with a fixed 25c per day reward. The study found that charging during peak demand periods could be further reduced, and this demand was shifted mostly to early morning periods. [31]

** Study used empirically measured data rather than self-reported*

2.6 Global EV charging policy positions

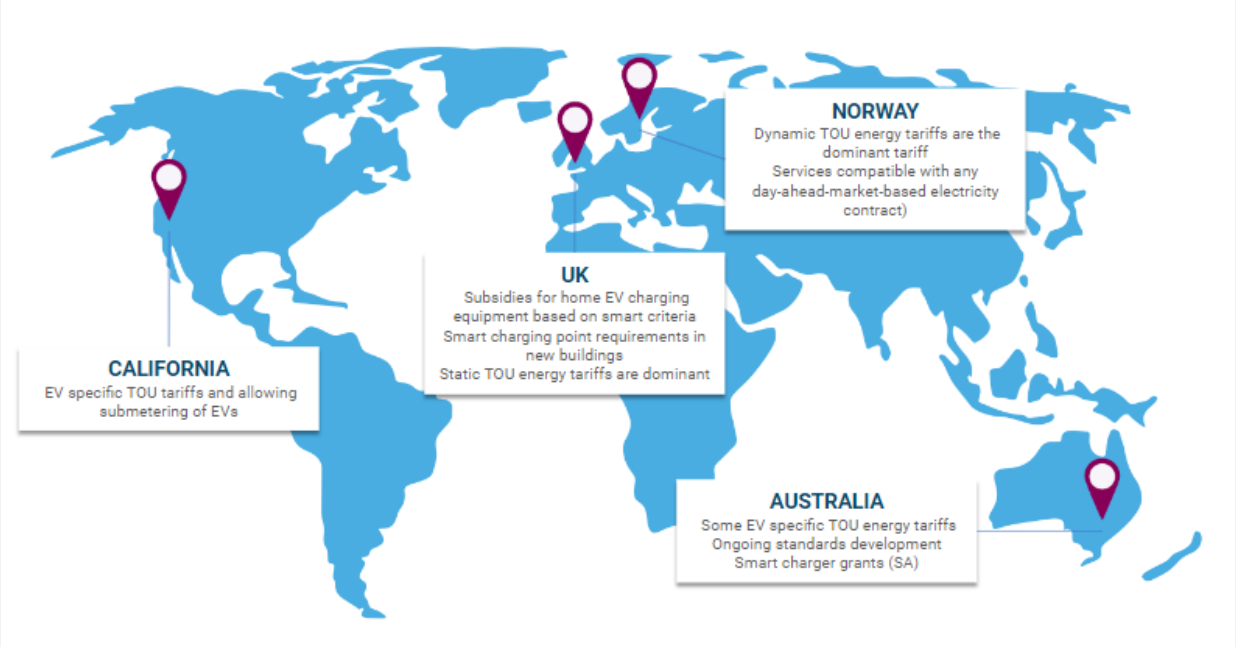
Numerous different policy positions relevant to influencing EV charging behaviours have been adopted globally. Broadly speaking, these positions can fall across a spectrum, as shown in Figure 5. Policies can range in the level of intervention from those that are designed to empower and enable EV drivers to change their charging behaviours via education or enabling technologies like smart chargers, incentivising charging behaviours financially, through to remotely controlling charging either by the user, an external aggregator service, or by a distribution network service provider (DNSP) or retailer.

Figure 5: EV Charging behaviour policy positions



The most common government policies globally to guide charging behaviours have been enabling and incentivising policies, including providing rebates or subsidies for smart chargers, and introducing TOU tariffs. Figure 6 shows examples of EV charging behaviour policy positions in selected markets, and the following sections will discuss these policy positions and provide key examples of them in global markets.

Figure 6: EV Charging behaviour policy positions in selected markets



2.6.1 Empower and enable

This section will discuss policies that are designed to empower EV owners to manage their charging via education and to enable them to shift their charging behaviours via smart charger charge scheduling tools.

2.6.1.1 Educational programs

Education programs for EVs to date have largely focused on increasing EV adoption through 'myth-busting' and fact sheet information pieces, charging sitemaps, charger guides, and events to familiarise people with EVs like World EV day [32], or the National Drive Electric Week in the US [33]. Electrify America has been particularly active in this space, launching the "Normal Now" Educational Campaign [34], and the 10 million "As Seen on EV" campaign [35]. Other examples include the Smart Columbus Electrification Program [36] and the Veloz Electric Foergy All campaign [37].

Campaigns targeting informing EV charging behaviour are less common, perhaps as early adopters tend to be more informed about electricity than non-EV owners as previously mentioned. The Zemo Partnership in the UK is working on one such education campaign to inform the time of charging [38].

As EVs reach mass market deployment, however, charging education pieces will become increasingly important. Education of owners has also been noted as crucial for the success of other policies like TOU tariffs [39], and programming EV charging in smart chargers [21].

2.6.1.2 Incentives to purchase smart chargers

The installation of smart chargers enables a raft of more sophisticated and dynamic energy management options. Most countries that have incentivised smart chargers have ensured they are ready to participate in such systems but have not mandated participation at this point.

One key global example of this policy is in the United Kingdom (UK). As at June 2022, all new EV private charge points sold for use in a domestic or workplace environment in Great Britain must have smart functionality [40], including the ability to send and receive data, respond to signals to increase the rate/time of electricity flow, a user interface, and to offer demand side response services.

The UK's Office of Zero Emission Vehicles (OZEV) has additionally provided funding of up to 75% of the cost of EV smart charge points at residential locations [41] on the condition that the charger is from an authorised seller, and that it must be set to off-peak charging time by default at installation. In effect, this provides a demand-response (DR) ready solution with a default position of a basic off-peak schedule but has no requirement enforcing the consumer to use either. EV owners are still free to override the schedule.

2.6.2 Incentivise

This section will discuss policies that are designed to incentivise EV owners to manage their charging via time of use tariffs.

2.6.2.1 Time of use tariffs

TOU tariffs are the most common and cost-effective way to create a meaningful direct benefit for the EV owner to charge in ways that help the grid. They also do not require a complicated system to manage them.

Overseas, optional TOU tariffs and even mandated ones without education have not resulted in satisfactory participation rates in smart charging practices. An international study by researchers from the UCL Energy Institute in the UK (2018) found that if consumers are given the choice to opt-in to general TOU tariffs, the adoption rate is generally low (as low as 1%) unless efforts are made to close the intention-action gap, but if enrolment is opt-out, the adoption rate could approach 100% [42]. The study also found that the willingness to switch to TOU tariffs is five times higher than the actual enrollment rate. This suggests that for consumers to embrace TOU tariffs, they need to have controllable loads like EVs and education is needed to increase consumer acceptance.

When they are adopted, however, TOU tariffs have been effective at modifying EV charging behaviours globally and in Australia. In the EV SmartCharge Queensland report in 2023, 22 of the 167 EV participants in the survey were on a tariff that encouraged charging after 1 AM [26]. They found that these owners created a very noticeable peak at this time

disproportionate to the number of drivers on the tariff. Preliminary findings from the AGL EV Orchestration trial also support this, where they found that their baseline EV population's charging profile (not remotely controlled) showed a noticeable increase in charging at 9 PM NEM time[3], suggesting that a large proportion of the EV owners are self-managing their charging to off-peak periods [27].

TOU tariffs were raised by the majority of WA energy and transport stakeholders interviewed (88%, n=8) as a possible solution for minimising the future impact of EVs, as will be further discussed in the following sections.

TOU tariffs are not well-established in Western Australia. While Synergy, the retailer for non-contestable customers in the South West Interconnected System (SWIS), offers a TOU option, it has historically had low uptake rates (approximately 3% of the general population[4]) compared to other states.

To participate in TOU tariffs, the EV owner must have interval data capability through a smart meter installed at their residence, which only half of the retail customers in Synergy's network currently have. This is currently being addressed through Western Power's rollout of advanced metering infrastructure (AMI) which is expected to finish in 2027 [43].

2.6.3 Automate and manage

This section will discuss policies that are designed to automate and manage EV owner's charging either by the EV owner themselves or via an external party. This can present as a sophisticated energy management and optimisation service, a location specific management system, or as a DNSP or retailer overriding the EV owner's charging behaviour by directly stopping or starting charging.

2.6.3.1 Sophisticated energy management and optimisation services

Energy management is a spectrum of ways to manage charging from simple low-tech solutions like charge scheduling to sophisticated aggregated services. The simpler energy management strategies which are readily available now are effective at moving charge away from peak demand periods as previously discussed. More sophisticated energy management systems can be used to further optimise costs to the EV owner, or to maximise self-consumption of PV generation, or to reduce/increase charging loads depending on the local and market-wide conditions.

[3] The NEM operates in Australian Eastern Standard Time (i.e. UTC+10) and does not change for daylight savings

[4] There are around 32,000 residential customers under a Synergy TOU tariff compared to approximately 1.1 million residential customers in the SWIS.

Sophisticated energy management in this report can be done at two different levels:

1. Home Energy Management Systems (HEMS) – A device controls all generation and loads in the home/property to optimise costs.
2. External Aggregator Service – A remote third party sends instructions to devices in the home to optimise them from the energy network's perspective for a share of the benefits in doing this.

In practice, these two methodologies may deliver similar outcomes, as they both take advantage of low electricity rates at periods when it's useful to the grid for EV owners to consume more energy. However, the control systems may differ in certain cases. For example, if there is excess solar generation in the grid, the External Aggregation Service may tell the EV to charge in order to help. Meanwhile, a HEMS device only optimises within the home and might not see the excess generation unless it is within the home, and therefore might not instruct the EV to start charging. External aggregation may therefore provide a better outcome for the grid in some circumstances but relies on a more complicated communications system given the controller is remote to all the devices it is controlling.

There are many global trials of external EV aggregation services. An Australian example is the AGL Electric Vehicle Orchestration Trial [27], comprising 300 EVs across Queensland, New South Wales, Victoria, and South Australia, and summarised in Table 3. The EVs were able to respond to the external control, minimising charging during high wholesale price events, and there was little or no adverse customer reaction to this charging schedule. Results from a similar study conducted by Origin Energy in the NEM also found that charging during peak demand periods could be reduced and that owners were satisfied with the service level during the study.

Aggregation is highlighted as a potential interest area in the WA EV Action Plan [4], which suggests that DER aggregation and market participation trials should be undertaken. This is mirrored by the expert stakeholders interviewed in this study, of whom 5 of 8 suggested smart energy management systems as a solution to minimise the impact of EVs in WA.

There are concerns, however, that external charging management will not be well-received by EV owners, and that there is insufficient social licence to automate EV charging [44], [45] as it can be perceived as an invasion of privacy and autonomy, especially as trust for energy utilities are at an all-time low in Australia [46]. The expert stakeholders interviewed mirrored this sentiment, as will be discussed in Section 4.

2.6.3.2 Location specific management and direct messaging

As EVs are co-located with other small loads and generation assets at the distribution level, policy can also work to address incentivising charging behaviours that can counteract issues with these technologies moving forward, like reverse feeder flow from rooftop solar PV, or high localised peak demand from air conditioners and other household loads. Additionally, a localised policy can work to ensure additional EV charging load does not exceed local feeder capacity limits. This might be able to reduce localised network augmentation in the future.

A location specific solution was raised as an issue by 6 of 8 expert stakeholders interviewed and recommended by 7 of 8. It could look like location specific tariffs, an external aggregator service which considers local conditions, or direct messaging from Synergy, Western Power or the Australian Energy Market Operator (AEMO) to target individuals to stop charging during constrained times or to begin charging if local solar generation is too high.

It might also look like dynamic operating envelopes (DOEs). Operating envelopes are the limits in which an electricity consumer can import and export from/to the grid. These limits are usually fixed and set at the time of connection by the DNSP. In DOEs, these limits are dynamic and can change over time and per location depending on the hosting capacity on the local network. For EVs, DOEs have the potential to constrain charging rates to what can be supported by the local network at that time, and in the future, to constrain how much can be exported via vehicle-to-grid (V2G).

DOEs are in research and trial stages in Australia, with notable projects include the Advanced VPP Grid Integration Project undertaken by the South Australian Power Network (SAPN) [47] and Project EDGE by AEMO [48]. Some Australian states are starting to adopt DOEs. For example, South Australia has mandated that from late 2022 all new solar installations must have DOE functionality and that all consumers will have the option to enter a dynamic connection agreement with SAPN, and in Queensland, Energex and Ergon Energy Network have developed dynamic connection standards, effective from late 2021 [49].

2.6.3.3 Charge override services

Globally, it is rare for DNSPs or retailers to have override capability for solar or EV systems. Australia is leading in this space due to its world-leading rooftop PV penetrations combined with generally long, stringy distribution grids rather than well interconnected and meshed grids more common overseas.

While there are few if any instances of DNSPs or retailers overriding (turning off) EV charging remotely outside of an external aggregation service, it is plausible that policies which do this for solar might be extended for EVs in Australia, like the South Australian 'smarter homes' policy for solar systems and the Western Australian Emergency Solar Management policy.

With solar, all systems generate at approximately the same time (following solar and cloud patterns) and are themselves a major source of grid instability. Turning solar systems off temporarily immediately resolves issues of surplus generation on the grid or local voltage issues. Overriding the PV system does not impact the user's access to power as they can still pull energy from the grid.

Unlike solar, however, overriding EV charging could impact the user's ability to use their vehicle afterwards. Any override policy for EVs would have to carefully consider the duration of override to avoid any loss of functionality for the vehicle, and perhaps implement state of charge calculations within the control system to ensure vehicles would have sufficient range to perform emergency trips.

DNSP overrides for residential EVs would likely be used to curtail charging at periods of high demand compared to supply, or during times of localised network constraint (such as a heat wave or cold snap). This might be at the standard daily evening peak period when demand is high, or in emergency periods when generation is unexpectedly shut-off, forcing demand to exceed supply. In the first case, for predictable peak demand periods, it could be argued that many vehicles with smart chargers (required for DNSP override) would already be on a TOU tariff or have a charge schedule in place that would address it. In that case, the ability of the DNSP to use this lever is limited as few vehicles would be charging. This lever would still be useful, however, if there were low uptake rates of tariffs or low compliance.

For these reasons we do not see charge override capability as an effective nor a practical policy to implement and so will not explore it in any further detail.

2.6.4 What Australian and global trends mean for WA

Standard global trends suggest that without any form of incentives, some EV owners will charge at the same time as daily peak demand in the evening, and therefore will exacerbate peak demand, driving network augmentation and therefore expensive electricity prices for consumers. More recent research coming from Australia's east coast suggests that EV owners are charging without specific incentives in the middle of the day. However, there is insufficient evidence in Western Australia to know which trend will prevail, and how EV owners will charge once the mass market begins to purchase them.

The same is true for types of chargers and location of chargers. Global and Australian literature suggest that 60-80% of EV owners' charge sessions are completed at home, and 40-80% charge with a Level 2 charger. Smart Level 2 EV chargers are essential to enable smart charging in the future in WA, but before the report, there had not been public studies to determine whether these trends hold for WA. Findings from this report suggest that 55% of EV owners have a dedicated charger installed at home. The key for WA is to keep this high uptake percentage as EV uptake becomes more mainstream.

