Large-Scale Network and System Integration of Electric Vehicles: A Techno-Economic Perspective

THE UNIVERSITY OF MELBOURNE

Electric Vehicle Charging

Consumer Survey

Insights Report

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C4NET Centre for New Energy Technologies

API The Australian Power Institute

Executive Summary

As electric vehicle (EV) uptake increases worldwide, a major concern is how consumer charging behavior will impact electrical networks. This project addresses this concern through the investigation of consumer behaviour, network modelling, and techno-economic modelling.

As part of the behavioural investigation, this report complements the literature review "Electric Vehicle Uptake and Charging: A Consumer-Focused Review" by examining EV charging preferences of Australian consumers. The analysis utilises data from current and potential EV owners obtained in an online survey conducted in mid-2021. The main conclusions are:

- Current EV owners drive almost two times the national average distance travelled per car per year. Those intending to buy an EV within the next year also driver longer distances than the national average.
  - Therefore, charging needs per individual are likely to decrease as the adoption curve reaches the majorities.
- Home is the preferred charging location for current owners and potential consumers. However, monetary savings can make workplace charging a strong alternative.
- Fast-charging service stations are perceived to be more convenient than standard chargers located at destinations of interest.
- Potential consumers seem to underestimate their ability to charge at home and at work.
- Residential charging is likely to take place during evening peak if unmanaged.
- Mainstream consumers are more responsive to ToU discounts than current EV owners.
- Acceptance of supplier-managed smart charging is higher among EV early adopters than mainstream consumers.
- To increase supplier-managed smart charging acceptance:
  - Monetary savings need to be evident and clear to consumers, even if tariff structure is dynamic and complex.
  - Third-party management and control need an interface via App that increases users' sense of control over charging and decreases their feeling of uncertainty.
  - Clarity in data sharing and user privacy policies is required.
  - Consumer awareness about environmental and community benefits need to be addressed in campaigns.
  - Public charging needs to be perceived as an easy and accessible backup plan.

Contents

1. Background and objectives

The Project

The project “Large-Scale Network and System Integration of Electric Vehicles: A Techno-Economic Perspective” is being conducted by researchers of The University of Melbourne in partnership with Energy Networks Australia, the Centre for New Energy Technologies, and The Australian Power Institute. The project aims to investigate the potential impacts of EV uptake on electricity networks under different future scenarios. The project is divided into four main research areas:

1. Consumer acceptance and charging of EVs.
2. Distribution network impacts from unmanaged EVs
3. Distribution network integration of EVs using management strategies.
4. Techno-economic network and system integration of EVs.

Findings from the project will provide strategic inputs about the effects of EVs on the network and the role of EV management in mitigating potential negative impacts. These results aim to inform a roadmap for EV deployment, including an updated view on how to drive positive consumer response to charging management, and insights into potential commercial and regulatory changes.

The Report

This report is part of Research Area 1 and presents the results of an exploratory online survey with vehicle owners in Australia. Two separate samples were investigated: internal combustion engine passenger vehicle (ICEV) owners and electric vehicle (EV) owners. The survey was developed based on results from a review of national and international literature on the preferences and behaviours of potential and current EV users.

A market research panel aggregator company was used to recruit and compensate participants. The data collection was approved by the Human Research Ethics Committee of The University of Melbourne (ID Number 20391). Data were collected between July and August of 2021. In addition to the traditional vagaries associated with online sampling, the data used in this study was collected during a time that respondents may have been experiencing diverse challenges related to the COVID-19 pandemic, which may have influenced their responses.

The outcomes of the survey include general insights into consumer charging intention and behaviour, which can be used as a starting point for the development of future electricity demand scenarios.

Survey Aim and Objectives

The aim of this survey is to generate insights into EV charging preferences of Australian consumers.

Objectives

1. To characterize EV ownership and purchase intention.
2. To identify preferred locations and times for EV charging among current EV owners and potential consumers.
3. To understand consumer willingness to adopt time-of-use tariffs and supplier-managed smart charging systems.

Research Design Considerations

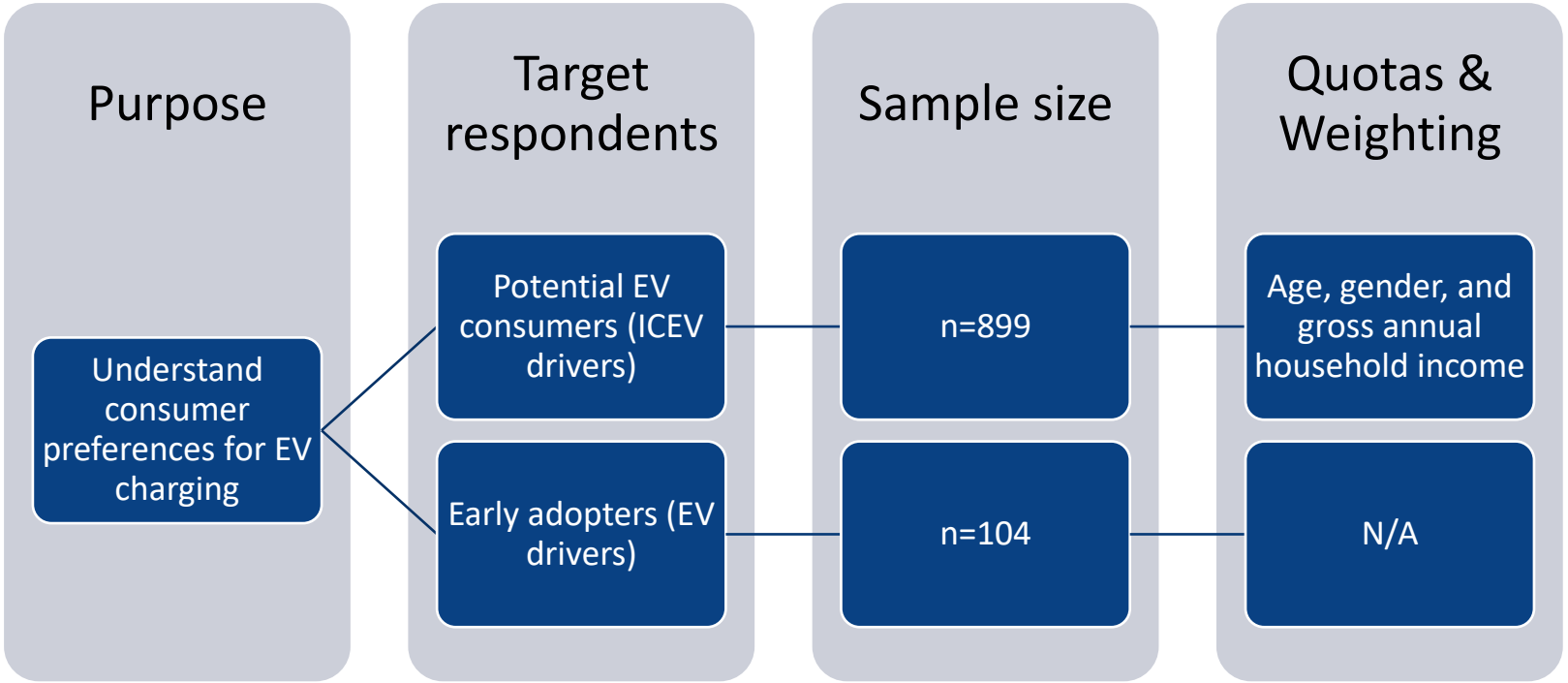
There are almost 15 million passenger vehicles registered in Australia, but only 20 thousand of these are EVs[1]. Considering this low incidence of EV ownership, a random sample of vehicle owners in Australia would not allow for an investigation of EV owners' preferences and behaviours. Therefore, this study sought to collect data from two samples totalling 1000 responses. Sample 1 targeted at 900 responses from ICEV drivers, who are potential EV consumers, while Sample 2 aimed to reach 100 EV drivers, who are early adopters of this technology. 'Drivers' were defined as individuals who are 18 years or older, hold a valid driver's license, and live in a household that owns at least one car. EV drivers not only had to own an EV, but they also had to be the person in the household to predominantly use and charge it.

Sample 1 was exogenously stratified to ensure national representativeness relative to Australia's adult population (driving age) in terms of age, gender, and gross household income. The socio-economic stratification was defined based on the distribution of age, gender, and household income of the adult population of Australia as these socio-demographic profiles are not available for the specific population of car owners. This approximation is acceptable considering that Australia has on average one car per adult and only 7% of Australian households do not own a car[2]. Non-interlocking socio-demographic quotas for Sample 1 were obtained using filter questions at the beginning of the online questionnaire and then weights were applied to the final sample for fine adjustments. Sample 2 did not target any socio-demographic distribution as the profile of the EV owner population of Australia is unknown.

A market research panel aggregator company, Qualtrics, was used to recruit and compensate participants. Online sample providers maintain a list of potential survey participants (email or user-id list) and utilise weighted randomisation techniques (based on the desired socio-demographic attributes) to send out survey invitations to potential respondents. Even though the invitation process can be considered probability-based, this sampling approach still suffers from frame coverage bias and selection bias. That is, only individuals who are capable and willing to join online market research panels are reached (frame coverage bias) and those who are invited can accept or reject survey invitations and opt-out while taking the survey (self-selection and non-response bias). Recruitment strategies aimed to minimise self-selection bias by omitting any information about the survey topic from the recruitment material. The use of sample providers cannot be considered a flawless probabilistic sampling approach but allows for better socio-demographic distribution coverage than other convenience sampling techniques. With the above limitations in mind, this report focuses on descriptive statistics rather than inferential statistics.