The most common government policies to guide charging behaviours globally have been time-of-use (TOU) tariffs, and incentivising smart chargers. Many studies note that education is vital to achieving success from either.

TOU tariffs have not historically been widely adopted in the SWIS or in the rest of Australia. There is evidence to suggest that EV owners in Australia are already more likely than the general population to adopt TOU tariffs [17], [26], [27], which is also supported by the findings of this study (as explained in Section 3.5.4).

Still, it is likely that WA will require education campaigns to promote TOU tariffs and better distribution of smart electricity metering infrastructure before TOU tariffs become widespread. The WA government could also explore the potential of opt-out TOU tariffs which have been shown to increase adoption rates [42]. These strategies will allow WA to minimise exacerbated peak daily demand.

Once smart chargers are ubiquitous, they allow for more sophisticated energy management and optimisation services, location specific controls, and charge override services. These control strategies will allow WA to target location specific issues that arise from EVs as well as other distributed energy resources (DERs) like rooftop solar PV to avoid the need for localised network augmentation.

3 WA EV behaviours and perspectives

This section summarises the key findings from the surveys of current and prospective EV owners within Western Australia. The rationale for this effort was to design, pilot and administer an online survey of EV owners and non-owners in Western Australia to understand EV purchasing patterns and intentions and establish current and intended EV charging habits and preferences for an efficient use of the power grid. The survey participants included a mix of EV owners & non-owners in Western Australia, to get perspectives from both these groups.

3.1 Survey design

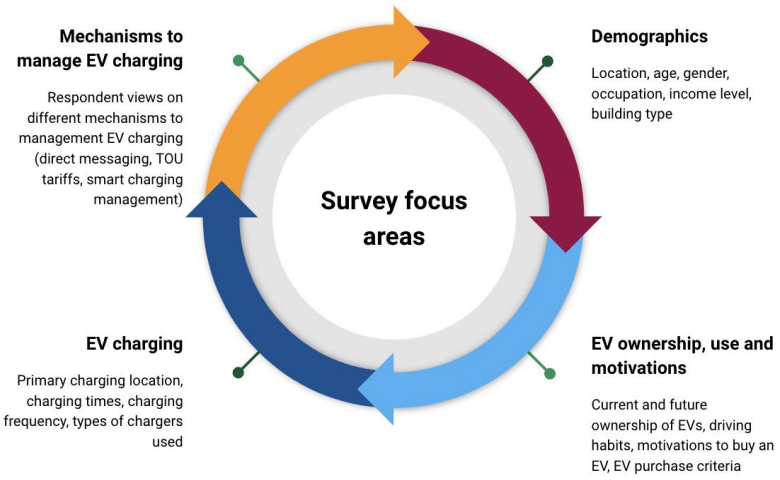
An online survey was created and delivered via several channels, which included the Tesla Owners Club of WA who distributed the survey link to their members, and several EV Facebook groups in WA. Non-owners were targeted by using a survey panel hosted by a WA-based professional market research company, Thinkfield.

The survey was conducted by Evenergi and the Institute of Transport and Logistics Studies (ITLS) at the University of Sydney over a 1-month period from 6 May 2023 to 6 June 2023, and was designed, piloted and administered via the Qualtrics platform. ITLS provided statistical analysis of the survey results. The minimum desired sample size of 200 owners and 200 prospective owners was exceeded, with a total of 1,253 respondents, consisting of 461 EV owners and 792 non-EV owners. Out of non-EV owners surveyed, 507 indicated their likelihood to buy an EV in the future (prospective EV-owners). Participants were asked questions within four key focus areas of the survey, as highlighted in Figure 7.

Not all questions were presented to every respondent in the survey. For instance, if a respondent indicated that they do not drive, the survey ended for them, and their responses were not recorded. Similarly, if a respondent expressed that they are unlikely to purchase an EV in the future, the questions related to EV charging and mechanisms for regulating charging behaviour were not asked.

Prior to asking the questions about charging mechanisms, participants were asked to assess their comfort level in answering them. If a respondent indicated discomfort, the set of questions related to mechanisms was not presented to them. A copy of the survey questions and the optional responses is provided as Appendix B.

Figure 7: Survey focus areas[5]



3.1.1.1 Limitations

The survey method chosen relies on accurate self-reporting. As insights like charging behaviours were not directly measured but rather indicated by the individual, results may have a degree of 'wishful thinking' included in them. This might skew the results in favour of behaviours or views that the participant thinks are correct or desirable.

Additionally, as will be highlighted in the demographics section, the survey of EV owners is skewed towards a small group of people which can be categorised as early adopters. As such, the patterns and perspectives found in this survey may not be representative of future EV owners in Western Australia once EV uptake increases. Also, given the overrepresentation of Tesla owners in Australia [6] and the fact that this survey relied heavily on distribution through the Tesla Owners Club of WA, the participants are likely mostly Tesla owners.

Survey results should be viewed in this light. When possible, insights from other Australian and global surveys have been included to better understand the results.

3.2 Demographics

The key demographic characteristics of EV owners and non-owners revealed from the surveys are summarised in Table 4 below. EV owners in the survey are predominantly male, 45-54 years of age, living in houses, full time or retired, and have a high household income. This is consistent with the profile of early EV adopters found in the global literature (described in previous sections), and Australia studies of current EV owners in Australia [15]–[17].

[5] While questions on EV charging behaviour, ownership and use were specific to EV owners, questions under the other focus areas (demographics, motivations to EV ownership, and mechanisms to manage EV charging) were posed to both EV owners and non-owners to understand similarities as well as differences in these aspects between the two cohorts.

Table 4: Survey demographics			
Parameter	**EV owners**	**Non-owners**	**Summary insight**
Age group	Predominantly 25 to 74	25 to 74 (with some notable numbers in the 18 - 24 and >75 age groups as well)	25 to 74 age group is the predominant category for both EV owners and non-owners
Gender	~83% of EV owners surveyed are men	~54% of non-owners are men	EV owners are more likely to be men while the distribution is more even for non-owners
Dwelling characteristics	Predominantly houses	Predominantly houses	There is a clear dominance of house dwellers among both EV owners and non-owners
Occupational status	Largest share are full-time workers (65%) and retirees (21%)	Again, largest share are full-time workers (61%) and retirees (11%)	The high percentage of full-time workers and retirees aligns with previous research on EV early adoption, often associating these groups with increased financial capacity and environmental consciousness.
Income levels	A large share (58%) belong to the higher income groups - $100k-$150k (30%), $150k-$200k (14%), and >$200k (14%)	A large share (60%) belong to the low to medium income groups - $40k-$60k (24%), $60k-80k (22%), and $80k-$100k (14%)	There is a positive correlation between higher income levels and EV ownership.

3.3 Purchasing decisions and motivation

Of the non-EV owners in the survey, 54% expressed an interest in purchasing an EV within the next 5 years, while 44% were not interested in an EV. Higher income earners were more likely to indicate that they would buy an EV within the next 2 years compared to lower income earners who indicated 2-5 years, which might reflect higher levels of disposable income available to purchase the relatively more expensive EV compared to an ICE. There is also a possibility that respondents belonging to the "not interested" group might hold that position because of lack of awareness and information about EVs and could potentially change their views with targeted educational campaigns and with increasing market maturity.

3.3.1 Information sources

The survey results suggest that prospective EV buyers primarily use EV brands' official websites (21%) for pre-purchase information. Social media and influencers (17%), as well as showroom visits and discussions with other EV owners (15% each), are also key sources. Industry blogs or trade magazines, advice from friends and family, and official resources like electricity providers or government websites make up less frequently used sources. Direct advertising and unspecified sources are least utilised, each accounting for 2% of information sources.

This data suggests a preference for first-hand information from trusted sources and the increasing influence of social media in purchase decisions. It also indicates a potential underutilization of traditional or official channels of information.

3.3.2 Motivations for EV ownership

Participants were asked about the motivating factors to purchase EVs, allowing multiple choices from the options of environmental concerns, lifecycle costs, government incentives, vehicle performance, and concerns about relying on certain forms of fuel/energy.

For EV owners, environmental concerns and lifecycle costs emerged as the two main motivating factors, with 46% and 50% of respondents, respectively, indicating these aspects as highly important in influencing their decision to buy EVs. The insights were quite similar for non-owners as well, with 54% and 50% of respondents highlighting the importance of these factors in their future decisions to buy EVs. These findings are consistent with other Australian studies [15] and suggest there is stability in purchase or behaviour drivers in the near/medium term.

Though the other parameters were mentioned as notable, only a small share of the respondents gave them high importance ratings in influencing EV purchase decisions. Interestingly, social status, technological innovations and performance benefits were not given high importance by a large share of the respondents.

3.3.3 Criteria for EV purchase

Participants were asked about the criteria they would or did use when purchasing an EV, including purchase price, range, proven technologies, charging network availability and vehicle safety. Purchase price emerged as the most important factor for both EV and non-EV respondents, with 28% of EV owners and 50% of non-EV owners ranking it as the top consideration. Range was also highlighted as a highly important factor by around 27% of both EV owners and non-owners. A smaller share of respondents also mentioned charging networks and safety as being important, while proven technology was not considered of much importance.

Purchase price and range are the most important criteria when purchasing an EV for both current EV and non-EV owners in WA

3.4 EV usage and trip purposes

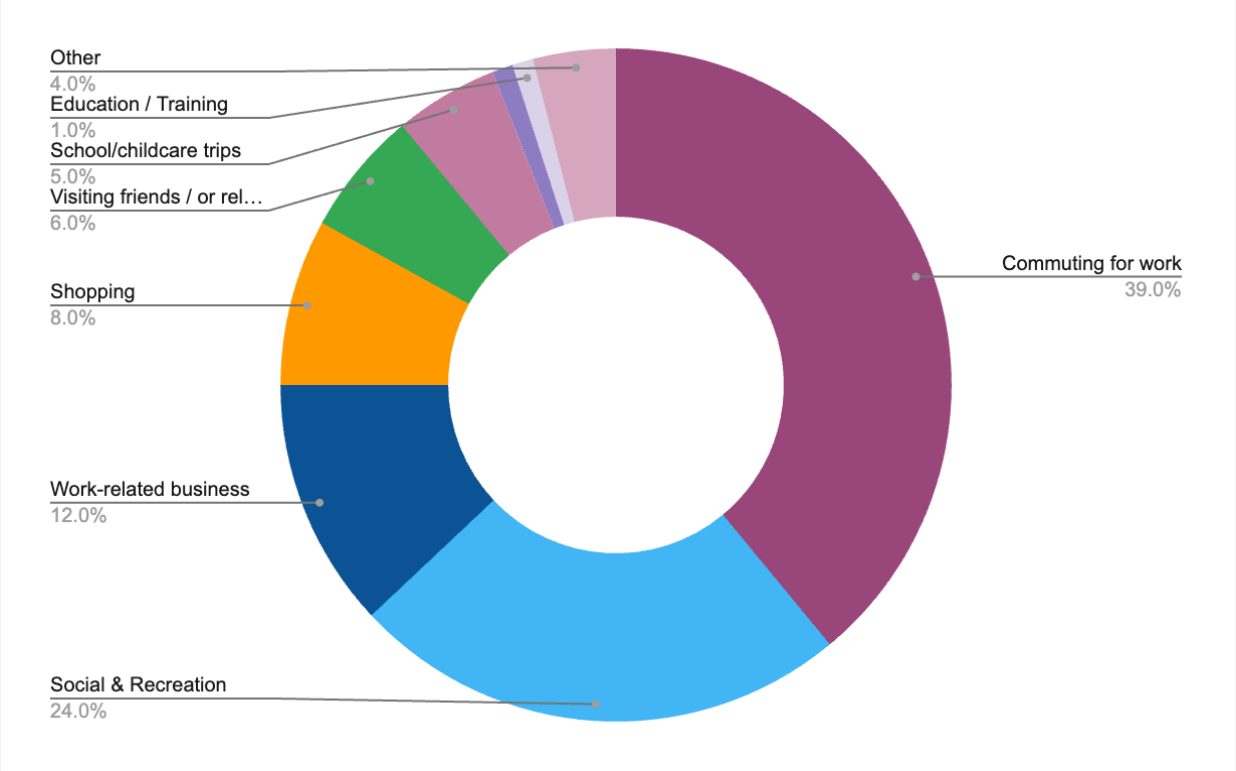
A large share of the trips by both EV owners and non-owners are seen to be of less than 30 min. duration, with 58% and 62% of owners and non-owners respectively reporting this to be the case. Trips over an hour were far less common across both user groups, with 12% and 10% respectively reporting this to be the most common trip duration.

The main trip purposes for which EVs are used by the respondents, as shown in Figure 8 include commuting to work (39%), social and recreational trips (24%) and work-related business trips (12%). This suggests that EVs are primarily used for routine, predictable travel like commuting.

The fact that the largest trip usage is commuting indicates that there are likely cars parked at workplaces or public transport park-and-ride locations which have the opportunity to charge during the day.

WA EV owners primarily complete trips under 30 minutes and use their EVs to commute to work or perform work-related business, and travel for social and recreational reasons

Figure 8: Primary EV trip purposes



3.5 Charging behaviour

Key parameters that were assessed to understand the charging behaviour of EV owners included charging times, charging locations, types of chargers, and charging frequency. Notable insights from this assessment are summarised below.

3.5.1 Charging locations

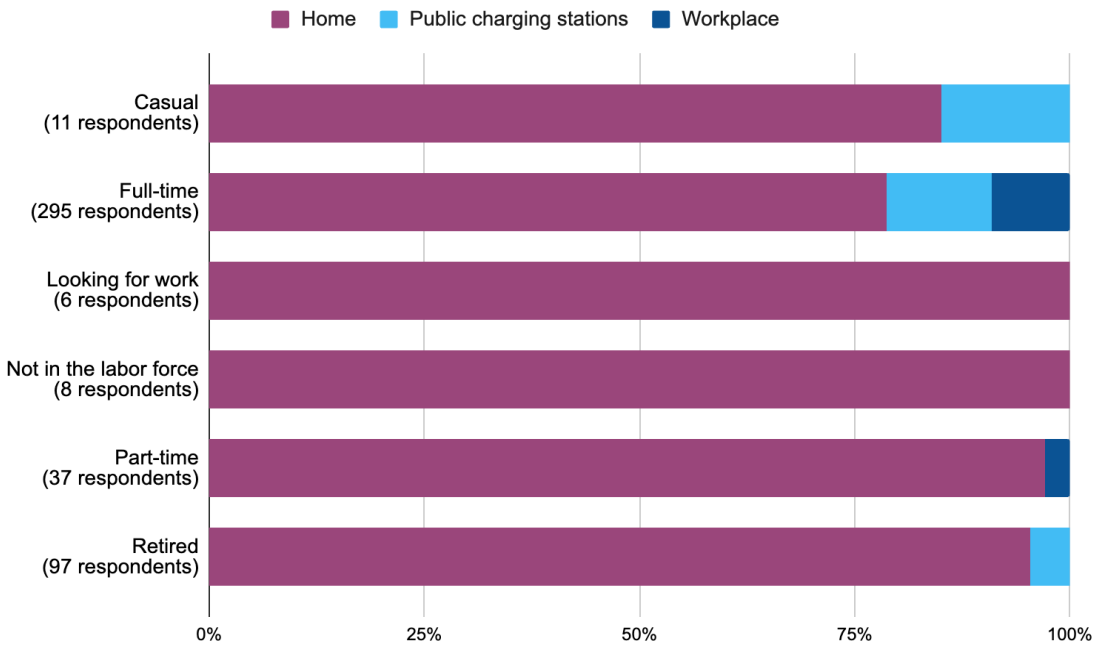
WA EV owners overwhelmingly reported that they charged at home (84%), with some charging at public charging stations (10%), and the remaining respondents charging at their workplace (6%). This is consistent with global findings and slightly higher than other Australian surveys previously discussed (60-80% [17], [20]), which might reflect a higher proportion of homes with a garage, or the lower deployment of public and workplace charging infrastructure in WA compared to other states and territories.

WA EV owners overwhelmingly charge at home, with a small amount of charging at public charging stations and workplaces.

Home charging is the most dominant across all employment categories, as shown in Figure 9. This is true even for full-time workers, possibly indicating insufficient amounts of charging infrastructure at workplaces, or that home charging is the most convenient.

There is a disconnect that the most common trip type is commuting while the least common charging location is at the workplace. This indicates that there are many EVs parked in workplace carparks and park-and-ride locations during the day, and that there is an opportunity to install chargers at those locations to maximise EV charging consuming solar generation.

Figure 9: Impact of type of employment on charging location



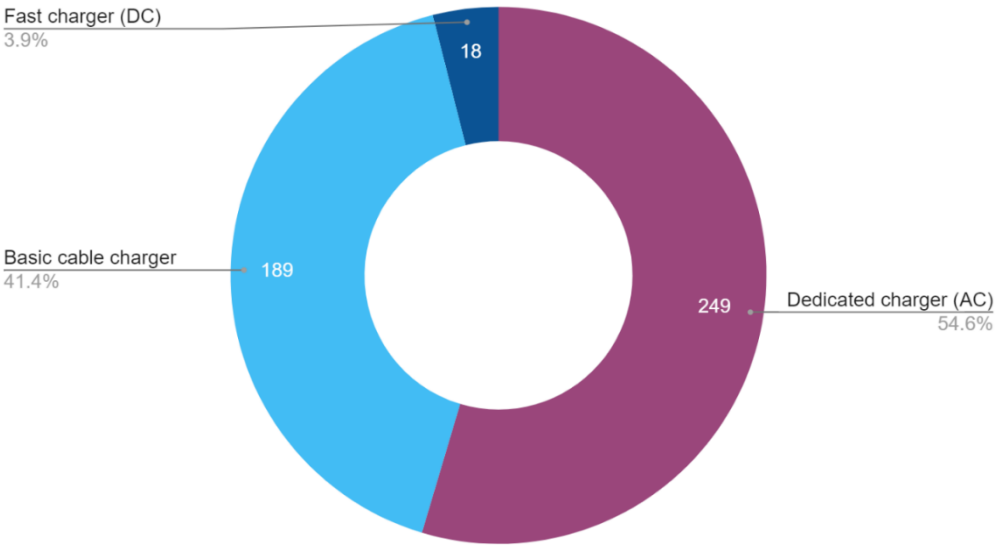
3.5.2 Charger types

The survey revealed a significant prevalence of dedicated Level 2 chargers, with around 55% of EV owners reporting using dedicated Level 2 chargers, as shown in Figure 10. This is consistent with global statistics of 40-80%, and Australian studies (61%, [17]).

Since a large share of EV owners are home charging, this means that a lot of the homes have Level 2 charger installations. This is a positive sign for the implementation of future smart energy management initiatives, however, it is important to note that not all dedicated chargers are 'smart', as discussed in Section 2.3.

At the same time, there are quite a few owners (~41% of respondents) using basic cable chargers who could potentially move to smart chargers in the future, if adequate incentives are in place coupled with awareness of their benefits.

Figure 10: Charger types

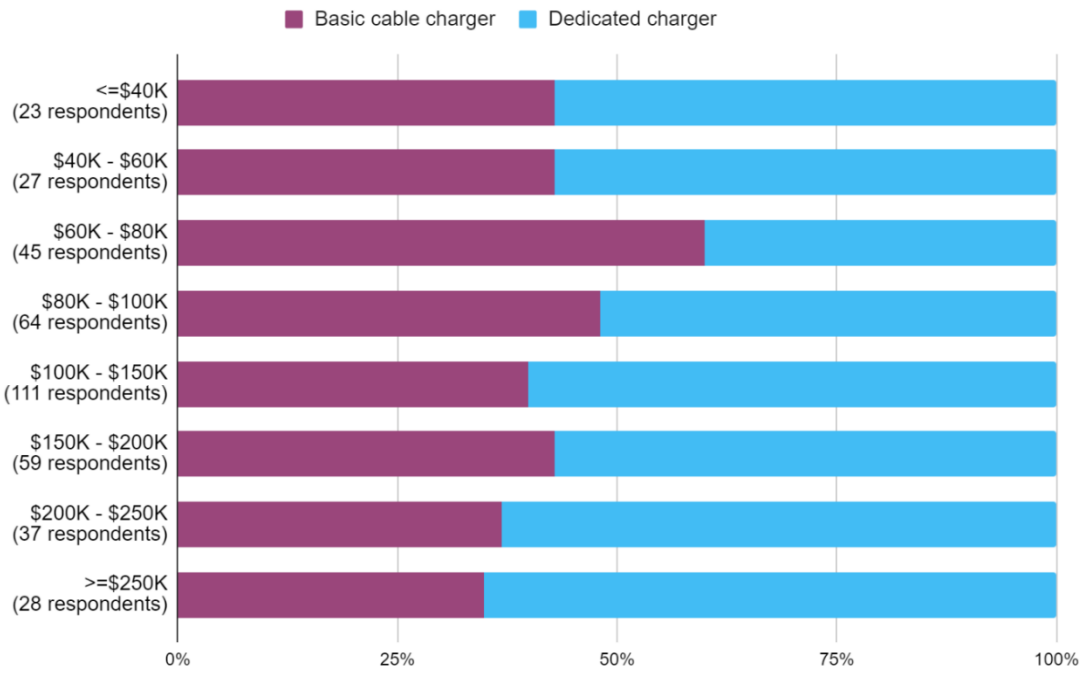


Full-time employees in the middle to higher income range ($80,000 to $250,000) have the highest share of ownership of dedicated Level 2 chargers. The installation of Level 2 chargers seems to be somewhat correlated to the EV owner's annual income, as per Figure 11, with high income earners more likely to have a dedicated charger than lower income earners. However, the proportion of Level 2 ownership does not vary significantly over income brackets suggesting cost is not an insurmountable barrier to smart charger ownership. This trend aligns with global literature [21].

The fact that it is likely most of the EV owners have Tesla's may also influence the ratio of EV owners with Level 2 chargers. Before 2020, Tesla bundled their wall charger with the vehicle on purchase however, as the majority of EVs in Australia have been purchased since then this is not likely the main cause. Tesla now offers a relatively cheap wall charger and does not include a Level 1 charger with the car so would still act to sway consumers towards the Level 2 charger option.

More than half (55%) of WA EV owners already use a smart charger to charge (even those at lower income levels).

Figure 11: Income vs dedicated Level 2 charger usage[6]



3.5.3 Charging frequency

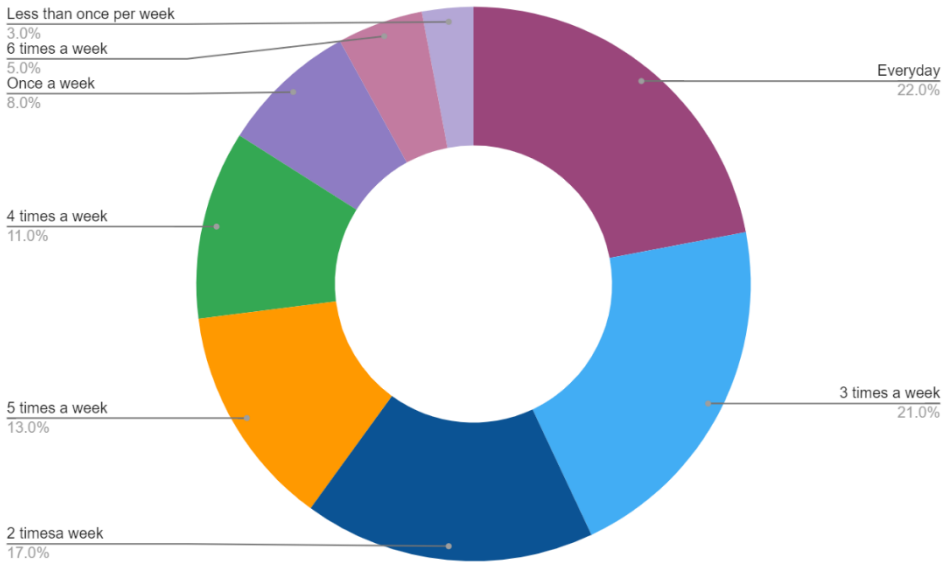
Participants were asked how frequently they charged their vehicles, in terms of days per week of EV charging. This is an important indicator of charging behaviour, as it gives insights into not just the level of usage of vehicles (and consequently their energy requirements), but also the propensity of owners to plug-in their vehicles for charging (irrespective of the battery's state of charge).

As shown in Figure 12, the survey reveals a wide distribution of charging frequency, ranging from everyday charging (~22% of respondents) all the way to once or less than once a week. Close to half of the respondents are charging their vehicles 3 or less days a week, indicating that a lot of these owners are not having significant daily usage relative to the vehicle's battery capacity. This is a consistent finding with the global literature, as discussed in the literature review section.

A fifth of EV owners in WA engage in daily EV charging habits, but many are only charging as needed every 2-3 days

[6] Please note that this has been normalised to 100% of the participants in that income bracket. There were few respondents in the very high and very low income brackets and therefore these results may be outliers. Please refer to the demographics section or the full report for more information.

Figure 12: Charging frequency



3.5.4 Charging times

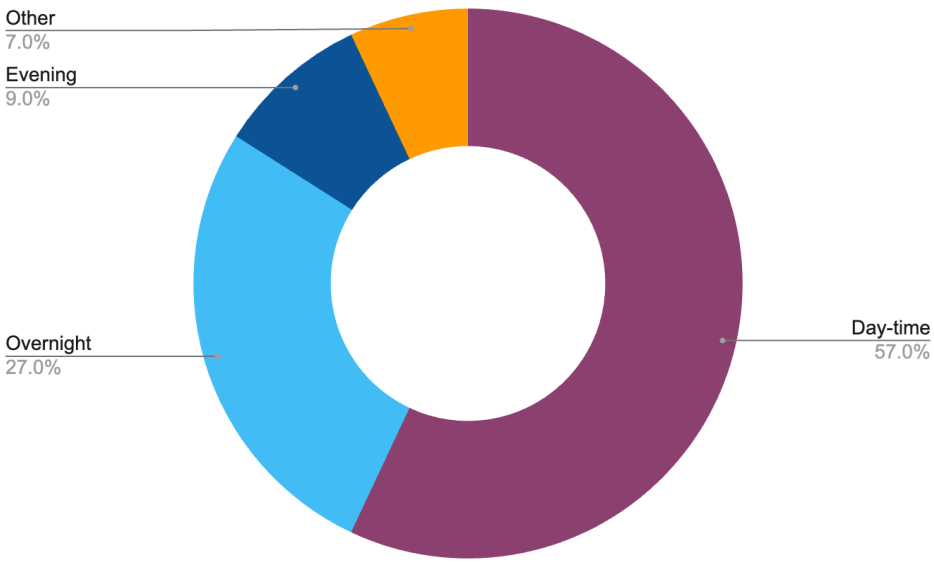
A high percentage of EV owners (~57%) in the survey typically begin their primary charging during the mid-day period, with overnight charging being the next highest share (~27%), as shown in Figure 13. Around 7% of the respondents reported "Other", which indicates that they have a diverse mix of charging time behaviour across different time periods, indicating a degree of flexibility in charging time patterns for this cohort.

This suggests that a high proportion of WA EV owners are likely to concentrate their charging during the middle of the day, as other Australian studies have found [20], [30] and might already be charging in an optimal way to avoid the peak demand periods and self-consume solar PV generation.

WA EV owners on average are predominantly commencing charging during the day (57%) or overnight (27%).

The following sections will explore in more nuance how the various demographic groups charge.

Figure 13: Most common time of commencing EV charging



Where "Other" represents respondents who did not choose a time period, perhaps indicating that they have a diverse mix of charging time behaviour across different time periods.

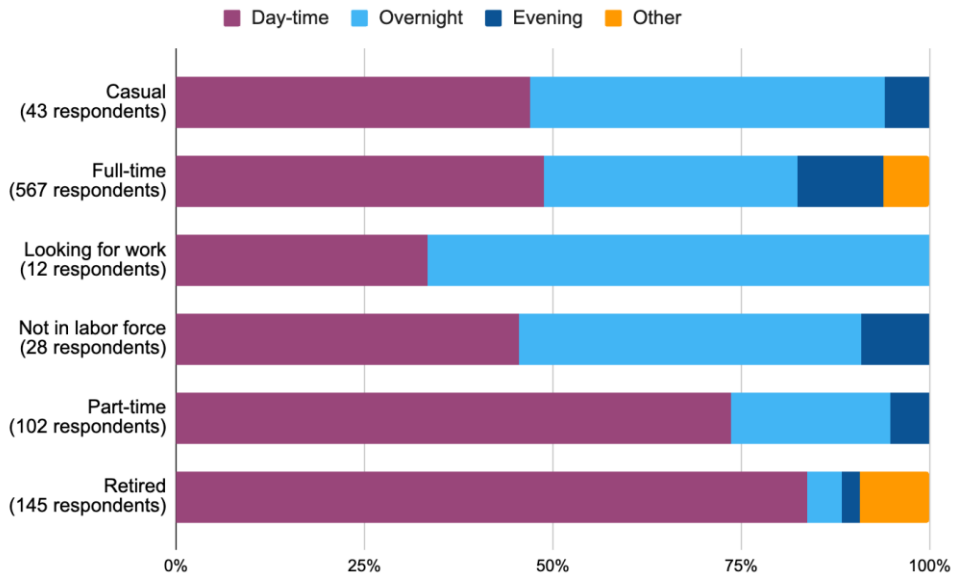
3.5.4.1 Employment type

Figure 14 shows the charging time distribution for EV owners belonging to different employment type categories. EV owners who are retired or working part-time are far more likely to engage in day-time charging compared to other employment categories and bring up the cohort average as they are overrepresented in this study compared to the general population in WA. This large share of mid-day charging may be attributed to this cohort having the flexibility to charge their EVs at home during the day.

As more of the WA population adopts EVs, it is likely that there will be a higher share of overnight and evening charging, as per the casual and full-time respondents. Even then however, a not-insignificant proportion of owners working full time or casually also participate in daytime charging which may indicate that working from home or public transit commuters who leave their car at home could also be contributing to a notable share of mid-day charging.