[1]Australian Bureau of Statistics, 2021. National, state and territory population, Dec 2020. (Accessed 16/08/2021)
[2]Australian Bureau of Statistics, 2021. Census of Population and Housing 2016. (Accessed 16/08/2021)

Survey Details



Data collection

- Between July and August 2021
- 15-minute online survey
- Recruitment and compensation by Qualtrics

Sample Weighting

Sample 1: potential consumers (ICEV drivers)

- Quotas of age, gender and gross annual household income were established aiming at a representative socio-demographic distribution of Australia's driving-age population based on data from the Australian Bureau of Statistics.
- Sample weights were calculated to adjust the quotas that were not met.
- Weights were calculated using an iterative proportional fitting (raking) method.
- Geographic variables and interactions between variables were not considered in the weighting process due to small sample size.

Original Sample 1 distributions

Age	
18-24	14.6%
25-34	12.1%
35-44	17.7%
45-54	15.7%
55-64	17.5%
65-84	22.4%

Gender	
Male	51.3%
Female	48.7%

Gross Annual Household Income	
$1-34,999	15.5%
$35,000-99,999	38.6%
$100,000 or more	45.9%

Driving-age population distributions[3,4]

Age	
18-24	11.9%
25-34	19.6%
35-44	17.7%
45-54	16.6%
55-64	15.4%
65-84	18.8%

Gender	
Male	49.3%
Female	50.7%

Gross Annual Household Income	
$1-34,999	17.2%
$35,000-99,999	40.1%
$100,000 or more	42.7%

[3]Australian Bureau of Statistics, 2021. National, state and territory population, Dec 2020. (Accessed 16/08/2021)
[4]Australian Bureau of Statistics, 2019. Survey of Income and Housing 2017-18. (Accessed 16/08/2021)

2. Characterising the samples

Samples' Description: Key Insights

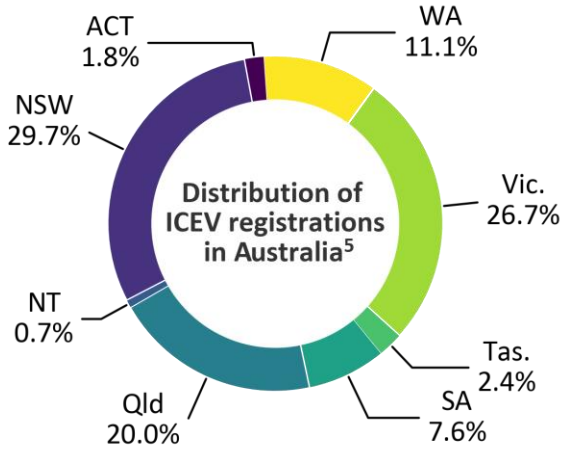
- The geographic distribution of both samples show an overrepresentation of NSW but distribution across remaining states follow the general trends of vehicle registrations.
  - 67.4% of ICEV sample and 82.7% of EV sample live in metropolitan areas.
- The ICEV driver sample is representative of Australia's driving-age population in terms of age, gender, and gross annual household income.
  - Employment status and education attainment distributions are not representative but are comparable to the population.
- The EV driver sample presents high shares of individuals who are
  - men,
  - between 35 and 44 years old,
  - have at least a Bachelor's degree,
  - are employed full-time, and
  - have a gross annual household income above $100,000.
- The average annual distances driven per respondent in the ICEV driver sample are below the national average (9,800 km compared to 11,100 km).
- The average annual distances driven per respondent in the EV driver sample almost two times the national average (20,500 km).
  - Associated with a high share of full-time workers and long one-way commute distances (average of 47 km).
  - Can also be explained by the fact that individuals who drive longer distances are usually willing to spend more money in car technologies that provide increased comfort.

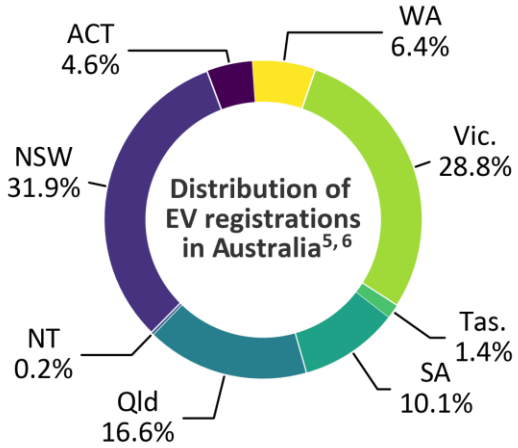
Location of Respondents (1)

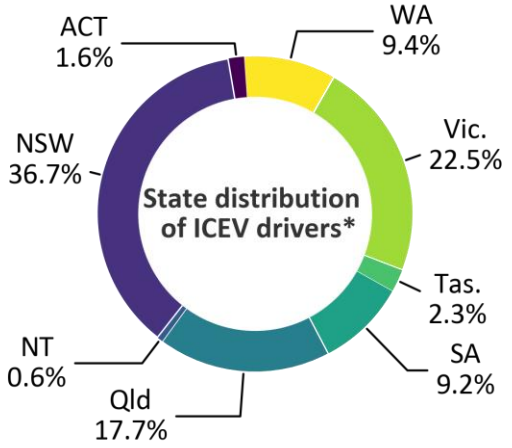
What?
Geographic distribution of survey respondents compared to the distribution of vehicle registrations per state.

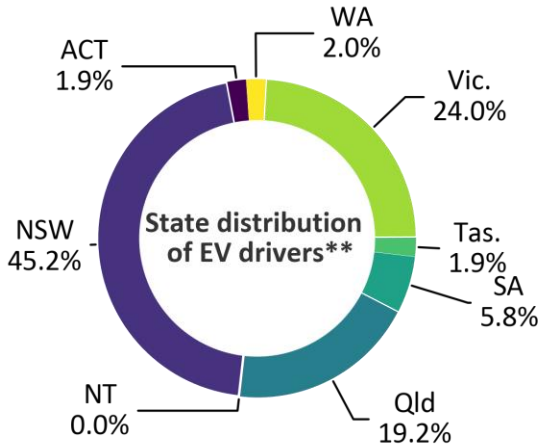
Why?
To understand the geographic representativeness of the samples.

Results
With a few exceptions, the geographic distribution of both samples follow the general trends of vehicle registrations across the Australian states. There is an overrepresentation of NSW in both samples, which is especially pronounced in the sample of EV drivers. We observe a higher share of ICEV drivers from SA than the share of ICEV registrations, while there is a lower share of EV drivers compared to registrations in this state. The opposite relationship is observed for Queensland.









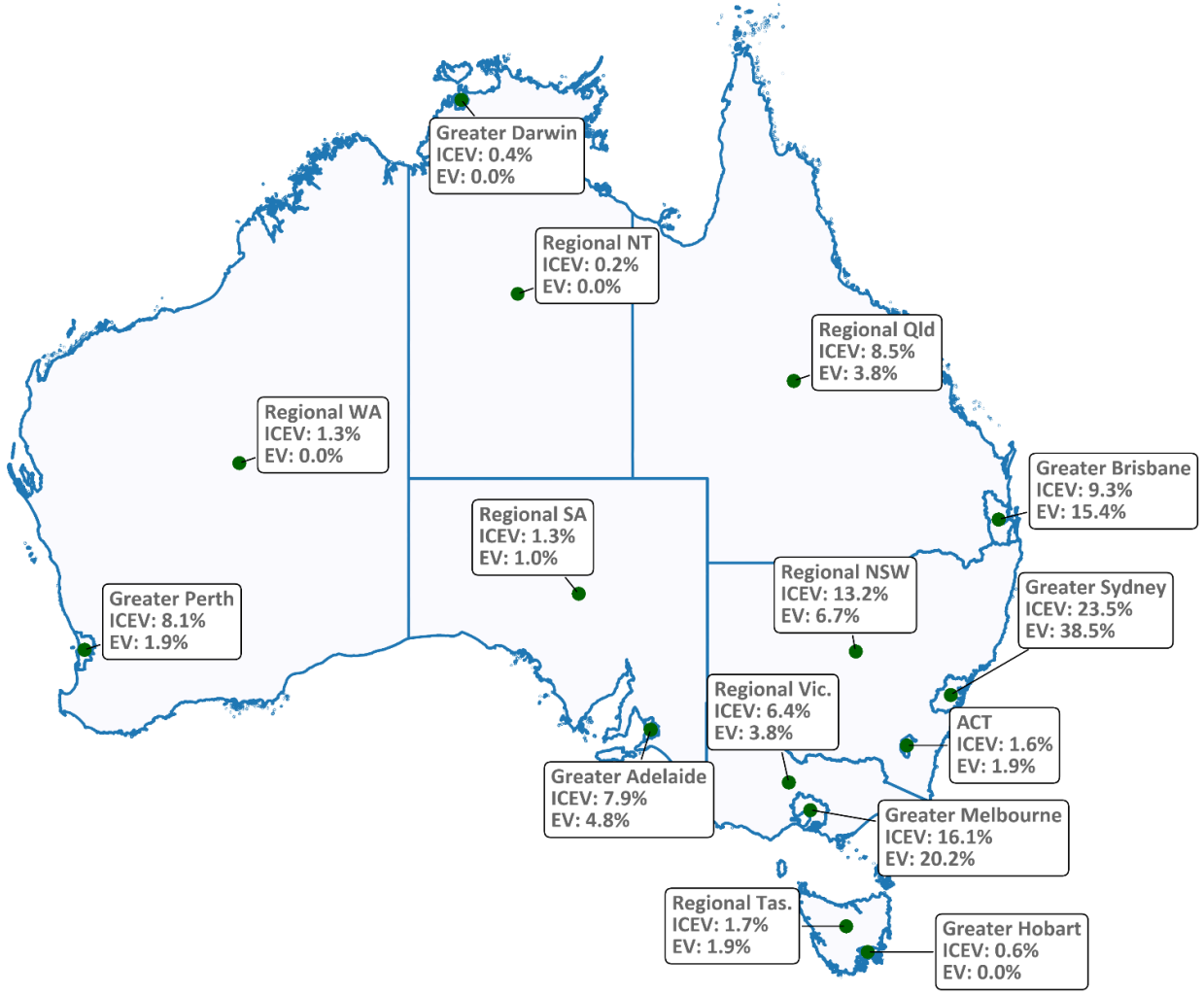
[5]Australian Bureau of Statistics, 2021. Motor Vehicle Census 2021. (Accessed 16/08/2021)
[6]Electric Vehicle Council, 2021. State of Electric Vehicles 2021. (Accessed 03/09/2021)

*N=899, all respondents who drive an ICEV
**N=104, all respondents who drive an EV

Location of Respondents (2)

ICEV drivers	
Metropolitan	67.4%
Regional	32.6%

EV drivers	
Metropolitan	82.7%
Regional	17.3%



Individual Socio-Demographic Characteristics (1)

What?