Retired and part time workers are more likely to charge during the day than others, but a notable share of full-time and casual employees are also engaging in day-time charging behaviour.

Figure 14: Type of employment vs. primary charging time period



Where "Other" represents respondents who did not choose a time period, perhaps indicating that they have a diverse mix of charging time behaviour across different time periods.

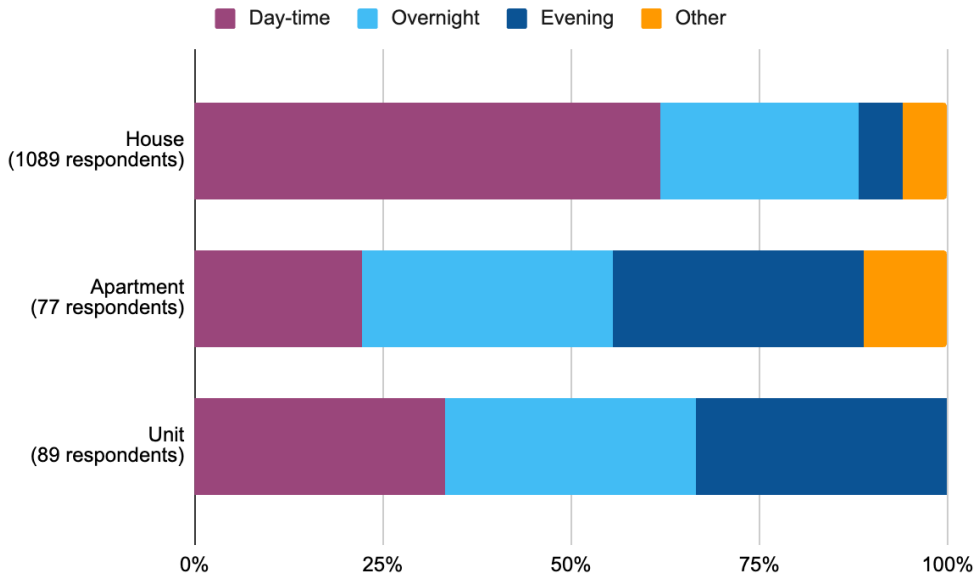
3.5.4.2 Type of residence

Figure 15 shows the primary charging time period by type of residence. Respondents that live in houses are more likely to charge their EVs during the daytime (between 9 AM and 3 PM) compared to those living in apartments or units. This may be as because a larger share of EV owners living in houses have solar PV ownership compared to those living in apartments and units, and a significant number of them also have the flexibility to adjust their EV charging time to the daytime to take advantage of solar generation (such as retirees and full-time workers working from home).

EV owners residing in houses are far more likely to start charging during the day than those in apartments and units.

In 2021, most people in WA lived in separate houses (79.7%) compared to flats or apartments (6.5%) [50] so this finding is encouraging. If growth in apartments and flat dwellings follows historical trends (from 5.7% in 2016 to 6.5% in 2021), the number of people in apartment and flat dwellings will further increase and therefore options for these EV owners to either charge during the day, or shift charging to overnight from the evening period should be explored. These might be options for on-street charging, workplace charging, or requirements in new apartment buildings for designated EV charging points.

Figure 15: Type of residence vs. primary charging time period



Where "Other" represents respondents who did not choose a time period, perhaps indicating that they have a diverse mix of charging time behaviour across different time periods.

3.5.4.3 Solar PV use

The presence of solar power at home has a notable impact on charging time behaviour, as close to 68% of respondents with solar power primarily charge their EVs during the day-time, while overnight charging has the largest share (50%) for EV owners without solar power, as seen in Figure 16. The overall averages on charging start times are heavily skewed as 75% of the respondents in the survey have solar. The proportion of EV owners with solar who begin charging overnight might indicate a lack of flexibility in adjusting their charging times.

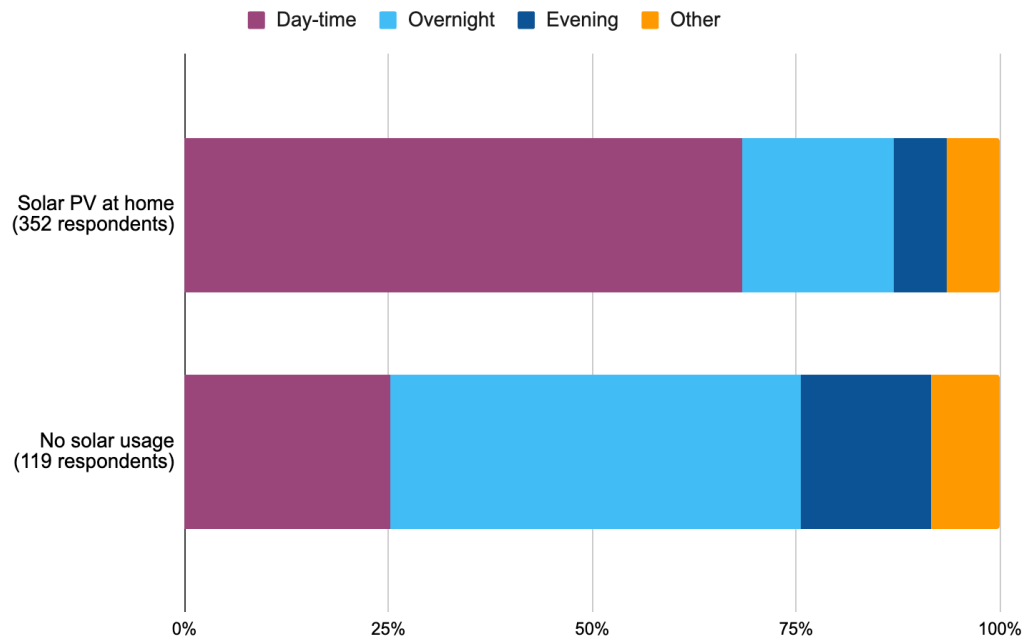
Interesting, 25% of the respondents who do not have solar are still beginning their charging during the daytime. This may be due to environmental concerns, it may indicate that it is convenient for them to charge at that time, or it may indicate that it is cheaper for them to charge during that time if they are on a Synergy TOU tariff. The larger proportion of non-solar EV owners who commence charging in the evening period may indicate that those without solar may have different levels of electricity industry knowledge and therefore may benefit from different educational campaigns. It also might indicate that these customers are on a flat rate tariff and therefore are not incentivised to move charging away from the peak.

Solar PV therefore seems to be a lever that the WA Government can push when incentivising charging during the middle of the day. Solar PV is already an attractive option for many consumers with a payback period typically between 3-6 years, with existing rules, regulations, and incentive programs. While the price that consumers can receive for exporting their solar generation remains lower than the price to buy electricity, EV owners with solar will be incentivised to charge during the day to maximise self-generation.

Policies which make solar more attractive to the mass market in combination with incentivising self-consumption are likely to have a positive carry-on effect on incentivising EVs to charge during the day.

Solar PV owners are more likely to prefer daytime charging. Incentivising day time charging via TOU adoption or incentivising solar PV with self-consumption will likely have a positive carry-on effect on incentivising EVs to charge during the day.

Figure 16: Solar PV use vs charging time



Where "Other" represents respondents who did not choose a time period, perhaps indicating that they have a diverse mix of charging time behaviour across different time periods.

3.5.4.4 Tariff type

The EV owners in the survey are more likely than the general public to be on a TOU tariff in WA, with approximately 43% of participants on one compared to approximately 3% of the general population[7]. As seen in Figure 17, EV owners on a TOU tariff are less likely to start charging in the evening to avoid the peak tariff rate and are more likely to charge overnight than those under a flat rate tariff, and less likely to charge in the daytime.

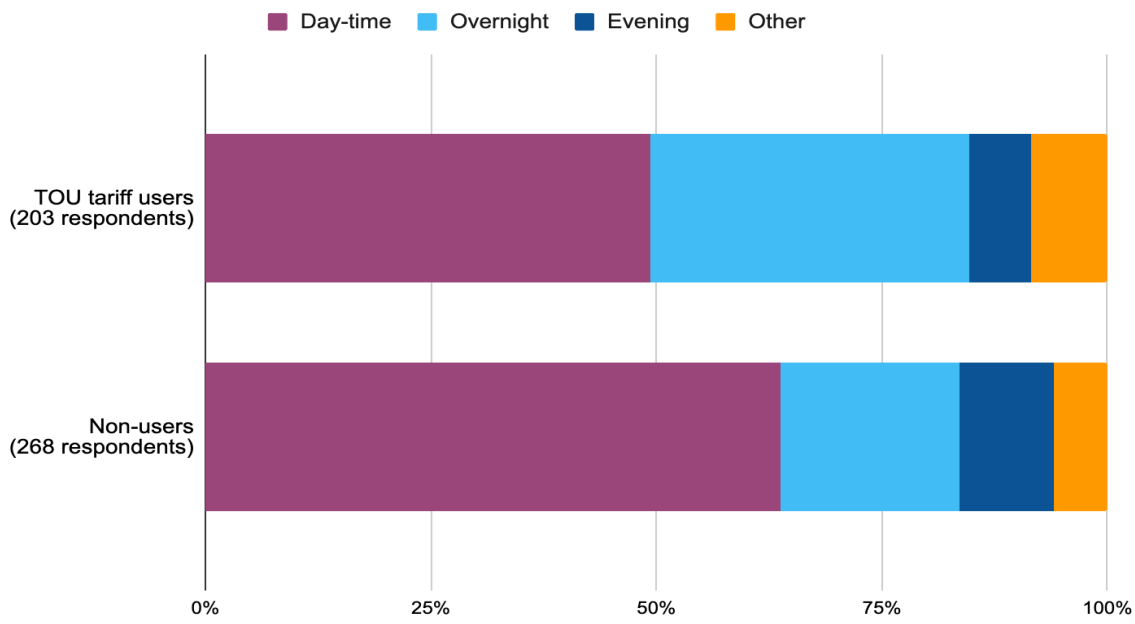
[7] There are approximately 32 ,000 residential customers under a Synergy TOU tariff compared to approximately 1.1 million residential customers in the SWIS.

TOU tariff users are more likely to avoid the peak charging period in the early evening compared to those under a flat rate tariff.

The fact that the TOU tariff users charge less during the daytime may indicate that these users are on a legacy TOU plan rather than the current Synergy Electric Vehicle Add On plan, which has a super off-peak low tariff during the daytime (9 AM to 3 PM). It may also be other factors such as home ownership or solar ownership skewing the daytime vs overnight results.

The key factor is that the amount of charging during the peak grid period is close to halve that for non-TOU tariff EV owners.

Figure 17: TOU tariff users vs. charging time

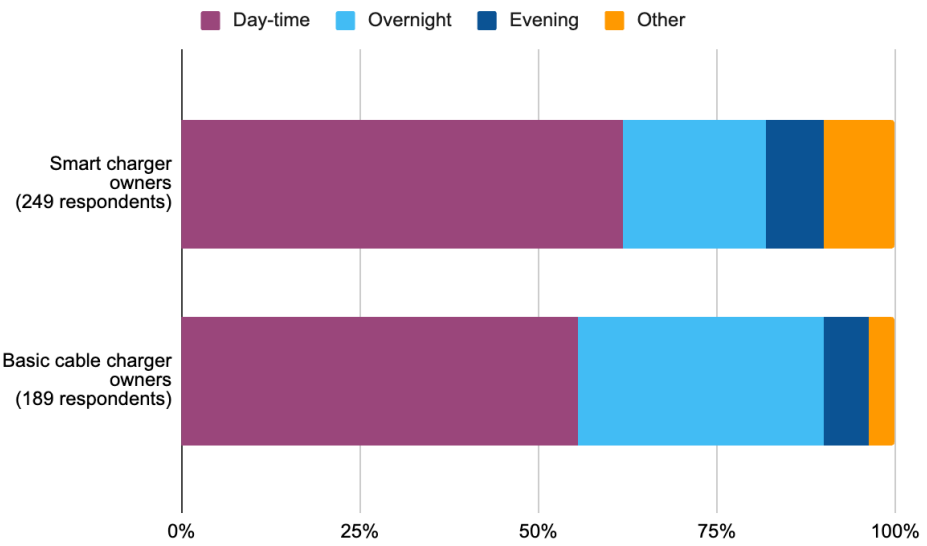


Where "Other" represents respondents who did not choose a time period, perhaps indicating that they have a diverse mix of charging time behaviour across different time periods.

3.5.4.5 Dedicated Level 2 charger ownership

Finally, dedicated Level 2 charger ownership does seem to have an impact on charging times, as shown in Figure 18. EV owners with a dedicated charger at home are less likely to charge overnight than those who use a basic cable to charge (Level 1 charger). This could be because a larger share of dedicated charger owners have solar PVs at home (~60%) compared to those with basic cable chargers (~45%). Also, a larger share of dedicated charger owners are seen to have flexible charging times (as noted by the "Other" category), which may be as they are likely able to adjust their charging times based on the day-to-day variabilities in solar energy availability.

Figure 18: Dedicated charger ownership vs. charging time



Where "Other" represents respondents who did not choose a time period, perhaps indicating that they have a diverse mix of charging time behaviour across different time periods.

3.6 Opinions on mechanisms to manage EV charging

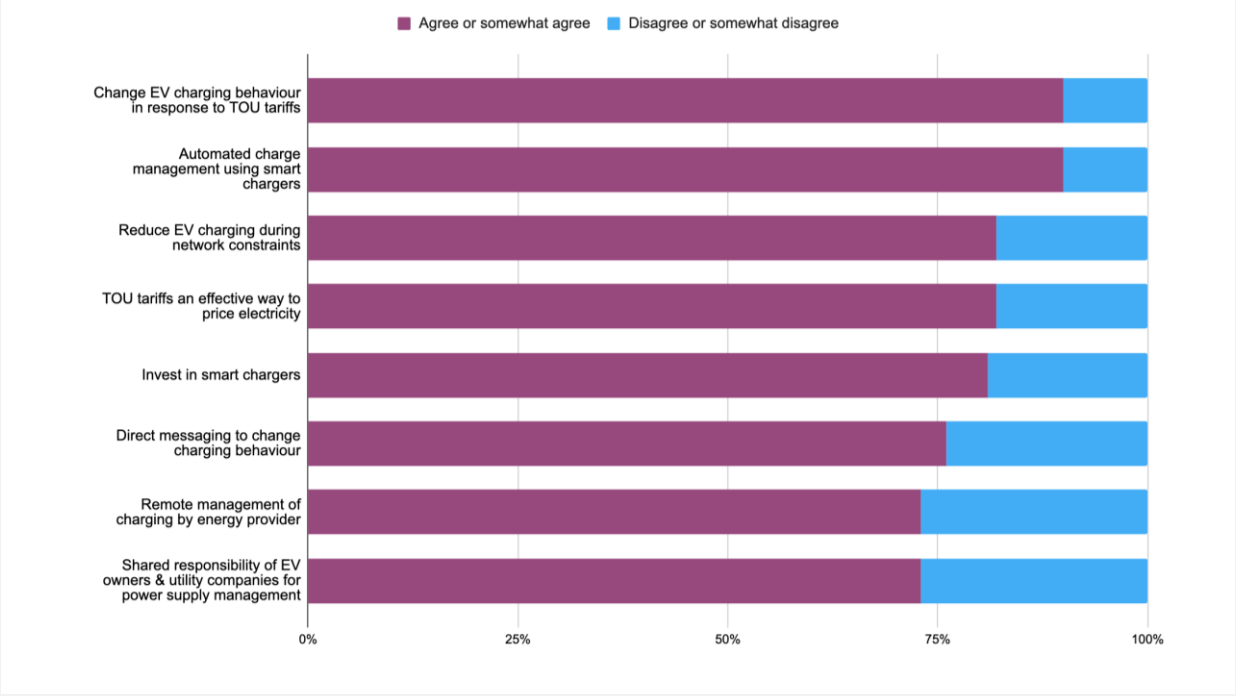
As previously noted, the participants were asked about their comfort level on answering questions on the impact of charging on the power network, and those who indicated 'not at all' were not shown the following questions. The survey asked participants about their opinions regarding various mechanisms to manage EV charging and their willingness to change their existing behaviour in response to these mechanisms. Participants were asked whether they agree, slightly agree, slightly disagree, or disagree with statements like '*I am willing to reduce my EV charging during times of network constraints to help manage the power supply*'. The full results are available in the survey report and are summarised in Figure 19.