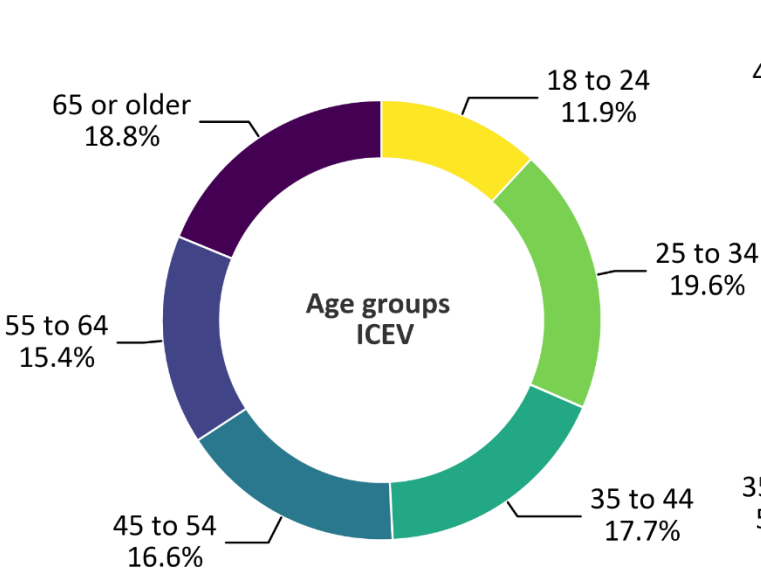
Age and gender distributions in the ICEV driver sample and in the EV driver sample.

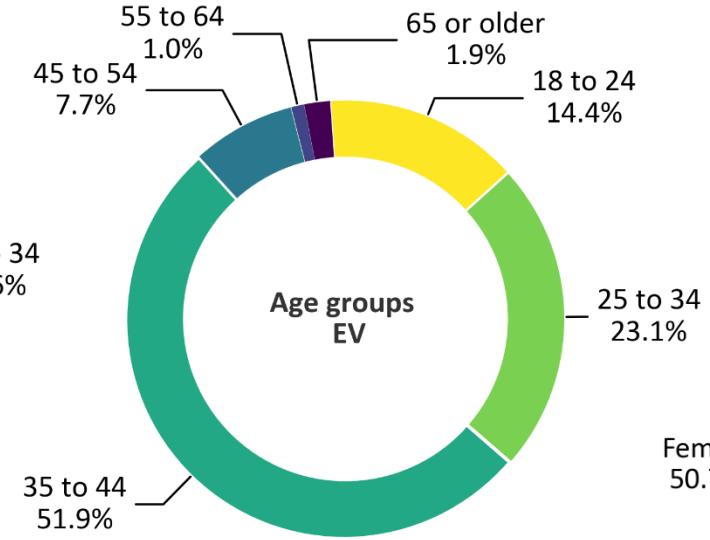
Why?

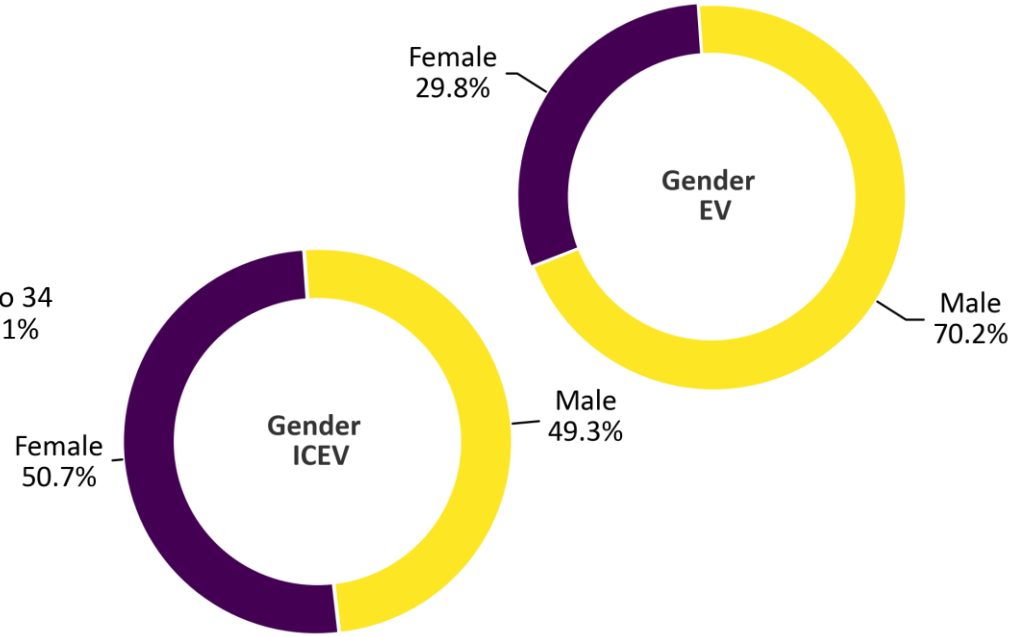
Age and gender differences between the samples may indicate how the profile of EV owners[+] compares to the general car consumers and may also help explain the stated preferences.

Results

While the distribution of age and gender of the ICEV driver group is representative of Australia's driving-age population, we observe that men and individuals between 35 and 44 years old are overrepresented in the EV drivers' sample, which is likely reflecting a population trend. Similarly, we observe a significant underrepresentation of individuals 55 years or older.







[+]Note that we cannot guarantee that the sample of EV drivers is representative of the EV driver population of Australia as characteristics of this population are unknown and we are not using a random sampling technique. However, the results observed here provide a general idea of the socio-demographic profile of this group.

Individual Socio-Demographic Characteristics (2)

What?

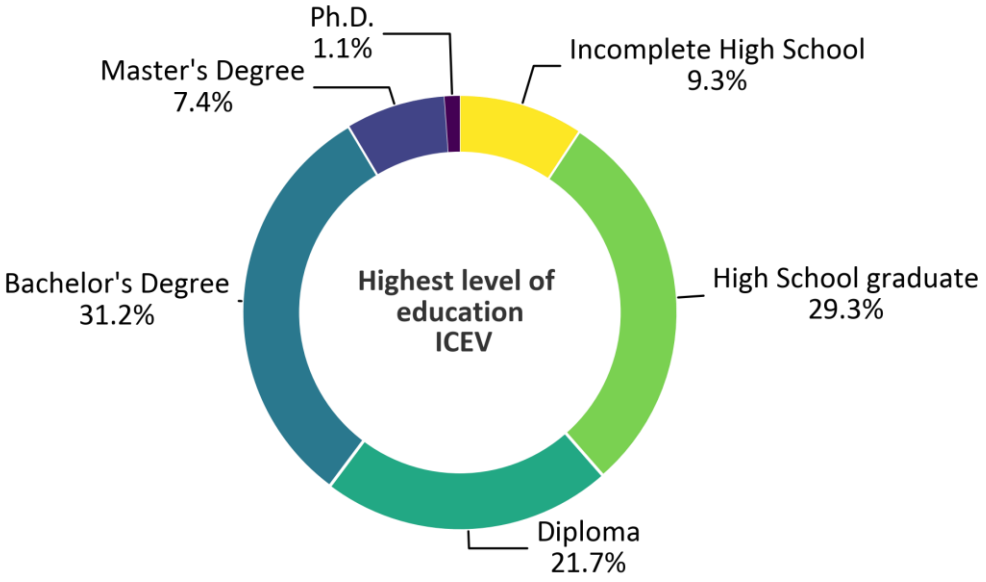
Education distribution in the ICEV driver sample and in the EV driver sample.

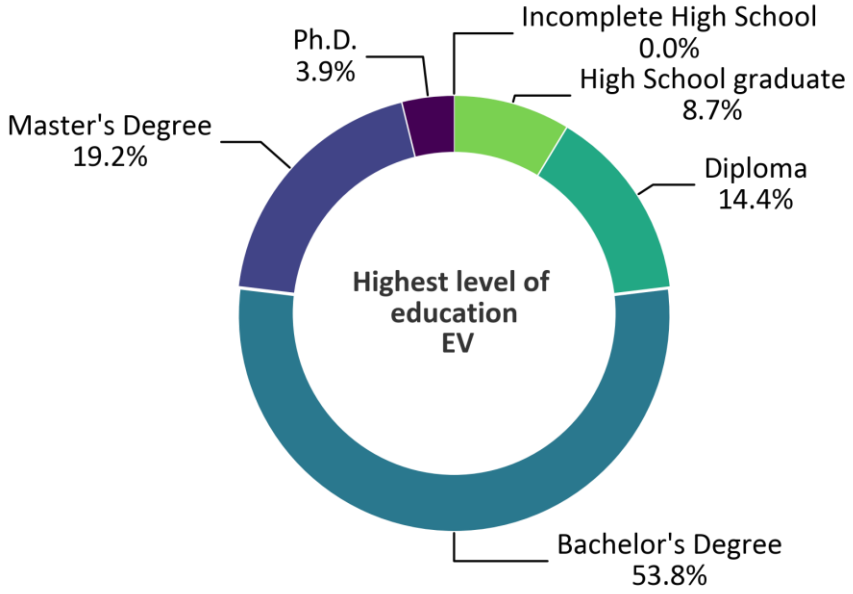
Why?

Education differences between the samples may indicate how the profile of EV owners compares to general car consumers and may also help explain the measured preferences.

Results

35% of Australia's adult population have a Bachelor's degree or a higher qualification, while 34% have Diplomas or Certificates in addition to school completion[7]. The sample of ICEV drivers has a higher share of individuals at both ends of the education spectrum compared to national averages. The sample of EV drivers is significantly skewed toward higher levels of educational attainment.





[7]Australian Bureau of Statistics, 2020. Education and Work, Australia 2020. (Accessed 16/08/2021)

Individual Socio-Demographic Characteristics (3)

What?

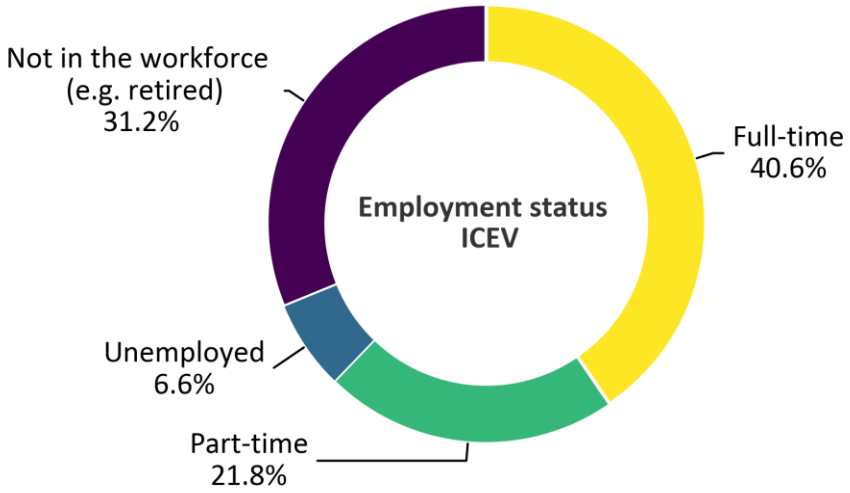
Employment status distribution and commute mode share in the ICEV driver sample and in the EV driver sample.

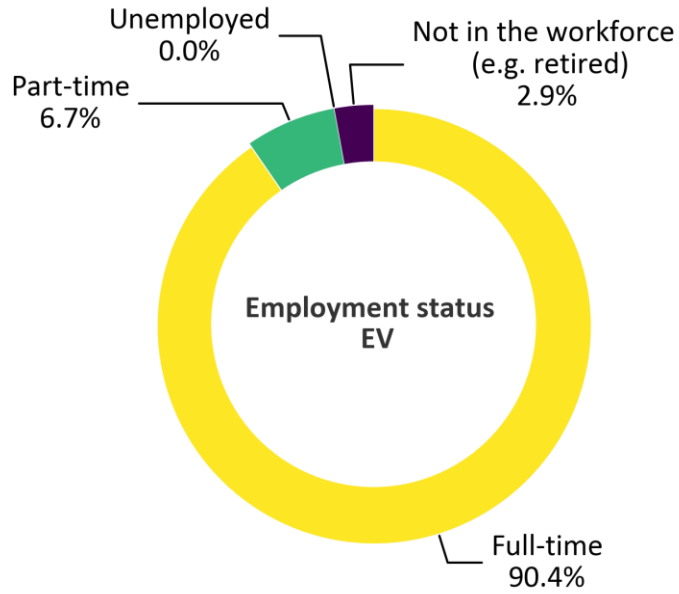
Why?

Employment status differences between the samples may indicate how the profile of EV owners compares to general car consumers. Commute mode differences help understand the potential use of workplace charging.

Results

Australia's employment distribution (43.4% full-time, 19.5% part-time, 4.6% unemployed) is similar to what we observe in the sample of ICEV drivers. There is a strong skewness toward full-time employment in the sample of EV drivers, which is expected considering this group's age and education attainment. 75% of the ICEV users currently drive to work (or used to drive to work prior to the pandemic), while the share among EV drivers is of 86%.





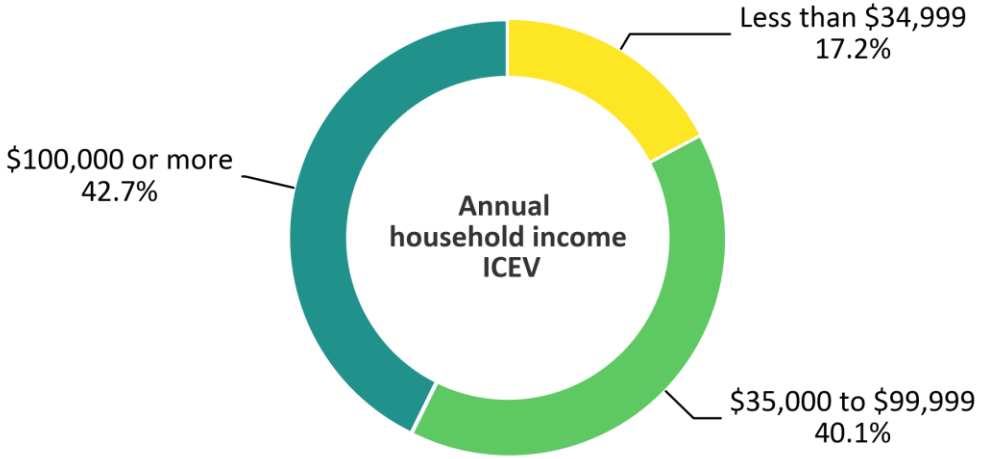
[8]Australian Bureau of Statistics, 2021. Labour Force, Australia, Detailed July 2021. (Accessed 27/08/2021)

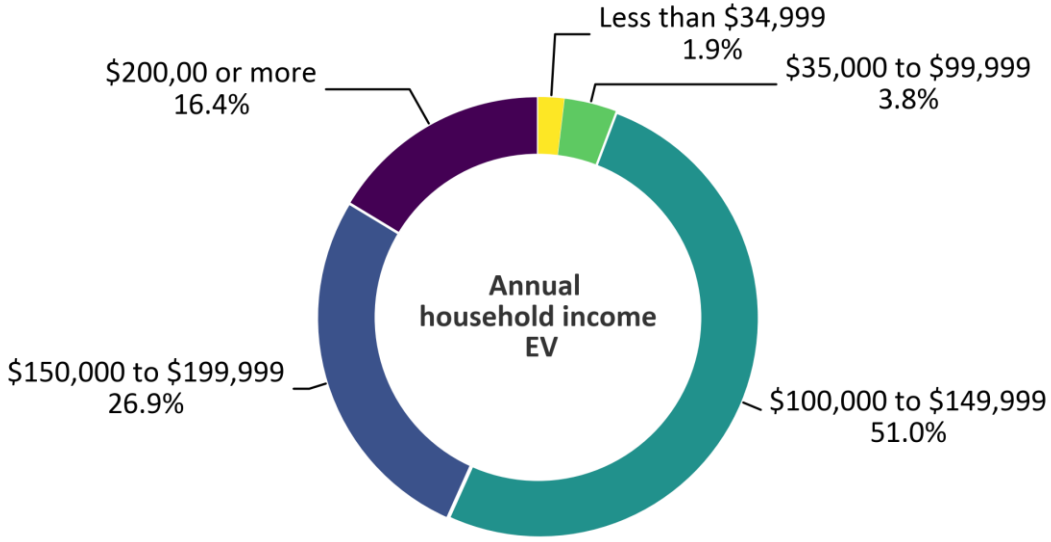
Household Socio-Demographic Characteristics

What?
Gross household income distributions in the ICEV driver sample and in the EV driver sample.

Why?
Household income differences between the samples may indicate how the profile of EV owners+ compares to general car consumers and may also help explain the stated preferences.

Results
While the distribution of gross household income of the ICEV driver group is representative of Australia's driving-age population, we observe that the great majority of the EV drivers are in the high-income segment (and thus, additional segmentation is shown).





Weekly Distances Travelled

What?

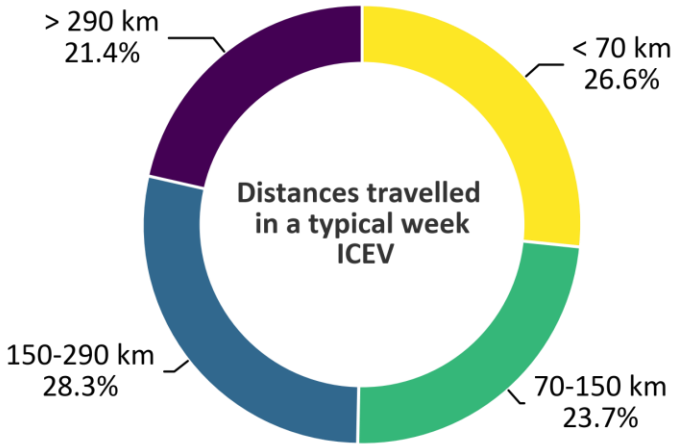
Distribution of weekly distances travelled by ICEV drivers EV drivers. The graphs are segmented based on quartiles defined using both samples merged.