A large share of the respondents (70% or more) agreed[8] with all the key mechanisms to manage EV charging, including automated charge management using smart chargers, TOU tariffs, direct messaging, and remote management by energy providers, while also being willing to change their behaviours in response to these mechanisms, such as shifting or reducing charging times, or investing in smart chargers.

This is a very encouraging finding for managing EV charging going forth. In particular, respondents overwhelmingly agreed they would change their charging behaviours in response to TOU tariffs and smart chargers.

[8] Either agreed or somewhat agreed

Figure 19: Survey perspectives on managed charging measures[9]



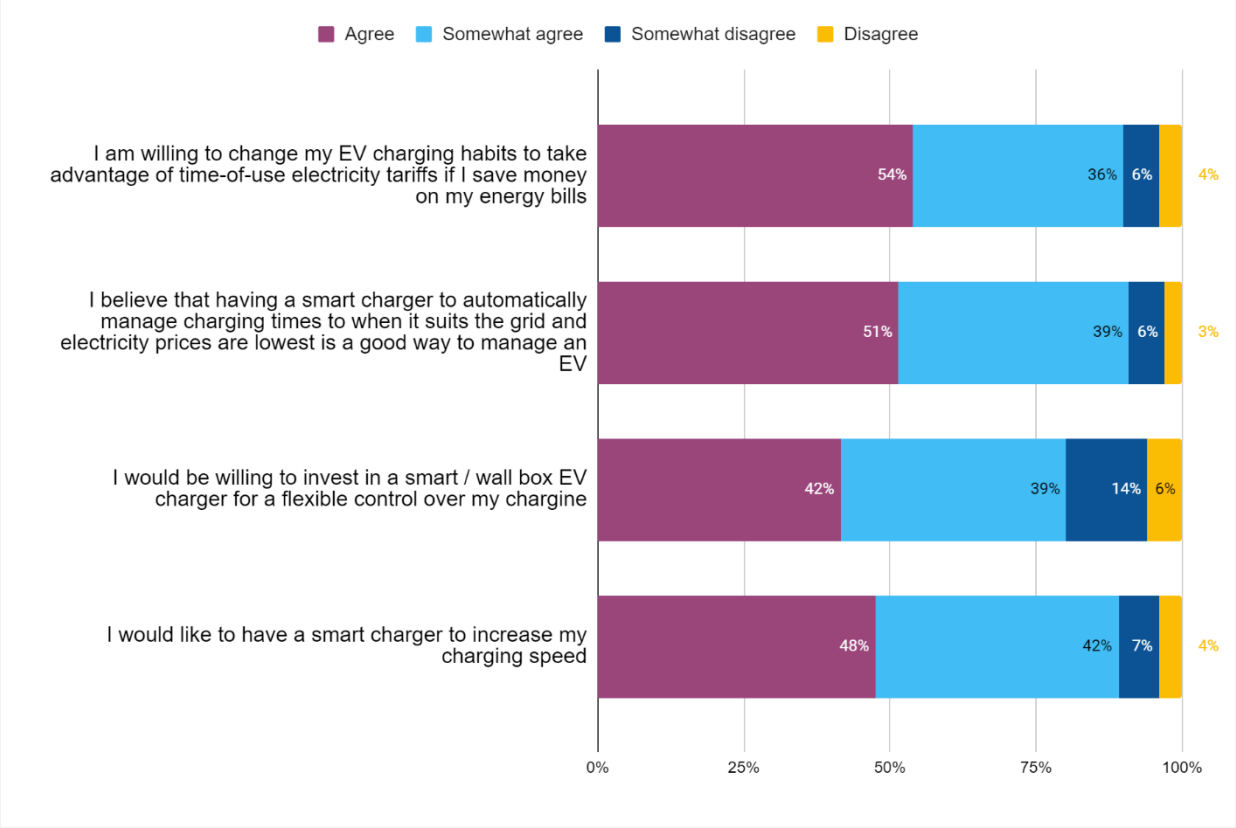
3.6.1 Smart chargers and TOU tariffs

Figure 20 provides the responses regarding selected questions about smart chargers and TOU tariffs. 90% of respondents either agreed or somewhat agreed that they are willing to change their charging behaviours for TOU tariffs. This trend is consistent regardless of income level and employment type. This is a favourable insight, as it creates, to a large extent, the right user environment for the adoption of TOU tariffs, in order to get the necessary charging behavioural shifts that can have a positive impact on grid management. This perception supports other Australian findings that EV owners are willing to, and do actively modify their charging behaviours in response to TOU tariffs [16], [27], [26], [30].

Around 90% of EV owners think that automatic charge management through smart chargers is a good way to manage an EV and indicate that they would like one to receive the faster charge speeds, but fewer (80%) would be actually willing to purchase one. This discrepancy highlights that there is some need for education and incentives for smart chargers before purchase even for these early adopters.

[9] Where 'Agree' includes both 'somewhat agree' and 'agree' responses, and similar for 'Disagree'

Figure 20: Selected statements on smart chargers and TOU tariffs



3.6.2 Direct messaging and external charge control

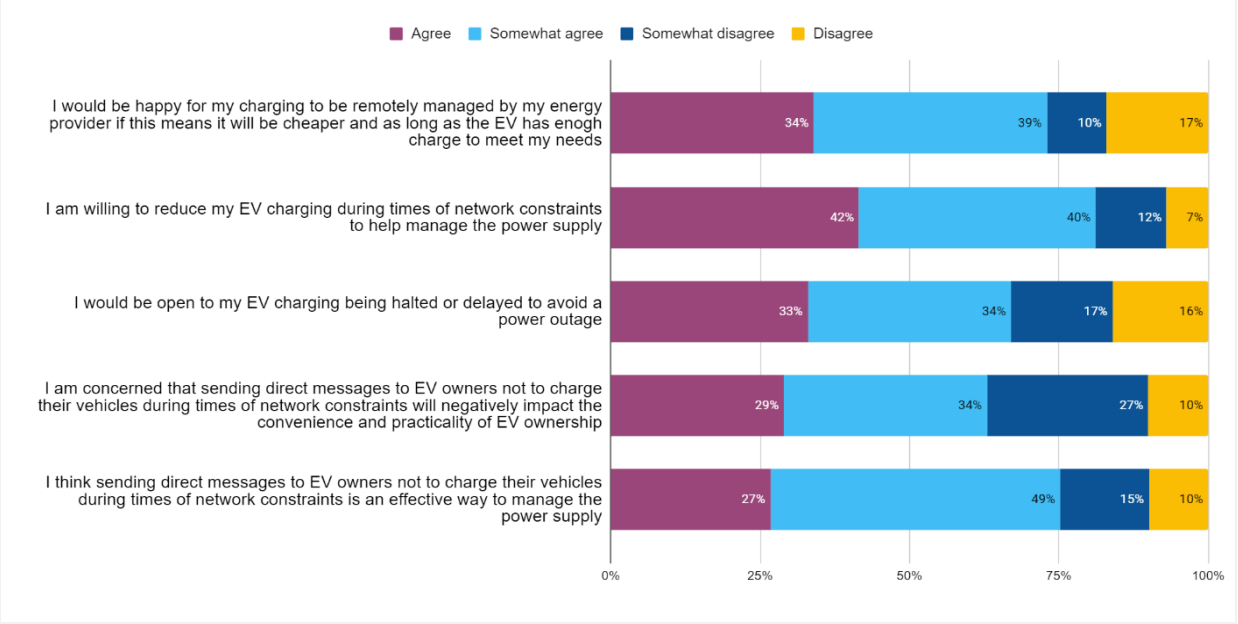
Figure 21 provides the responses regarding selected questions about smart chargers and TOU tariffs. While a significant 84% of respondents affirmed the belief that the power network should be equipped to accommodate EV charging at any moment, irrespective of the associated costs, a majority of respondents (82%) were willing to adjust their EV charging habits during periods of network strain, demonstrating a cooperative approach to power supply management.

The proposition of remote charging management by energy providers, with potential cost benefits and sufficient charging for user needs, finds acceptance among 73% of participants. A slightly lower, but still substantial, 67% of respondents express openness to interruptions or delays in their EV charging to prevent a power outage.

EV owners were also asked about their perception towards direct messaging during times of network constraints. There is a moderate level of concern (63%) that such direct messages could negatively impact the convenience of EV ownership. 76% of respondents agreed or somewhat agreed that direct messages to avoid charging during constraints would be an effective way to manage the power supply, but respondents seemed less sure of this than other mechanisms. Notably, this question was framed as stopping charging, however the

reverse, asking people to start charging in the middle of the day, might be equally as helpful to help manage network constraints and may have less negative perceptions.

Figure 21: Selected statements on externally controlled charging and direct messaging



While an in depth study on perspectives on managed charging measures has not yet been completed in Australia, these results do seem to support perspectives in various smart charging and EV TOU trials in Australia that have found that EV owners are comfortable with TOU tariffs and open to managed charging [27], [31].

Over 70% of WA EV owners have agreed with managed charging measures including TOU tariffs, automated charge management using smart chargers, reducing charging during network constraints, direct messaging, and remote management by an energy provider. Remote control mechanisms had a much higher proportion of detractors though.

4 WA Government stakeholder interviews

This section summarises the key findings from expert interviews with key stakeholders in the WA and Federal Government and community advocacy groups. Specifically, the discussions focused on two main sets of issues:

1. Concerns if EV charging behaviour is not regulated, and
2. Recommendations to control/regulate EV charging behaviour

The discussions also focused on the current policies and positions that the WA government is working on to prepare the state's electricity system for the future growth of EVs, as part of its long-term net zero and energy transformation strategy goals, and how these efforts can inform the policy recommendations in this study. These include the Distributed Energy Resources (DER) roadmap, DER orchestration: Roles and Responsibilities framework, and the Electric Vehicle Action Plan.

Potential interviewees were identified in consultation with the DMIRS. A total of 8 interviews were conducted by telephone / teleconference in January / February 2023. A copy of the briefing note is provided as Appendix A.

4.1 Main concerns of not regulating EV charging behaviour

Table 5 highlights the main concerns of not regulating EV charging behaviour that were raised by the stakeholders, as well as the proportion of the stakeholders who raised the issue as important.

Two key categories of concerns emerged from these discussions. Firstly, the stakeholders were concerned about the impacts of not regulating EV charging behaviour, mostly pertaining to the negative impacts that would result on the grid from unregulated EV charging demand. The grid concerns align with those outlined in Section 1.1.1 and in the literature review, considering network constraints during peak demand and the need for high-cost infrastructure upgrades. The stakeholders also raised concerns that EV charge management policies should consider location-based impacts, as discussed in Section 2.6.3, and were concerned that current tariff policies were limited in their scope to meet these challenges.

Secondly, stakeholders were concerned about the existing roadblocks and challenges in regulating EV charging behaviour, based on the unique contextual aspects of WA. In particular, stakeholders highlighted the concern that consumers will have limited engagement with, and/or behavioural resistance to, any policies that aim to modify EV charging behaviours. This speaks to the global studies discussed in the literature review that have concluded that there needs to be significant efforts to educate consumers before behavioural changes can be made.

Table 5: Stakeholder's main concerns regarding EV charging behaviour		
Aspect	**Key insights**	**Respondents raising as important**
Policy, regulatory and institutional aspects	• Limited consumer engagement • Limitations in current tariff policies (lack of location-specific/usage-based tariffs and affordability considerations) • Regulatory challenges from monopoly such as lack of flexibility in implementing innovative solutions and balancing customer needs • Privacy laws limiting access to information about EV ownership and charging locations	6
User characteristics	• Behavioural resistance due to lack of understanding, trust barriers or inconvenience • Affordability considerations (cost conscious consumers) • Users in regional areas (availability and accessibility of charging stations)	5
Grid impacts	• Network constraints during peak demand • High costs of infrastructure upgrades • Frequency fluctuations • Reliability • System security and capacity	4
Charging infrastructure	• Inadequate charging infrastructure • Distance and accessibility (particularly in regional areas) • Reliability and capacity of charging networks • Uptake and market readiness for smart chargers	3

The consistency of these finding across multiple different types of studies suggest that an educational campaign needs to be multipronged – educating consumers on the benefits of smart chargers for the EV driver and the grid before purchase and then how to use them effectively after, the benefits and availability of TOU tariffs, how they can switch, and how they can use their smart chargers to take advantage of low rates outside of peak periods.

Expert stakeholders in WA are concerned that EV owners may resist policies to shift EV charging behaviour due to lack of understanding, trust barriers or inconvenience.

Stakeholders also raised that there may be regulatory challenges that arise from the non-contestability of EV customers, as the monopolistic nature of electricity retailers for small customers in the SWIS may not incentivise innovative EV charging solutions through third party aggregation. This highlights the need for smart charging and third-party EV charge management trials in WA to ensure that multiple solutions are tested to best serve the dual needs of EV owners and the grid.

4.2 Recommendations to control/regulate EV charging behaviour

There are multiple strategies that can be adopted to control/regulate EV charging behaviour to mitigate the impacts on the grid, reduce grid upgrade costs, and maximise the integration and use of renewable energy. This was reflected in the range of recommendations provided by the stakeholder experts, which were found to broadly fall under the themes in Table 4.

Implementation of TOU tariff policies, EV charging policy and regulatory frameworks, various forms of smart energy management systems and educational and awareness campaigns were cited the most by experts as key recommendations to control/regulate EV charging behaviours.

4.2.1 Time of use tariffs

Most of the interviewees emphasised the adoption of time-of-use or peak/off-peak pricing structures as a prominent recommendation. These pricing mechanisms serve to incentivize EV owners to engage in off-peak charging, resulting in a more evenly distributed charging load throughout the day. This approach effectively encourages EV owners to charge their vehicles when demand on the grid is lower, without compromising their autonomy and freedom of choice. They also specified that location-based tariff policies could be considered in order to address some of the concerns in the distribution grid.