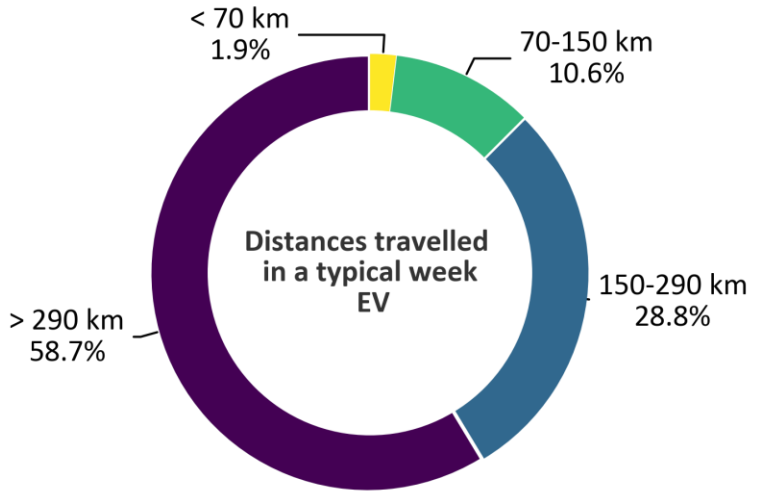
Why?

Understanding vehicle usage is important to understand charging requirements and the potential for range anxiety among prospective buyers.

Results

In 2020, passenger vehicles in Australia travelled on average 11,100 km[9]. In the ICEV driver sample and the EV driver sample, the average annual distances driven per respondent are 9,800 km and 20,500 km, respectively. Considering that Australia has on average one car per adult, these results indicate that EV owners in the sample drive almost twice as much as the national average. This skewness is a consequence of long commute distances (the average one-way commute in the EV driver sample is 47 km).





[9]Australian Bureau of Statistics, 2021. Motor Vehicle Census 2021. (Accessed 16/08/2021)

3. Characterising EV ownership and purchase intention

Characterising EV Ownership and Purchase Intention: Key Insights

- In Australia, annual sales of Plug-in Electric Vehicles (PEVs) have been more than five-times higher than of Plug-in Hybrid Electric Vehicles (PHEVs) since 2019[10]. However, the survey sample has an even split between owners of these two types of EVs.
  - The sample is not representative of Australia's EV population. Yet, very few behavioural differences were found when comparing PEV and PHEV drivers.
- PHEVs are more likely to be the only household vehicle than PEVs.
- There is no significant difference in weekly distances driven by PEV and PHEV drivers.
- Tesla is the most popular PEV brand in the sample (42% of PEVs).
- The majority of the sample has more than one year of experience owning an EV.
- The distribution of intention to purchase EVs among ICEV drivers indicates a small overrepresentation of potential early adopters in the sample.
  - Selection bias may have contributed to higher response rates among enthusiasts and rejecters of EV technology.
- Almost 81% of ICEV drivers in the sample can be considered mainstream consumers.
  - 44% of the mainstream consumers do not consider purchasing an EV within the next 10 years.
- Segmentation of intention to purchase an EV by weekly distances driven shows that potential early adopters drive longer distances than the remaining sample.
  - This travel profile is similar to what we observe in the sample of current EV drivers.

[10]Electric Vehicle Council, 2021. State of Electric Vehicles 2021. (Accessed 03/09/2021)

Electric Vehicle Type and Model

What?

Types and models of electric vehicles owned, and whether the household has additional vehicles.

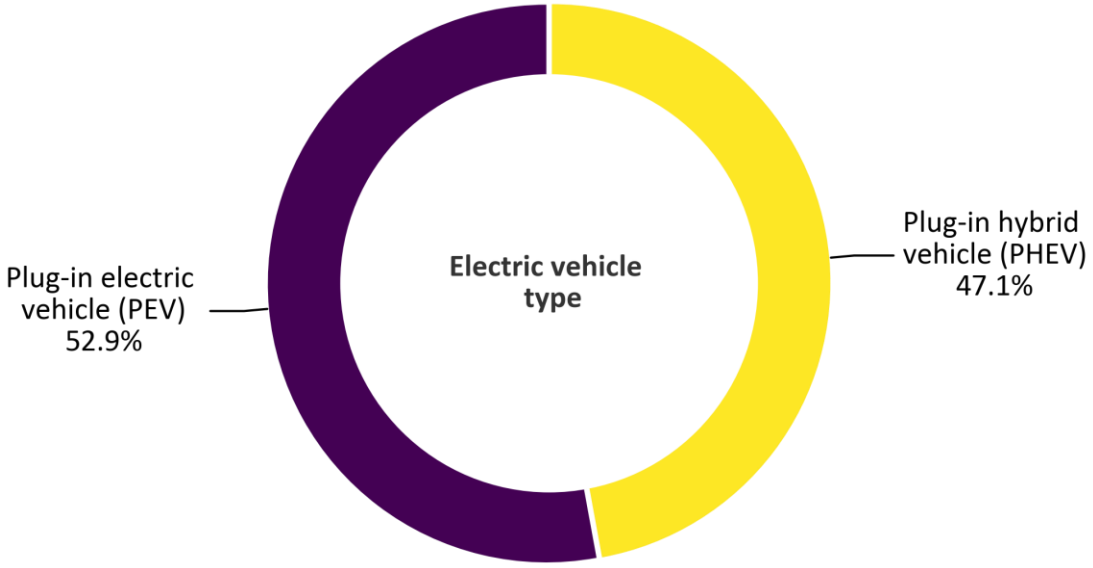
Why?

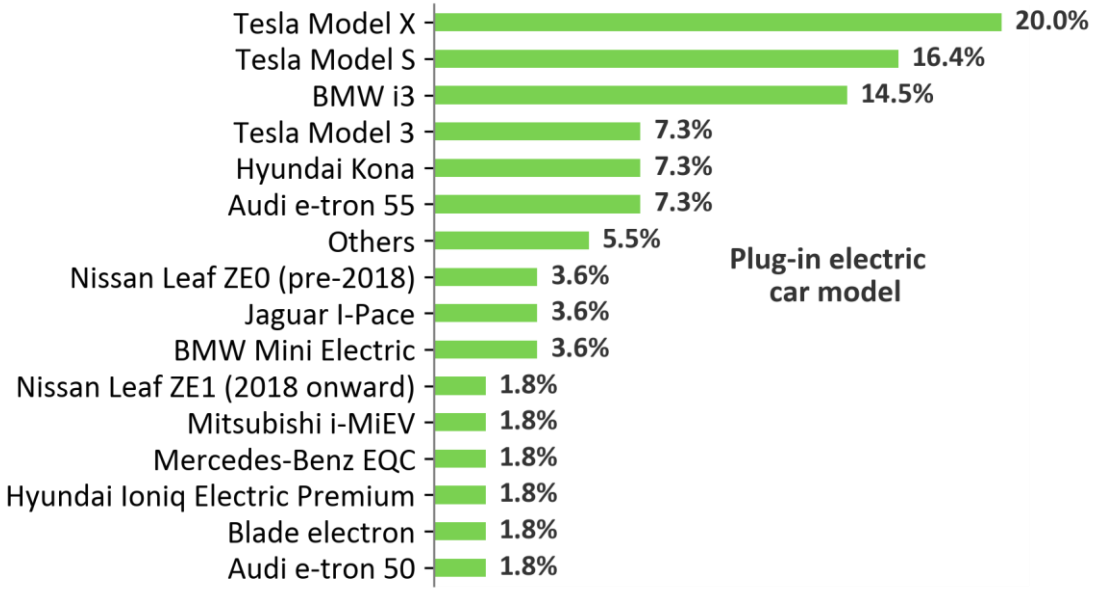
To understand potential charging requirements and how much users rely on EVs as their main vehicle.

Results

The sample has an even distribution of PEV and PHEV drivers. Teslas are the most popular PEVs, with almost 42% of the PEVs being of this brand.

44% of the PEV drivers and 60% of the PHEV drivers do not have any additional vehicle in the household, which may be an indicative that the hybrid technology has greater consumer trust.





N=104, all respondents who are the main drivers of an electric vehicle

Electric Vehicle Length of Ownership and Usage

What?

Length of EV ownership and weekly distances travelled.

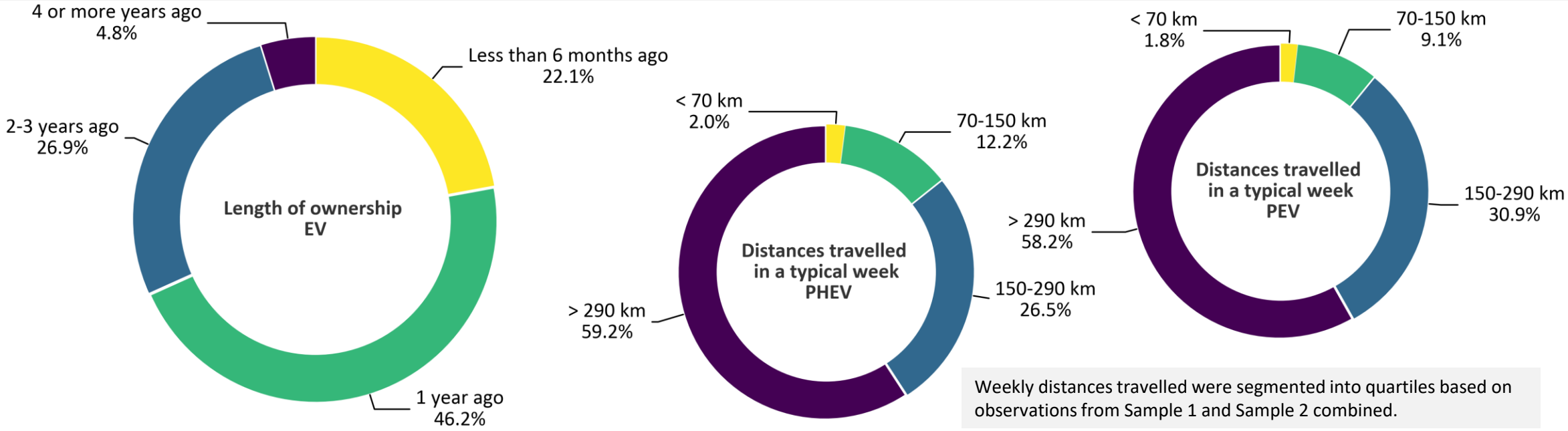
Why?