A few stakeholders highlighted the importance of exploring financial incentives for businesses, especially in low-income communities, to encourage the installation and maintenance of EV charging infrastructure. Additionally, integrating EV charging infrastructure into new developments was mentioned as key to promoting widespread adoption and accessibility.

Several respondents emphasised the crucial goal of finding an equilibrium between accommodating customer demands and ensuring the reliability of the power grid. Adopting an incremental approach, avoiding stringent enforcement measures, and providing simplified incentives and flexible participation options are key strategies. These measures aim to motivate EV owners to willingly comply with regulations while ensuring a positive and convenient charging experience. This approach prioritises customer satisfaction while effectively managing the transition to regulated EV charging behaviour.

Table 6: Stakeholder recommendations to control / regulate EV charging behaviours		
Theme	**Key recommendations**	**Respondents recommending**
Tariff policies	• Time of use (TOU) and location-based tariff policies that provide sufficient incentives to shift charging behaviour to off-peak times. • Simplifying tariff structures for ease of understanding by users	7
EV charging policy and regulatory frameworks	• Need for the development of comprehensive EV charging policies that lay a clear direction on what types of behaviour should be encouraged and minimum technology standards for charging equipment (such as smart chargers), among other things, and policy levers to promote them. • Incorporating EV charging infrastructure requirements into the planning and development rules for new businesses • Tailoring regulations and policies to address specific challenges and opportunities around regional differences can enhance effectiveness and uptake.	5
Smart energy management systems	• Range of possible solutions within this umbrella, from basic controlled charging mechanisms to more advanced solutions such as virtual power plants (VPPs), and V2G systems that can not only optimise charging and overall energy consumption but also integrate home electricity generation with the grid.	5
Education and awareness	• Educating users about the benefits of shifting their charging behaviour and how that can directly contribute to grid reliability and cost management. • Educating users about the benefits of installing smart chargers at home	4
Incentives for smart chargers	• Grants for households and businesses for the installation of smart chargers	3
Solar and battery integration	• Implementing systems that integrate EV charging with solar panels and home battery systems in order to maximise the use of renewable energy and provide cost-effective charging options for EV owners.	3
Charging infrastructure incentives for businesses	• Promote businesses to install charging infrastructure for fleet vehicles and employee use, thereby reducing the strain on home charging and leveraging excess solar production during the day.	2

4.2.2 Smart chargers and minimum technology standards

There is a shared advocacy for the promotion of smart chargers. This sentiment arises from the belief that these devices provide the end-users with the ability to set and customise their charging schedules in a way that suits their needs while also serving the broader grid stability.

Many stakeholders raised the point that there needs to be a clear direction on what types of charging behaviour should be encouraged and minimum technology standards for charging equipment (such as smart chargers) that supports this direction.

4.2.3 Sophisticated energy management and optimisation services

Embracing smart charging technologies, such as remote control and energy management services, allow for optimised charging patterns and better balancing of demand on the grid. This ensures efficient energy utilisation, enables consumers to save money and minimises grid overload or localised network constraints. In the expert consultation process, a range of opinions about the implementation of external charging control were raised. A group of interviewees underscored the potential advantage of a regulator being able to manage charging activities via smart chargers under certain conditions, which they believe could be instrumental in preserving grid stability.

Conversely, another subset of interviewees expressed concerns about the possible adverse reactions from the public towards such external intervention.

4.2.4 Regional or location specific policy

Some stakeholders raised that regulations and policies (including TOU tariffs) could be location specific to address specific challenges and opportunities around regional differences can enhance effectiveness and uptake. Virtual power plants were primarily raised as a way to address location-specific issues such as voltage stability. Dynamic operating envelopes were not discussed.

4.2.5 Education programs

Many stakeholders mentioned messaging as part of the recommendations to address charging behaviour. Launching comprehensive communication programs and initiatives is vital to educate EV owners about the optimal charging times and the impact of their charging behaviour on the power system. By fostering behaviour change, WA can effectively manage demand and alleviate strain on the grid.

5 Policy recommendations

This section provides recommendations on charging policy and strategy that draw from learnings overseas and in the NEM, as well as expert stakeholders in WA and the behaviours and perspectives of WA EV owners. It provides insights into how these policy recommendations might align with current policies and initiatives and inform policy in the future.

5.1 Current policy landscape

As mentioned in the introduction, EVs sit within a few current energy policy strategies including the *Distributed Energy Resources (DER) Roadmap* [3], and the Electric Vehicle Action Plan: Preparing Western Australia's electricity system for EVs [4]. The following sections will provide an overview of key actions being undertaken within these strategies, and comment on how they relate to EV charging.

5.1.1 DER Roadmap

The DER Roadmap is one of three work streams within the Energy Transformation Strategy and presents a timeline of various actions between 2020 and 2025 in order to 'deliver a future where DER contributes to a safe, reliable and efficient system where all customers can enjoy the benefits of DER [3], as per Figure 22.

Figure 22: Elements of the DER Roadmap (Source: [3])

Many of these actions will also aid EV charging, notably:

1. The distribution network visibility program: to enhance the understanding of distribution network power flows and constraints. This will inform any areas where localised EV charging strategies will need to be deployed, or candidates for direct messaging.
2. Tariff pilots: for alternative tariff structures to better reflect the price of energy at different times of the day. Findings regarding public acceptance of these tariffs will be useful to inform future EV specific tariffs.
3. Customer engagement programs: will aid in increasing awareness of PV and EV concerns, as well as exploring customer acceptance and gaining social licence for more sophisticated energy management and aggregation products.
4. The findings of the DER orchestration pilot (Project Symphony): of VPP technology and market participation and incorporating aggregated DER into the WEM could be used to inform any future EV aggregation, particularly for setting appropriate roles and communication between Synergy, Western Power, AEMO, EPWA, and any potential future aggregator service provider
5. Changes to the Distribution System Operator (DSO) and Distribution Market Operator (DMO) function set to enable the participation of DER in the WEM via a DER aggregator will enable EVs to participate in such programs. This led to the DER orchestration: Roles and Responsibilities framework [51], which provides guidance on the roles and responsibilities of the DSO, DMO, and DER aggregator functions.

5.1.1.1 DER Orchestration Pilot (Project Symphony)

Project Symphony is a pilot project where customer distributed energy resources (DER) are orchestrated as a virtual power plant (VPP), with the ability to offer and bid energy into the balancing market while adhering to a dynamic operating envelope, offer network support services, constrain DER energy output to zero, and offer contingency raise essential system services to manage locally detected frequency deviations. It is a collaboration between Western Power, Synergy, AEMO and Energy Policy WA, and is funded by the Australia Renewable Energy Agency (ARENA). The trial is set to be completed by mid-2023 with a minimum of 900 DER assets (air conditioners, PV, residential batteries, hot water systems, pool pumps, etc.) from 500 customers in South East Perth [52].

The pilot does not include EVs but provides a good framework for how an EV charging aggregation service trial might be run going forward and has highlighted the importance of defining roles and open communication between Synergy, Western Power, AEMO, EPWA, and any potential future aggregator service provider.

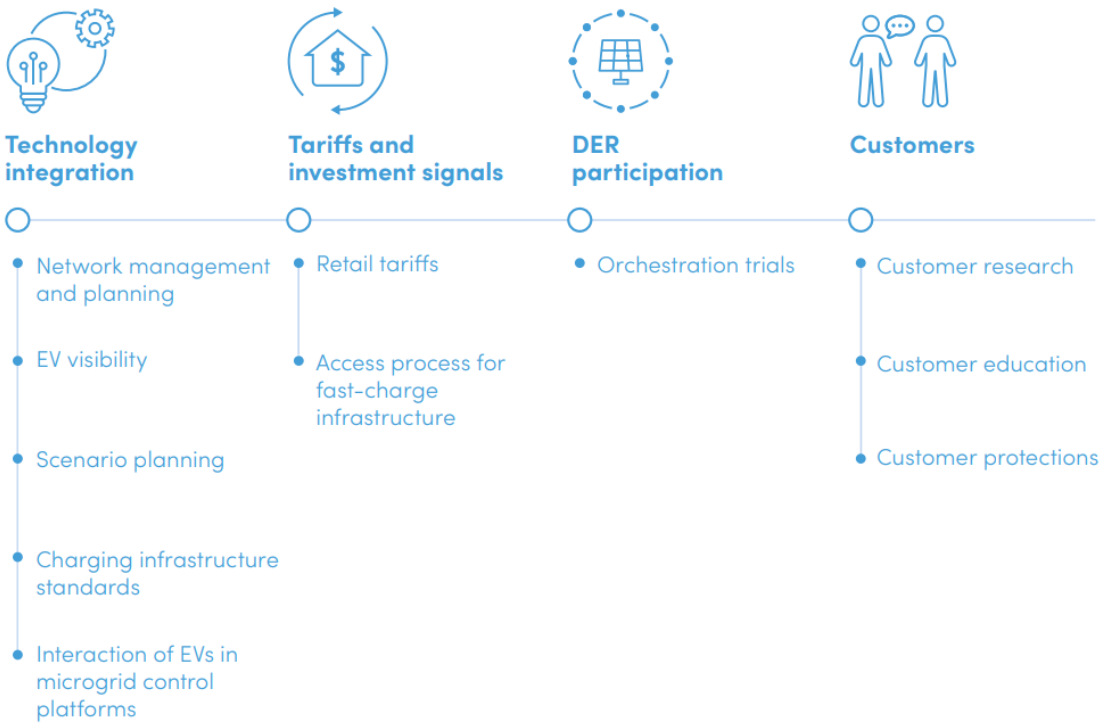
Results from the pilot give early indications that customers will engage with the concept of a VPP. This, in combination with the findings of generally positive views towards managed

charging in this report, may suggest that customers may also engage with an aggregation service for EV charging, but more research will need to be carried out to confirm.

5.1.2 Electric Vehicle Action Plan

The EV Action Plan [4] was developed to fulfil Action 16 of the DER Roadmap and presents an integrated set of actions designed to deliver a future where EVs contribute to a safe, reliable, and efficient electricity system while playing a role in accelerating Western Australia's transition to a low-carbon future. The plan has 26 actions, divided into four themes, as shown in Figure 23.

Figure 23: Themes of the Electric Vehicle Action Plan *(Source:* [4]*)*



Notable actions arising from the Action Plan which relate to this work include:

- Charging infrastructure (EVSE) standards: supporting national standard developments.
- Integration of EVs in microgrid control platforms: trialling integrating EVs into the Onslow DERMs project.
- Retail tariffs: developing an updated EV-specific retail tariff and assessment of network tariffs for charging stations
- Orchestration trials: evaluating the need and optimal timing for controlled charging and V2G trials
- Customer research: understanding customer norms and behaviours
- Customer engagement: developing an outreach program and demonstration days

- Customer protections: assessing the requirements for electricity licencing arrangements relating to EVs

5.1.3 State Electric Vehicle Strategy

The State Electric Vehicle Strategy for Western Australia [2], published in 2020 outlines the actions to prepare for the transition to low and zero-emission EVs (including both battery electric and hydrogen fuel cell vehicles) and is accompanied by a $21 million investment fund. It has four priority areas of action:

1. Stimulating EV uptake
2. Investing in and facilitating EV and hydrogen refuelling infrastructure
3. Developing and updating guidelines, standards, and requirements for planning approvals for EVs
4. Developing areas of industry relevant to EVs

Two notable actions from the Strategy that relate to this work are the adoption/development of EV charging infrastructure standards and guidelines, and the works to update planning guidelines in new residential buildings for EVs. Both of these actions are enabling actions for smart charging in the future across different building types (houses, apartments and units).

5.2 Policy options & their implications for the SWIS

The findings from the survey of EV owners in WA are highly encouraging and suggest that early adopters of EVs are already mostly avoiding charging during the evening peak, opting instead to charge during the middle of the day or overnight. However, these participants have a higher representation of rooftop solar and adoption of TOU tariffs than the general population. It is not clear whether the general population will follow these trends once EV adoption reaches mass market, and therefore policy should aim to continue to support the reasons for this good behaviour and implement policies to avoid unwanted charging behaviours.

EV charging policy should keep supporting the levers currently incentivising good charging behaviours (e.g., rooftop solar, smart charger and TOU adoption) and introduce new initiatives to prevent new EV owners adopting poor charging behaviours.

As discussed in the literature review, global trends suggest that the default behaviour of EV owners without incentives or PV is to charge at home each evening and commence charging when they arrive home. While EV charging does not currently represent an issue in the WEM due to the small numbers of EVs in WA, it could result in a material addition to the peak load in the SWIS and at feeders in the distribution network in the future if this charging behaviour is allowed to become the norm. At least in the short term, these EVs will not be evenly spread

across the distribution network, with some areas transitioning quicker than others, particularly in wealthy areas.

In the literature review, five main policies positions were found to be deployed globally:

1. Education Campaign
2. Smart Charger Adoption
3. Time of Use Tariffs
4. Energy Management and Optimisation Services, including location specific controls, and/or direct messaging.
5. Charge Override Capability

WA EV Owners who participated in the survey overwhelmingly seemed willing to participate in these charging management mechanisms and agree that charge management is important. These policies, apart from charge override capabilities, were also recommended by the WA expert stakeholders who participated in the interviews. Additionally, these stakeholders also recommended a focus on EV charging policy and regulatory frameworks, including:

- Development of comprehensive EV charging policies that lay a clear direction on what types of behaviour should be encouraged
- Minimum technology standards for charging equipment (such as smart chargers), among other things, and policy levers to promote them

Table 7 outlines the expected impacts of these policy options on the SWIS and provides global examples of their deployment.

Table 7: Impact of selected policy options on the SWIS				
Policy	**Implications for the SWIS**	**Examples**	**Stakeholder perspectives**	**WA EV Owner perspectives**
Implement Education Campaigns[10]	The impact of education alone is not thought to have a material impact on the behaviours of EV owners and therefore, while it is not a relatively expensive policy mechanism to introduce, education on its own is not expected to materially help the grid. When used in combination with TOU tariffs, smart charging, and energy management systems, however, education can be key in the public adopting more impactful policies.	UK Electric Vehicles (Smart Charge Points) Regulations 2021: 32% of the respondents who overrode their charging schedule did so because they were unsure how to change the preset time [21]. Endeavour Energy (TOU consumer insight study): education provided to customers about TOU tariffs will directly impact the level of support for these tariffs and willingness to change behaviour [40].	**Positive**: highlighted as a key recommendation	Not asked
Encourage Smart chargers[11]	Implications to the SWIS inherent to increased smart charger deployment include higher charge rates (which could result in increased charging peaks), faster charging times (which could increase the amount of flexibility each EV has to charge) and potentially could provide the opportunity for greater network visibility of charging to grid operators. The most significant benefit that smart chargers offer, however, is their ability to assist in charge scheduling to avoid peak demand periods and/or focus charging during sunshine hours, and to allow for future technology developments like V2G.	The UK has provided funding of up to 75% of the cost of EV smart charge points at residential locations [41] on the condition that certain technical standards be met to ensure interoperability and future smart charging.	**Positive**: highlighted as a recommendation by some who highlighted that clear standards or minimum functionality need to be adopted for smart chargers (e.g. remote management capability)	**Positive**: current EV owners in WA already have a high adoption rate and support both the use of and the investment into smart chargers

[10] When used in combination with 1 or more of the other policies.