To understand users' level of experience with EV usage and charging.

To understand regular usage patterns and weekly charging requirements.

Results

Most of the EV drivers in the sample (77.9%) are experienced with the technology as they have owned the vehicle for one year or longer. Weekly distances driven by PEV and PHEV drivers are similar and substantially longer than distances driven by ICEV drivers. However, this difference may, in part, be associated with differences in the employment status distributions of both samples.



Weekly distances travelled were segmented into quartiles based on observations from Sample 1 and Sample 2 combined.

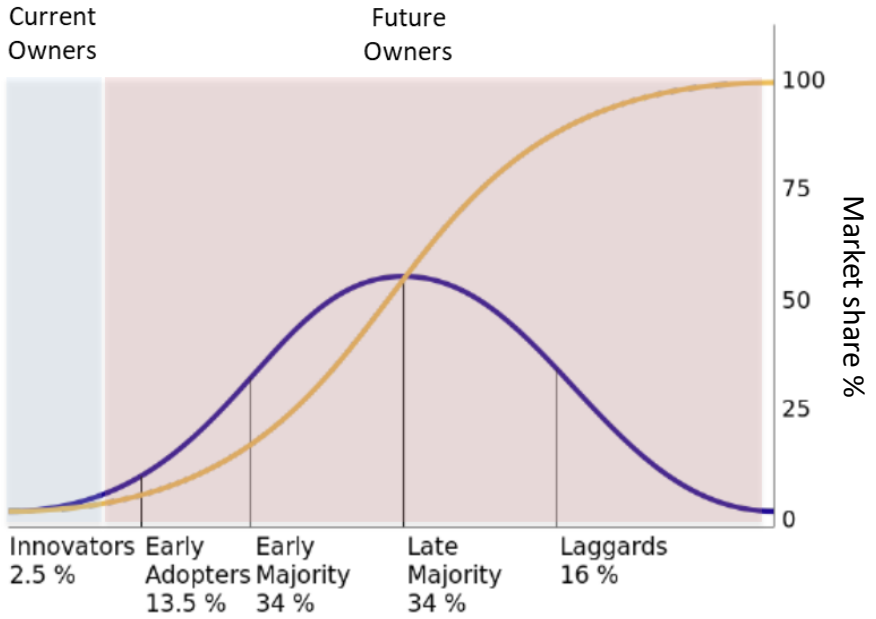
N=104, all respondents who are the main drivers of an electric vehicle

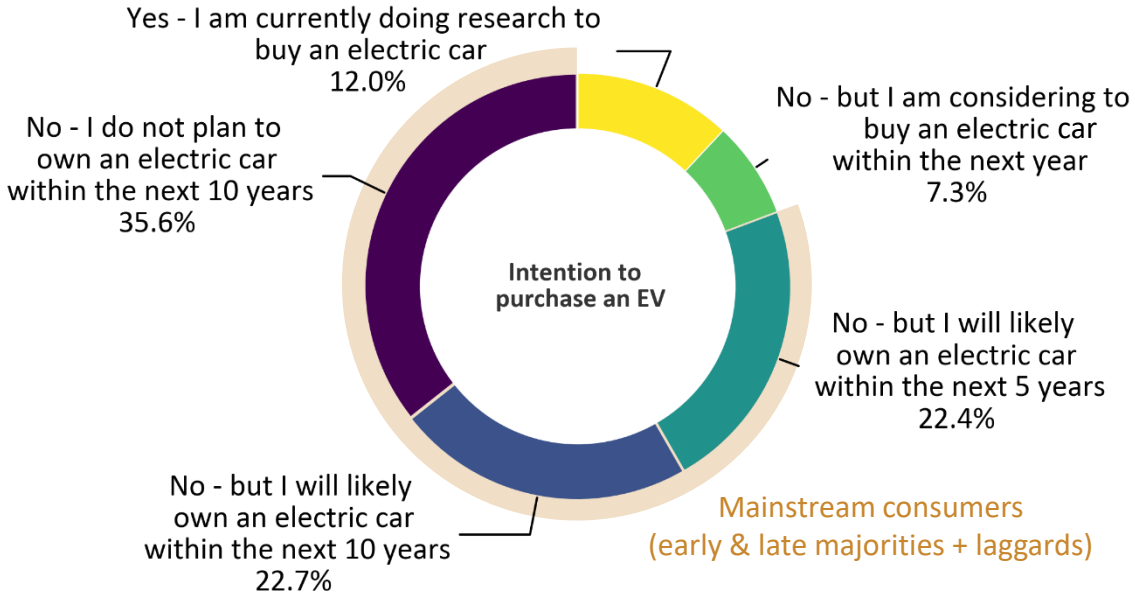
Intention to Purchase an EV

What?
Intention to purchase an EV within the next 10 years.

Why?
To understand the level of interest in EV adoption among sample respondents and compare it to the diffusion of innovations curve. Intention to purchase an EV may impact attitudes and preferences towards charging.

Results
Respondents currently doing research or considering to purchase an EV within the next year can be classified as potential early adopters of EV technology (19.3%). Therefore, the sample has an overrepresentation of this group, which is expected due to selection bias. That is, higher response rates among enthusiasts (and rejecters) of the technology. The reaming respondents can be considered mainstream consumers. The 35.6% of respondents currently rejecting EVs indicate that it would be too optimistic to consider that EVs will reach high levels of market penetration in a 10-year timeframe without significant changes in the current policy scenario.





N=899, all respondents who drive an ICEV

4. Where and when do EV drivers charge?

Characterising EV Driver Charging Behaviour: Key Insights

- Most EV owners can charge their vehicles at home.
  - While more than 87% own their dwellings, only 61% have Level 2 chargers installed.
    - No significant difference between PEV and PHEV owners.
- Special tariffs (EV specific or ToU) and/or solar panels are used by half of the EV owners.
  - PEV owners are 2 times more likely to adopt these than PHEV owners.
- 82% claim to be able to set a timer to start charging their vehicles.
  - However, almost 30% reported to start charging between 5-8pm and another 21% between 8-10pm.
  - Evening peak charging is more common among PHEV drivers.
- Mid-day (10am-2pm) ToU tariff discounts of 20% would potentially attract around 40% of the EV owners who currently charge at different times.
  - Higher discounts would not attract significantly more customers.
- A 50% tariff discount after 11pm could attract up to 2/3 of EV drivers currently charging at different times.
- 91% of the EV owners who drive to work can charge their cars where they park.
  - Half of them can charge for free.
  - Most respondents without access to free charging at work would use it instead of home charging if available.
- 85% use public chargers at least occasionally.
  - Half of them use chargers that do not have an associated charging fee.
    - For this group, if charging fees were implemented, no major behavioural change would be observed.
- Almost 60% of the sample charges at home at least 3 times a week.
  - Similar charging frequencies for PEV and PHEV owners.
- Considering all locations, on average, respondents charge their cars 4 times a week.
- Considering average weekly distances driven, each charging session would correspond to 78km of added driving range.
- Convenience and time seem to be more important than price on most occasions.

Ability to Charge the EV at Home

What?

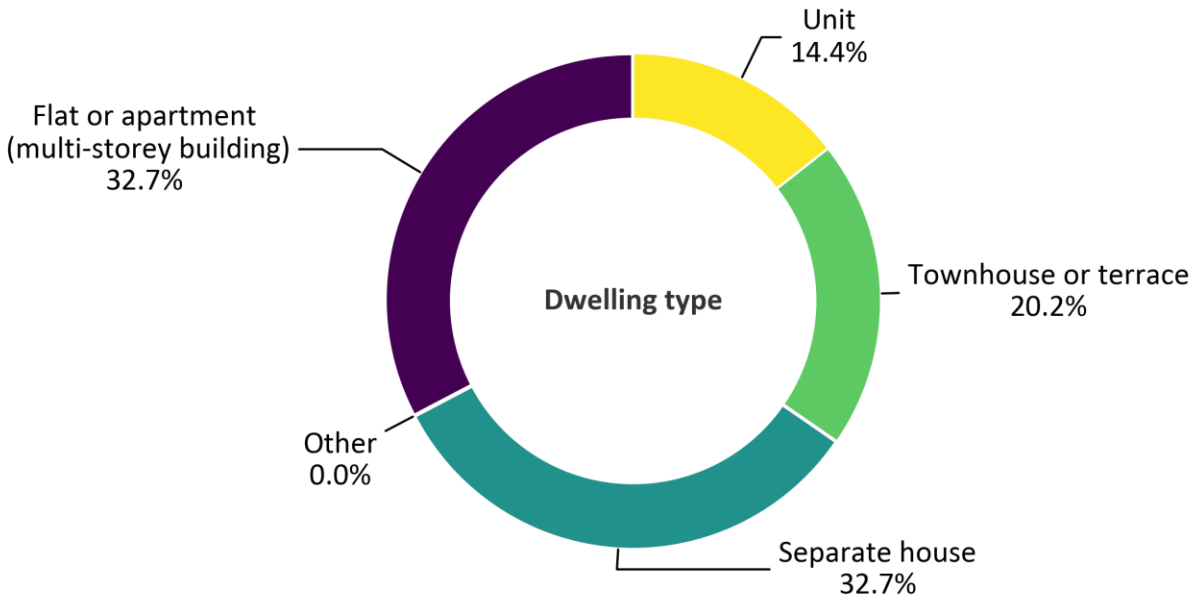
Dwelling type and ownership, off-street parking availability and distance to a power point are variables associated with the ability to charge at home.