[11] When used in combination with 1 or more of the other policies.

Introduce and promote TOU Tariffs	The implications for the SWIS are significant, including the ability to delay charging out of peak demand periods, shifting demand to sunshine hours to absorb solar which helps to stabilise the grid and allow it to cope with higher renewables penetration levels without other forms of intervention. These benefits can result in reduced grid upgrades required to transition to EVs and reduced overall network costs.	Australian studies show good outcomes from using TOU tariffs for EVs. Examples include the EV SmartCharge Queensland report in 2023 [26] and the AGL EV Orchestration trial [27].	**Positive**: highlighted as a recommendation by the majority, but they note that the tariffs have to be simple enough to understand (in terms of its potential value, how it works, and how to realise the benefits).	**Positive**: current EV owners in WA already have a high adoption rate, seem to be incentivised by it, and support TOU tariffs
Implement energy management and optimisation services	These systems can dynamically react to abnormal and extreme events to help stabilise the grid in ways that fixed tariffs and management systems cannot. This has the potential to avoid catastrophic grid failures in the most extreme cases, but more commonly enable Western Power and generators to defer or even avoid significant infrastructure upgrades to deal with the peak demand or impact of solar in the peak of summer.	Australian studies suggest that external charge management is effective at reducing peak demand [31] and has generally low opt-out rates [16], [27].	**Divided**: Some recommended it as instrumental in preserving grid stability. Others expressed concerns about the possible adverse reactions from the public towards such external intervention.	**Positive**: 73% of EV owners were open to the proposition of remote charging management by energy providers if they had their transport needs met
Regional or location specific policies (including Direct Messaging)	A location specific solution might look like location specific tariffs or direct messaging to people in certain locations to stop charging during constrained times or to begin charging if local solar generation is too high. EV charging could counteract issues at the distribution level, like reverse feeder flow from rooftop solar PV, low or possibly negative demand during sunshine hours, or high localised peak demand from air conditioners and other household loads. Additionally, a localised policy can work to ensure additional EV charging load does not exceed local feeder capacity limits. This might be able to reduce localised network augmentation in the future.	There are few examples of this globally, but direct messaging could follow a similar strategy used by the WA government in 2022 to raise awareness for peak summer demand periods [53], where Western Power sent targeted texts to residents living in areas which were likely to have blackouts, amongst other less targeted educational materials.	**Positive**: Some stakeholders raised that regulations and policies could be location specific to address specific challenges and opportunities around regional differences can enhance effectiveness and uptake.	**Hesitant**: 76% thought direct messaging could be an effective tool, but 63% thought that it would negatively impact EV ownership.
Charge override	DNSP overrides for residential EVs would likely be used to curtail charging at periods of high demand	Globally, it is rare for DNSPs or retailers to have override	Was not mentioned as a recommendation	**Hesitant**: 67% were open to

	compared to supply. This might be at the standard daily evening peak period when demand is high, or in emergency periods when generation is unexpectedly shut-off, forcing demand to excess supply. As discussed in Section 2.6.3.3 however, the scope for this to benefit the SWIS is limited if EV owners were already on TOU tariffs or under a smart charger charge schedule and would need to carefully consider the duration of override to avoid any loss of functionality for the vehicle.	capability for solar or EV systems. This policy mechanism draws from the South Australian 'smarter homes' policy for solar systems where the DNSP can override solar generation, and the Western Australian Emergency Solar Management policy, where Synergy can override solar generation.		interruptions or delays in their EV charging to prevent a power outage, but this also had the highest negative response from survey respondents too.

Table 8 provides EVenergi's assessment of the investigated policy positions on their impact to the grid, as well as their value proposition to the EV owner and policy and technology readiness.

Table 8: Summary of policy options compared to no policy intervention

	Policy	EV owner value proposition	Impact on SWIS	Policy readiness	Technology readiness	Implementation timeline
1	Education	Low	Moderate	High	High	Near-term
2	TOU Tariffs	High	High	High	Moderate	Near-term
3	Smart chargers	Moderate	High	High	High	Near-term
4	Energy management and optimisation services	Low: when used alone High: when used in combination with a TOU tariff	Low: when used alone High: when used in combination with a TOU tariff	Moderate (HEMs & external aggregators) Low: V2G	Moderate (HEMs & external aggregators) Low: V2G	Mid-term: trials Long-term: deployment
5	Regional or location specific policies (including Direct Messaging)	Worse than no policy intervention, unless additional incentives provided	Low	High	Moderate	Near term
6	Charge override	Worse than no policy intervention, unless additional incentives provided	Low	Moderate	Moderate	Mid-term: trials Long-term: deployment

5.3 Policy recommendations and implementation plan

Evenergi recommends 7 key action items in two tranches, based on the global policy positions, opinions of WA expert stakeholders, and the behaviours and perspective of WA EV early adopters and is summarised in Figure 24.

Tranche 1: The first tranche contains three policy mechanisms which together will largely drive EV charging behaviours into the periods of the day that will suit the grid and support the consumption of surplus solar on the grid (apart from owning rooftop solar).

1. Education programs: educate future EV owners on the benefits of and how to use smart chargers and TOU tariffs.
2. Encourage smart charger adoption: promote the installation of dedicated smart chargers that meet minimum technological requirements allowing for future remote charging management and consider leveraging financial incentives to do so.
3. Refine and promote time of use tariffs: link the smart charger incentive to an opt-out TOU tariff which incentivises EV owners to charge during the day and overnight.

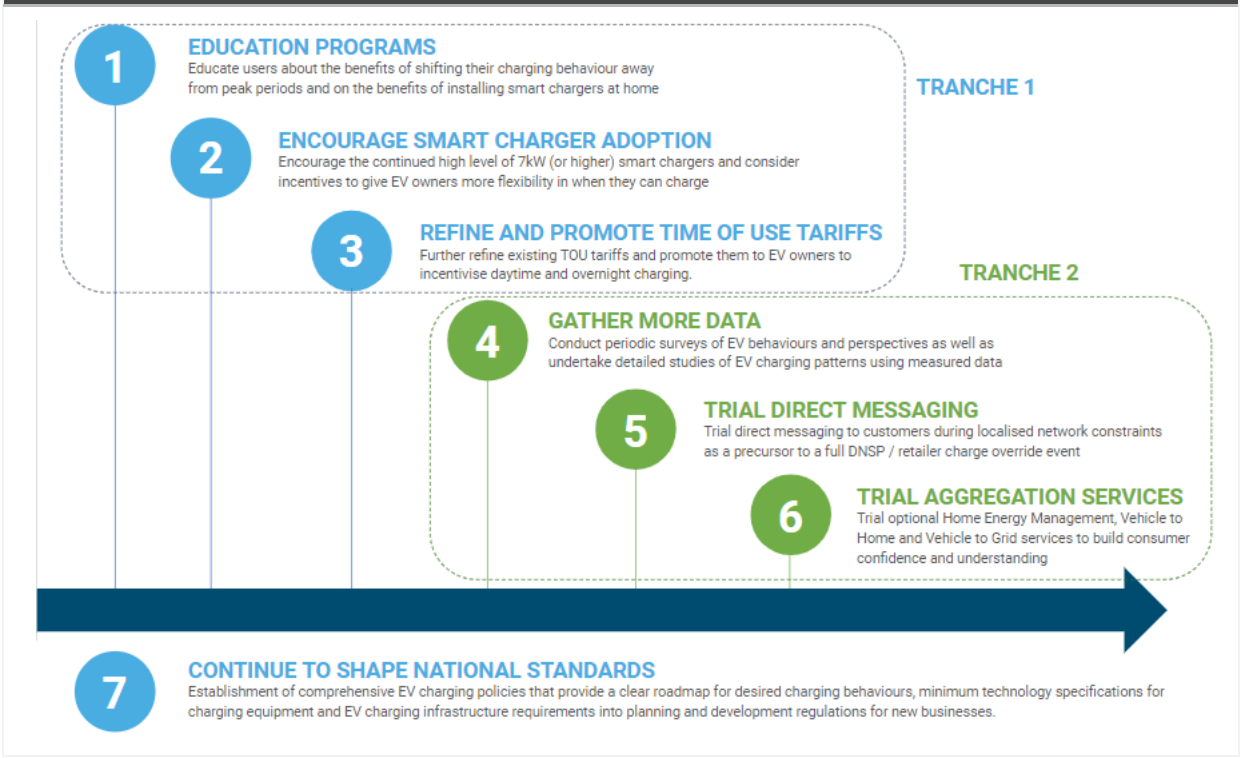
Tranche 2: The second tranche contains three policy mechanisms which will drive knowledge gathering and inform future policy as technology and social licence for charging management grows, and as more diverse groups adopt EVs.

4. Gather more data: conduct periodic user surveys and in-depth charging pattern studies to provide insights that shape future EV strategies.
5. Trial direct messaging: to customers during localised network constraints to either stop or start charging to determine effectiveness. This was accepted by the EV owners surveyed, but they noted it would be an inconvenience.
6. Trial aggregation services: to build consumer confidence and understanding and explore the potential benefits to the EV owner and the grid, including external EV charging management via smart chargers and bi-directional charging aggregation services.

The final and seventh recommendation is to:

7. Continue to shape national standards: continue to work with federal and state governments to shape national standards for EV charging infrastructure and grid policy, including ensuring that smart chargers meet minimum technological requirements which allow for future remote charging management and ultimately V2G to enable charging behaviours that assist the grid.

Figure 24: Policy recommendations



The following sections will provide key recommendations through the lens of the survey results. It will discuss how they fit within the current WA policy landscape, and comment on risks and success metrics.

5.3.1 Tranche 1

The first tranche of policies is designed to be implemented in the near term and use current technology.

5.3.1.1 Education programs

Results from the survey suggest that WA EV owners feel confident discussing the grid and are already purchasing and using smart chargers at home and are already managing their EV charging to optimise for either solar self-consumption or off-peak TOU tariff rates.

This might be as these owners are early adopters and have therefore needed to do independent research to decide if an EV was right for them. For the high proportion of EV owners in the sample that also owned solar PV, the high levels of grid knowledge may have been gained during the process of purchasing and operating PV. Solar ownership may play a dual role in incentivising EV charging behaviours, while also educating the EV owners on energy management and ways to benefit from existing grid structures like TOU tariffs.

It is likely that once the majority of the population adopts EV they will require more education to charge their vehicle in a way that is aligned with the grid, to decide to install a smart charger, and to decide to go under a TOU tariff.

The expert stakeholders interviewed highlighted the concern that consumers will have limited engagement and/or behavioural resistance to any policies that aim to modify EV charging behaviours. This speaks to the global studies discussed in the literature review that have concluded that there needs to be significant efforts to educate consumers before behavioural changes can be made.

The consistency of this finding across multiple different types of studies suggest that an educational campaign needs to be multipronged:

1. Educate owners about the benefits of shifting their charging behaviour and how that can directly contribute to grid reliability and cost management, and
2. Educate owners about the benefits of installing smart chargers at home
3. Educate owners on how to use smart chargers effectively
4. Educate owners on the benefits and availability of TOU tariffs and how they can sign up
5. Educate owners on how they can use their smart chargers to take advantage of low rates outside of peak periods.

This should be through a variety of different media including broad mass-marketing and/or tailored customer segments and should be distributed through different sources including EV manufacturers and charging infrastructure providers, prominent industry influencers, as well as more traditional sources like government websites. The survey found that prospective EV buyers prefer first-hand information from trusted sources, and primarily use EV brands' official websites (21%) for pre-purchase information, followed by social media and influencers (17%) and showroom visits and discussions with other EV owners (15% each).

Additionally, traditional sources like advertisements and articles on government and utility websites shouldn't be neglected as increasing amounts of the general population begin investigating EVs. Energy retailers have run similar campaigns for reducing air conditioning loads during peak summer days in Australia, which might provide more insights into designing successful campaigns.

Different messaging will be appropriate at different points in the EV owners journey:

- **On / before purchase**: information should be given on the benefits of installing smart chargers and TOU tariffs, and how to effectively use their features such as programmable charge scheduling. The survey results suggest that prospective EV buyers primarily use EV brands' official websites (21%) for pre-purchase information as well as social media and influencers (17%), therefore these channels are likely good targets to provide smart charging information.

- **Near critical grid events (summer peaks)**: reminders will be useful for EV owners to remember to update their charge schedules to avoid critical peak periods. This might be through direct messaging (as done by Synergy regarding general electricity consumption last summer), or advertisements and general media announcements.
- **General**: best practice guides to charging available online for engaged consumers. This could be promoted through EV user groups, trade shows, car dealerships etc.

5.3.1.2 Encourage smart chargers that meet strict criteria

The findings from the literature review and expert stakeholder interviews highlight that smart chargers are important to enable future smart charging as they:

- support high charge rates beyond that which can be offered by the standard wall plug which allows for greater flexibility in charging time,
- offer the ability for the EV owner to pre-program simple charge scheduling which will enable them to benefit from TOU tariffs by avoiding peak demand charging and/or consuming solar generation in the middle of the day,
- offer the ability for external charge management through a HEMS device or an aggregation service in the future.

The survey results suggest that WA EV owners overwhelmingly charge from home currently, and more than half (55%) already use a dedicated Level 2 charger, even those at lower income levels. EV owners in WA with higher household incomes seem slightly more likely to have a smart charger than those with lower incomes, although the small sample sizes at the lower income end of this study make this inconclusive.

Findings from the literature review indicated that the higher upfront cost of purchasing smart chargers can be a barrier to their adoption. Reducing the upfront cost of installing a smart charger, along with an education campaign explaining the benefits of smart chargers, will likely drive higher uptakes of smart chargers, as it has done in the UK. As EV owners in WA move past the early adopters to the general population, this will become increasingly important. As such, financial incentives should be considered for early adopters to mitigate the higher upfront costs of smart chargers as part of EV trials.

It is important however that any incentives on smart chargers, perhaps as part of EV trials, are dependent on them meeting certain requirements to ensure they will be able to facilitate charge scheduling now, and to enable energy management in the future. They should be capable of communicating with a 3rd party system for management and reporting. Remote management capability requirements to facilitate greater customer engagement and value for the electricity grid could be foreshadowed in timeframes consistent with future DER aggregation market development in WA.

We recommend that these incentives are tied to signing up to a TOU tariff for a minimum amount of time. This is a positive scenario for both the SWIS and the EV owner, as the EV

owner can access cost savings from the TOU tariff in addition to receiving the discounted smart charger and opens them up to capitalise on future revenue from participation in aggregation services. We recommend that this is the case regardless if the EV owner has solar or not for equity reasons and as it is beneficial to those with and without solar PV, assuming that the feed-in-tariffs for solar export are not modified.

The minimum time window, for example 3 months, allows the owner to become familiar with the tariff and smart charger before immediately opting out, which should improve effectiveness of the modified charging behaviours, while ensuring that owners who cannot change electricity consumption behaviours (EV or otherwise) are not unfairly penalised.