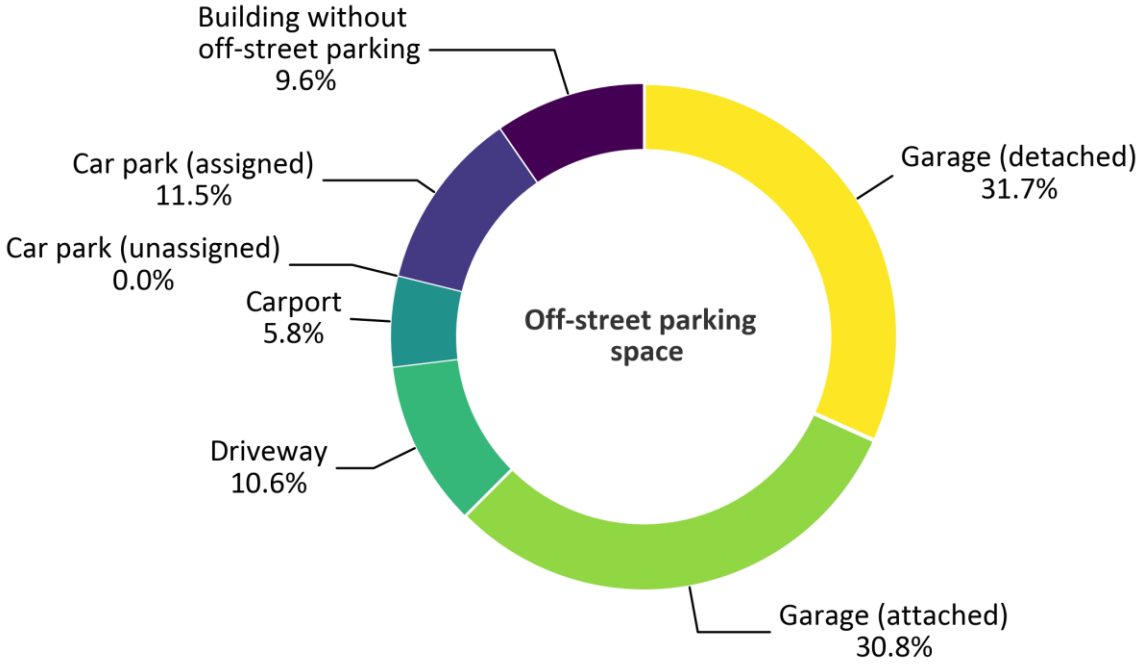
Why?

The ability to charge at home is a key determinant of EV ownership and residential charging behaviour is a major concern for utility providers.

Results

Most respondents own their dwellings (87.5%) and there is a diversity in dwelling types in the sample. Most respondents park their vehicles in garages and only 16.3% of the parking spaces are more than 10 metres away from a power point. Even though 9.6% of respondents do not have off-street parking, only 7.7% claim to be unable to charge at home.





N=104, all respondents who are the main drivers of an electric vehicle

Charger Level, Electricity Plan and Solar Power

What?

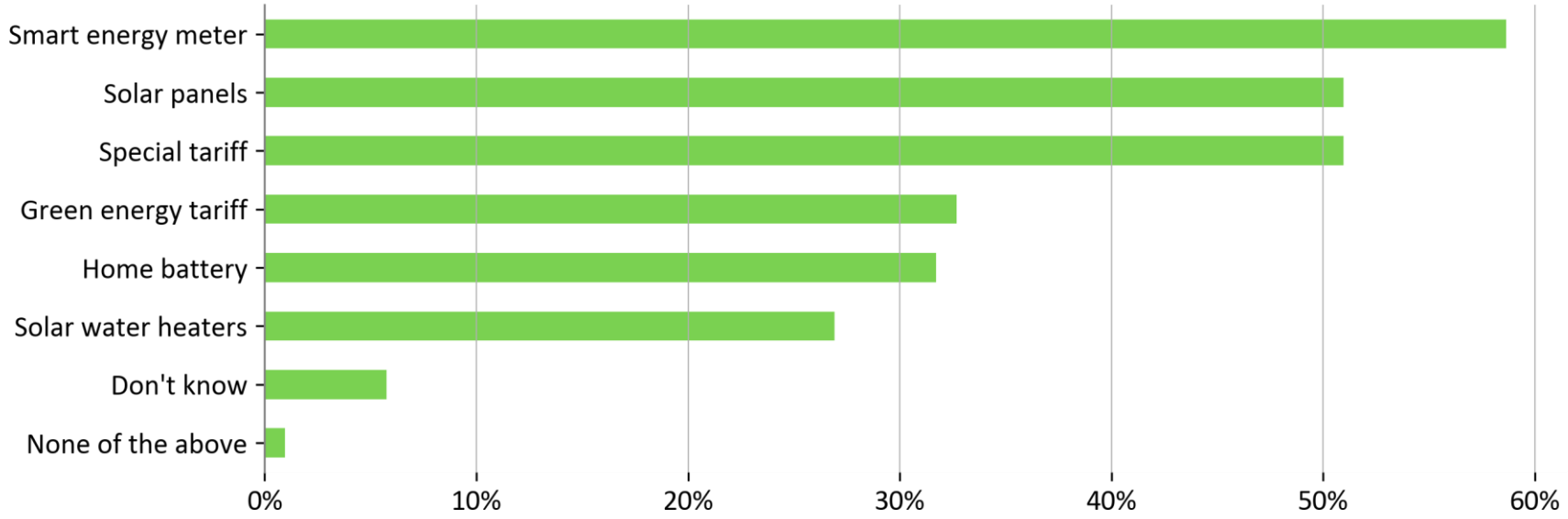
The charger level, electricity plan and the availability of solar panels.

Why?

These variables can help determine how much power is drawn from the network and when. Also, the adoption of time-of-use (ToU) tariffs can be an indicator of acceptance of demand response mechanisms.

Results

Almost two-thirds of the sample have Level 2 chargers installed in their residences, with no significant difference between PEV and PHEV owners. Half of the EV owners use special tariffs (EV specific or ToU) and/or solar panels are used by half of the EV owners, with PEV owners being two times more likely to adopt these than PHEV owners.



N=104, all respondents who are the main drivers of an electric vehicle

Home Charging: Usual Start Time

What?

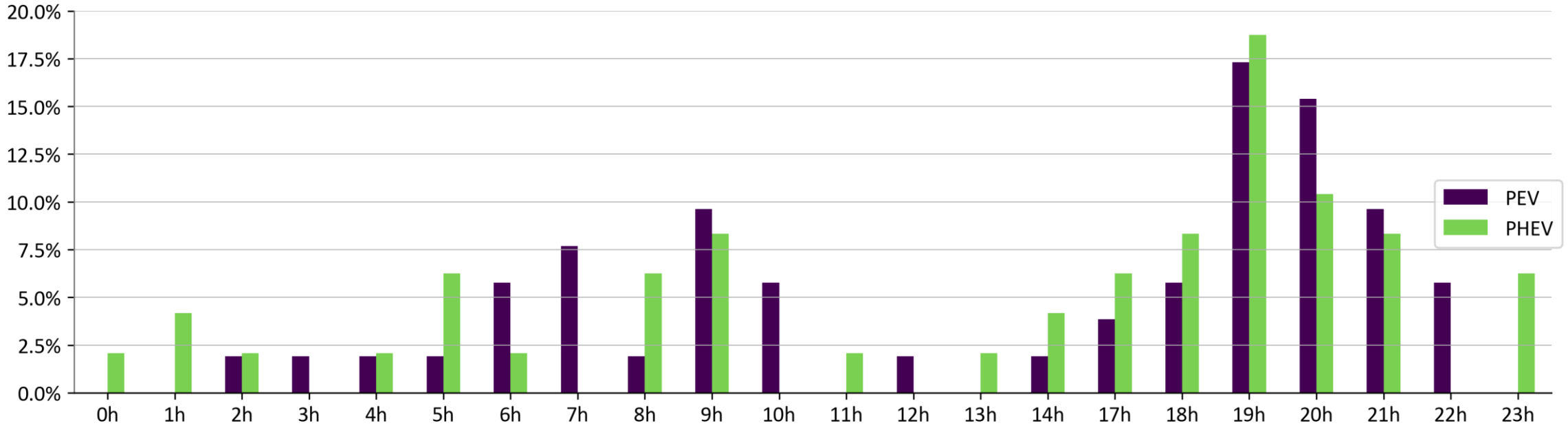
Usual start time when charging at home and ability to use a timer (within the car or charging station) to set a charging start time.

Why?

These variables can help determine whether EV users are contributing to peak electricity demand.

Results

Even though 82% of respondents claim to be able to set a timer to start charging their vehicles, close to 50% of the sample reported to start charging during evening peak (30% between 17h-20h) or shoulder times (21% between 20h-22h). Evening peak charging is more prevalent among PHEV than PEV owners.



N=100, respondents who charge their electric vehicle at home

This question requested respondents to report their charging start time based on a 24h clock, which may have caused some measurement error.

Home Charging: Willingness to Change Start Time

What?

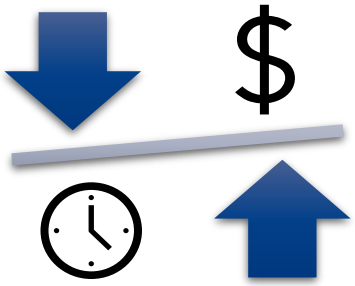
Willingness to delay home charging start time to 11pm or to change it to between 10am and 2pm

Why?

The 11pm scenario provides insights into the acceptance of traditional demand response programs based on ToU tariffs. While the mid-day charging scenario represents demand response programs that aim to use EVs to absorb excess solar power generation.