This recommendation therefore comes in three parts:

1. develop minimum smart charger criteria
2. encourage residential smart chargers that meet said criteria and are tied to signing up for a TOU plan with Synergy
3. explore the option of introducing pre-installed charging schedules that can be later modified by the user, as done in the UK

5.3.1.3 Refine and promote TOU tariffs to incentivise daytime and overnight charging

A key recommendation for the government, based on our comprehensive research, surveys, and stakeholder interviews, is to refine and promote Time-of-Use (TOU) tariffs to incentivise daytime and overnight EV charging. Such tariffs would align EV charging with the grid's capacity and operational requirements, thereby mitigating the risk of network overloads.

The EV owners (both those with and without solar PV) will see higher rates during the shoulder/peak periods and lower rates during the day and overnight. There is a significant direct financial benefit to EV owners if they can access this low-cost energy to charge their EV. The average EV owner stands to more than halve their costs to charge their EV by using a TOU tariff and adjusting their charging behaviours compared to a fixed tariff, saving approximately $440 each year[12]. In order to achieve this, they will simply need to program their smart charger or vehicle to turn on at the appropriate times as a once-off exercise.

The endorsement of TOU tariffs is a common thread woven throughout both our survey responses and stakeholder interviews. 88% (7 of 8) of the expert stakeholders agree that this policy measure could play a pivotal role in ensuring that EV charging aligns with the grid's capacity and optimal operating periods. Similarly, the survey respondents echoed this sentiment, noting that they are open to adopting TOU tariffs to minimise their potential impact on the grid, and a large number of the participants (43%) were already on a TOU tariff. This is

[12] For an average EV user travelling 11,300km pa, consuming 2,600kWh pa. Comparing the Synergy Home Plan (A1) at 30c/kWh with the Synergy EV Add-on plan at 8c/kWh off-peak, 50% time and 18c/kWh peak, 50% time

especially high considering the general low adoption of TOU tariffs by the general population of WA.

This consensus aligns with findings in both global and Australian literature on EV charging behaviour and policy. Research shows that TOU tariffs can be an effective mechanism to guide charging behaviour, provided the public understands the rationale and benefits of this policy. Therefore, education programs will be crucial to ensure widespread awareness and acceptance of TOU tariffs. These programs should aim to highlight the benefits of TOU tariffs, such as reduced electricity costs and grid stability, thereby encouraging individuals to shift their charging to off-peak periods.

Moreover, the adoption of smart charging infrastructure that supports start and end charging time randomisation is an essential complement to TOU tariffs. This feature will ensure that the start of the off-peak period does not trigger a secondary peak demand, effectively distributing charging sessions over the entire off-peak window. The pairing of TOU tariffs with smart charging technology will therefore not only optimise grid operations but also foster sustainable and efficient EV charging practices.

5.3.2 Tranche 2

The second tranche contains three policy mechanisms which will drive knowledge gathering and inform future policy as technology and social licence for charging management grows, and as more diverse groups adopt EVs.

5.3.2.1 Gather more data

Gathering more data on EV owners' behaviours and perspectives can further enable informed and effective decision-making and could provide crucial insights that shape future strategies and initiatives. We recommend three forms of data collection.

Firstly, conducting periodic user behaviour and perspective surveys can offer valuable longitudinal data on the transition from early adopters to a more mainstream user base. These regular assessments would enable tracking of changes in user demographics, charging behaviours, and attitudes over time, thereby contributing to a nuanced understanding of the evolving EV landscape. By mirroring the approach undertaken by Ergon/Energex in Queensland [26], these surveys could serve as a powerful tool to measure the efficacy of education campaigns and inform necessary adjustments.

Secondly, we recommend undertaking detailed studies of EV charging patterns using measured data, as opposed to relying solely on self-reported preferences. These studies would go beyond surface-level trends to explore in depth how, when, and why owners charge their vehicles. This measured data can present a more accurate depiction of charging behaviours, avoiding the pitfalls of wishful thinking and providing a solid foundation for policy decisions.

Thirdly, more work should be done to understand the patterns of poorly represented demographic groups which will participate in the subsequent waves of EV owners – particularly of people who live in apartments/flats, those who don't own their own home, young people, women, and those with lower income levels.

The proposed supplementary activities – periodic user surveys and detailed charging pattern studies – will add significant depth to our understanding of the evolving EV sector. While they may not directly inform policy development in the short term, these initiatives will underpin robust, data-driven policy decisions in the long term, thus enhancing the effectiveness of our responses to the opportunities and challenges presented by EV technology.

5.3.2.2 Trial direct messaging to customers during localised network constraints

A pressing challenge that requires consideration in the context of increasing EV adoption is localised network constraints. In the absence of smart energy management systems which have localised incentives, direct customer messaging during periods of such constraints might be a viable solution to alleviate this issue. This method involves the network operator reducing the rate of charge during periods of network constraints, similar to practices currently in place for home NBN services. It could be a precursor to a full DNSP / retailer charge override event.

A significant majority of survey participants, approximately 76%, expressed agreement with the idea that direct messaging to stop charging could help modify charging behaviour, but 63% thought that it would negatively impact EV ownership. This finding suggests that many consumers are open to being directly informed about grid stress conditions and may be willing to adjust their charging patterns accordingly but would do so at their detriment. This may therefore be a policy that is best used sparingly.

While not directly explored in this study, the direct messaging could also be used to incentivise EV owners to start charging during periods of lower demand, probably during times of high solar generation. This form of engagement could also provide consumers with a better understanding of the impacts of their charging behaviour on local network conditions. This should be done in conjunction with a broader education program, beyond EV drivers to precondition people to good behaviour and to be receptive to the message.

For those not near their vehicles at the time, a smart charger with remote management capabilities would be vital to enabling EV owners to react to the message. However, it is yet to be determined whether or not this will result in a noticeable demand reduction or what sort of participation rates we will see if this is an opt-in policy.

The concept of direct messaging was not raised in our expert stakeholder interviews or surfaced in the literature review, however, stakeholders did raise the concern that there was a lack of location-specific incentives.

The introduction of direct messaging could particularly benefit EV owners who do not opt for market aggregation products or external management systems. By receiving notifications during periods of network constraints, these owners would have the opportunity to manually adjust their charging behaviours, contributing to the overall network stability. As such, a trial of direct messaging to customers during localised network constraints is a recommendation worth considering.

5.3.2.3 Trial charging aggregation services

More intelligent energy management systems including Home Energy Management Systems (HEMS) and external aggregation services had a general but lower level of acceptance by the WA EV survey participants than other charging mechanisms. Direct charging management by an external party was seen as negative by 31% of the survey respondents and would be expected to be viewed with hesitation by the general population.

The stakeholders interviewed were divided on using such systems. A group of interviewees underscored the potential advantage of a regulator being able to manage charging activities via smart chargers under certain conditions, which they believe could be instrumental in preserving grid stability. Conversely, another subset of interviewees expressed concerns about the possible adverse reactions from the public towards such external intervention. They feared that regulatory control over charging could be perceived as overreach, triggering not only negative responses but potentially leading to consumer backlash.

We believe the expected pushback from EV owners on this point has stopped governments globally from mandating participation in sophisticated energy management systems to date, as well as the lack of required hardware in place for aggregators and service providers to create the value proposition to convince EV owners to participate in the future.

We therefore suggest implementing charging aggregation trials to build consumer confidence and trust, as well as the required institutional knowledge and regulatory procedures. This could leverage the solutions and learnings from the DER Orchestration Pilot (Project Symphony), and provide a good framework for setting appropriate roles and communication between Synergy, Western Power, AEMO, EPWA, and any potential future aggregator service provider. EPWA could look to the AGL and Origin trials, outlined in Table 3, which are investigating external charging management via smart chargers [27], [31].

Future trials should also extend to bi-directional charging aggregation (also known as vehicle-to-grid, V2G) to utilise the car battery as a stationary battery and opens many new options for EVs to power the home and/or support the grid and be rewarded for it. This could be the factor which creates material value for the EV owner from a sophisticated energy management system, however these chargers will need to significantly reduce in price in order to be a viable option beyond trials, and more EV models will need to support bi-directional charging capability.

Standards for bi-directional charging are a work in progress, and the technology is still not yet commonly commercially available, and therefore we recommend first following the predominate V2G trials currently happening, like the Realising Electric Vehicle-to-Grid Services (REVS) project by the Australian National University [54] and the Project Sciurus trial in the UK [55]. The Project Sciurus trial tested over 320 V2G units installed in homes throughout the UK over a three-year time frame. The REVS trial ran between June 2020 and March 2023 [54] and demonstrated V2G technology in a fleet of 51 Nissan Leafs in Canberra. Through this process have published numerous lessons learnt and reports on the business models and standards needed for V2G in the National Electricity Market. We recommend that WA runs additional trials to capture the unique regulatory requirements in WA.

This recommendation therefore comes in two parts:
1 Trial external EV charging management via
2 Trial bi-directional charging aggregation services

These could be bundled into one trial with different components, as was done in the Origin Trial.

5.3.3 Ongoing policy

5.3.3.1 Continue to shape national standards

In the stakeholders interviews, a recurring theme that emerged, supported by 5 of 8 stakeholders, was the need for the development of consistent national standards for EV charging. As part of these unified standards, the stakeholders recommended the establishment of:

- comprehensive EV charging policies that provide a clear roadmap for desired charging behaviours,
- minimum technology specifications for charging equipment, such as smart chargers,
- embedding EV charging infrastructure requirements into planning and development regulations for new businesses.

For Western Australia (WA), these minimum technology specifications for smart chargers, should be aligned with international standards such as the OCPP 1.6 rather than state/territory specific, and should align with federal guidelines. This alignment is crucial to ensuring that WA's EV owners have access to a comprehensive range of options for smart chargers and to avoid any compatibility issues between chargers, vehicles, and aggregation platforms. The absence of such standardisation could inhibit the seamless operation of these technologies and restrict the choices available to consumers. We understand national harmonisation efforts are underway through the Department of Climate Change, Energy, the Environment and Water's (DCCEEW) EV Integration Working Group.

Many smart charger brands and models are now readily available in Australia and are fully capable of managing charging times and also communicating with other systems to manage charging times as part of a broader energy management system. An example of minimum requirements for EV chargers which the WA Government could modify is the South Australian Government's Technical Regulator Guidelines [56], which will apply to chargers installed after 1 July 2024.

Other countries and regions have offered incentives through the vehicle sellers, but this has not been a dominant strategy in Australia. The international standard for this is OCPP 1.6J. We would not recommend creating any standards that chargers must meet which do not align to international markets, as they may severely curtail available options and have a negative impact on the market and overall adoption rates.

While not the focus of this piece of work, V2G systems may become an important value add to the EV owner in the future. V2G technologies offer the potential for vehicles to sell their electricity to the power grid, particularly during periods of high demand, thereby playing a key role in balancing supply and demand. However, to fully realise this potential, the establishment of clear, consistent standards is essential.

The survey results highlighted that despite commuting to work being the most common trip purpose, only 6% of charging was done at the workplace. This indicates that there are many EVs parked at workplace carparks and park-and-ride locations during the day, and that there is an opportunity to install chargers at those locations to maximise EV charging consuming solar generation. The WA Government is addressing this via the Charge Up Workplace EV Charging Grants [57] which provides 50% co-funding of charging infrastructure for $15 million of grants. As raised by the expert stakeholders, embedding EV charging infrastructure requirements into planning and development regulations for new businesses will allow for more workplace charging opportunities which will further incentivise charging during sunshine hours.

Finally, these efforts to create national standards for EV charging should not exist in isolation but form part of a broader initiative to develop consistent standards for distributed energy resources (DER) in general. By working closely with federal and state governments, it will be possible to devise a set of uniform standards that facilitate the effective integration and operation of DER, including EVs, within the Australian power grid.

6. Conclusion

Western Australia is still early in its electromobility transition and because of that WA EV owners are primarily early adopters. They fit the same demographic profile that has been seen globally, predominantly high socio-economic individuals.

Unlike the early adopters in countries like Norway, however, WA EV owners seem to be charging in a way that is conducive to grid operations – with 57% opting to start charging during the day, and 27% overnight. This aligns with emerging Australian research which also finds a significant amount of charging throughout the day in the absence of direct charging management. This is perhaps unsurprising as Western Australia, and Australia as a whole, is world leading in rooftop solar photovoltaic installations. WA EV owners also seem to actively manage their charging more than we might expect, are likely to have a dedicated Level 2 charger at home (55%) and are more likely to participate in TOU tariffs and have solar than the general population.

This is a highly encouraging finding, as early adopters will spread their EV experiences and influence subsequent waves of EV owners. However, given that early adopters fit one specific demographic, it is not a given that this behaviour will continue if left unmanaged. The WA government has a role to play to shape and guide the purchasing decisions and behaviours of the current and next cohort of EV buyers to ensure efficient interactions with the electricity grid moving forward.

Considering the recommendations of key expert stakeholders from the WA government, as well as the stated perceptions of the survey participants, this report recommends seven actions to keep incentivising these charging behaviours in early adopters, and to ensure that new EV owners of different demographics also have sufficient incentives.

The first tranche of policies is designed to be implemented at the same time and support each other. They are policies that are low cost and relatively easy to implement but have a high potential impact on firstly enabling and empowering EV owners to modify their charging behaviours, and secondly to shift charging away from peak demand periods. They include designing education programs, financially incentivising smart chargers, introducing and promoting EV-specific TOU tariffs.

Firstly, we recommend designing education campaigns that inform potential EV owners on the benefits of installing smart chargers and going onto a TOU tariff, as well as educational materials to inform EV owners about optimal charging behaviours. These education pieces will likely need to support customers with and without solar differently as those with solar seem to already have a high level of understanding of the grid and have a high uptake of TOU tariffs.

Secondly, we recommend encouraging the adoption of 7kW+ smart chargers that meet strict minimum technical standards and are linked to signing up to a TOU tariff for a certain amount of time, after which the user can opt-out. We recommend that this is the case regardless of if the EV owner has solar or not for equity reasons and as it is beneficial to those with and without solar PV, assuming that the feed-in-tariffs for solar export are not modified. This is important for providing EV owners with more flexibility in their charging and to allow them to schedule and remotely manage their own charging in the future.

Third, we support the excellent EV-specific TOU tariff Synergy has implement and suggest this is refined and promoted to maintain the relatively high uptake seen by EV owners to date in WA. The implementation of TOU tariffs was almost unanimously accepted and could be implemented without materially impacting EV adoption or owners' sentiments. These first three recommendations will inform, enable and incentivise moving EV charging behaviours into the periods of the day that will suit the grid and support the consumption of surplus solar on the grid.

The second tranche of recommendations are to gather more data on how EV owners charge, to trial direct messaging to customers during periods of localised network constraints and to trial charging aggregation services. These measures were generally accepted by the EV owners surveyed, but to a lower extent than TOU or smart chargers, and therefore we suggest trials in this space to build consumer confidence and understanding of the benefits they might provide.

Finally, we recommend continual work with the federal and state/territory governments to shape EV standards to ensure that WA's EV owners have access to a comprehensive range of options for smart chargers and to avoid any compatibility issues between chargers, vehicles, and aggregation platforms.

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