Results

For the night period charging program, there is a non-linear increase in acceptance. A 50% discount shows the greatest marginal benefit with 2/3 of the valid sample accepting to delay their charging start time. Acceptance of mid-day charging is constrained by the car location during this time window. 20% of the sample stated that their vehicles were never at home during this time. Based on respondents' stated preferences, a discount of 20% during this time shows the greatest marginal benefit in the acceptance rate increase.



Discount Level	Change to 11pm*	Change to between 10am and 2pm**
No discount	13.6%	16.5%
10% discount	19.8%	24.2%
20% discount	27.2%	40.7%
50% discount	66.7%	53.8%

*N=81, respondents who charge at home and whose charging start time in between 7am and 10pm

**N=91, respondents who charge at home and whose charging start time is not between 10am and 2pm

Workplace Charging Availability

What?

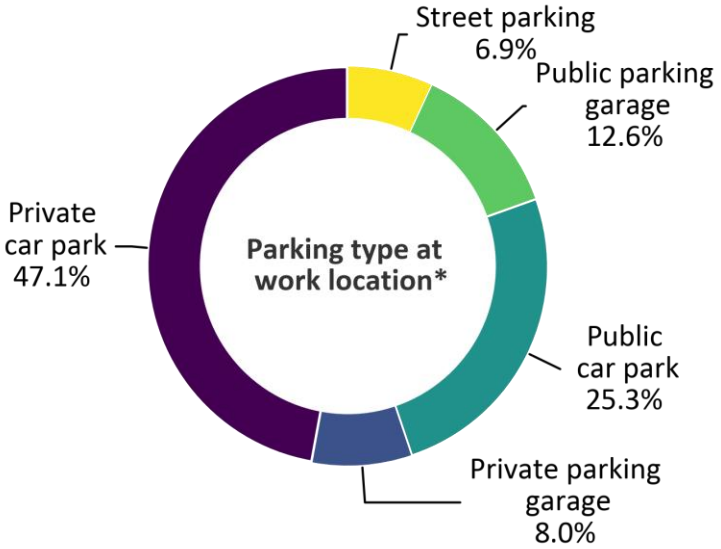
EV owners who are in the workforce and drive to their primary work location reported parking type and access to EV charging as well as intention to charge at work if free charging is available.

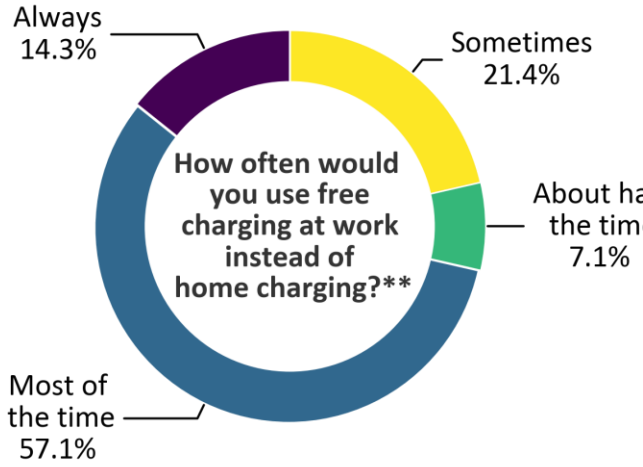
Why?

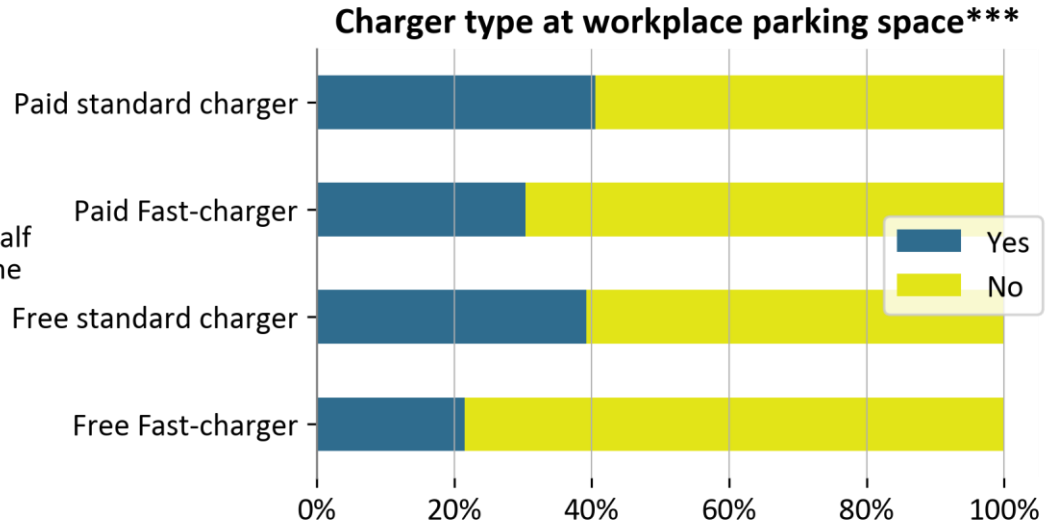
To understand the current ability to charge in the workplace and the potential for workplace charging to act as a substitute for residential charging.

Results

Most respondents park their cars in car parks. 91% are able to charge their cars where they park and half of them can charge their vehicles for free. Access to paid and free standard charging is similar, while fast-chargers are more likely to require payment. Most respondents without access to free charging at work would use it instead of home charging frequently.







*N=87, respondents who drive to their primary workplace; **N=42, respondents without access to free charging at their primary workplace parking location; ***N=79, respondents with access to one or more chargers at their primary workplace parking location.

Public Charging

What?

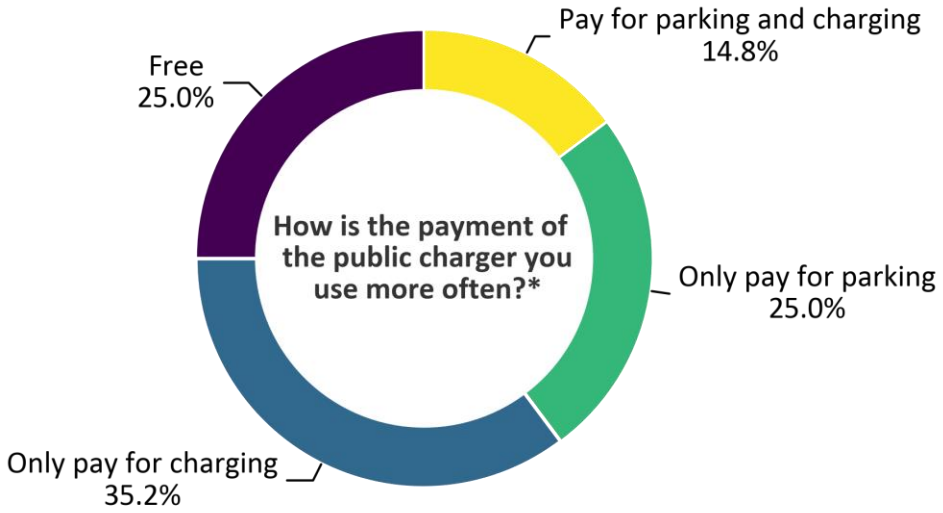
Use of public chargers, payment structure of the public charger most often used, and response to the elimination of free charging.

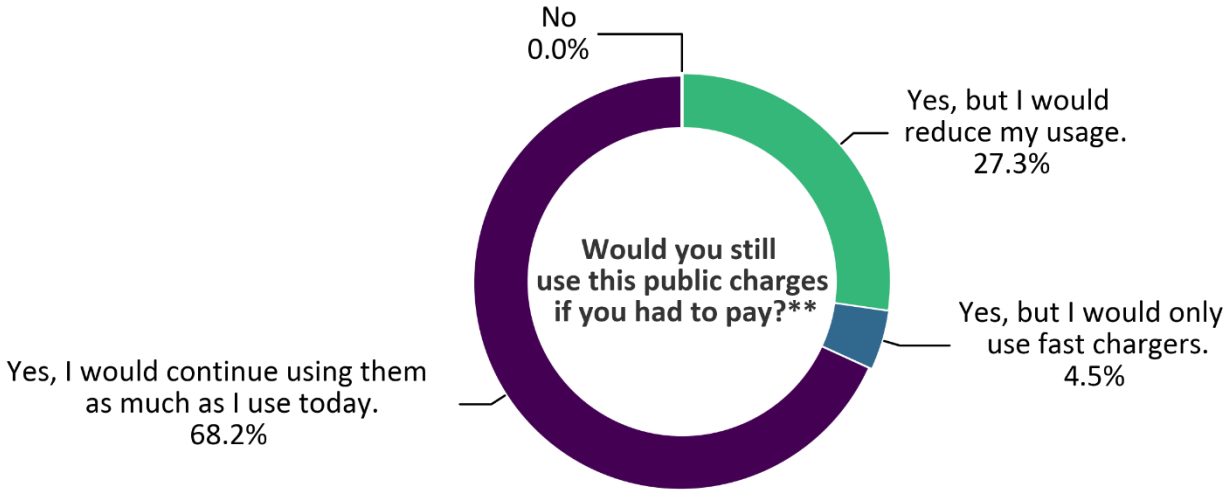
Why?

To understand the current use of public chargers and how this may change in a future that free public charging is no longer available.

Results

85% of the EV drivers in the sample use public chargers at least occasionally. Half of them use chargers that do not have an associated charging fee. For this group, if charging fees were implemented, no major behavioural change would be observed. Only one-fourth of them would reduce their usage of public chargers but nobody would stop using this type of facility. It is important to note that innovators and early adopters tend to be less sensitive to cost increases than the early and late majorities.





*N=88, respondents who use public chargers
**N=44, respondents who only use public chargers that don't have a charging fee

Charging Frequency by Location

What?

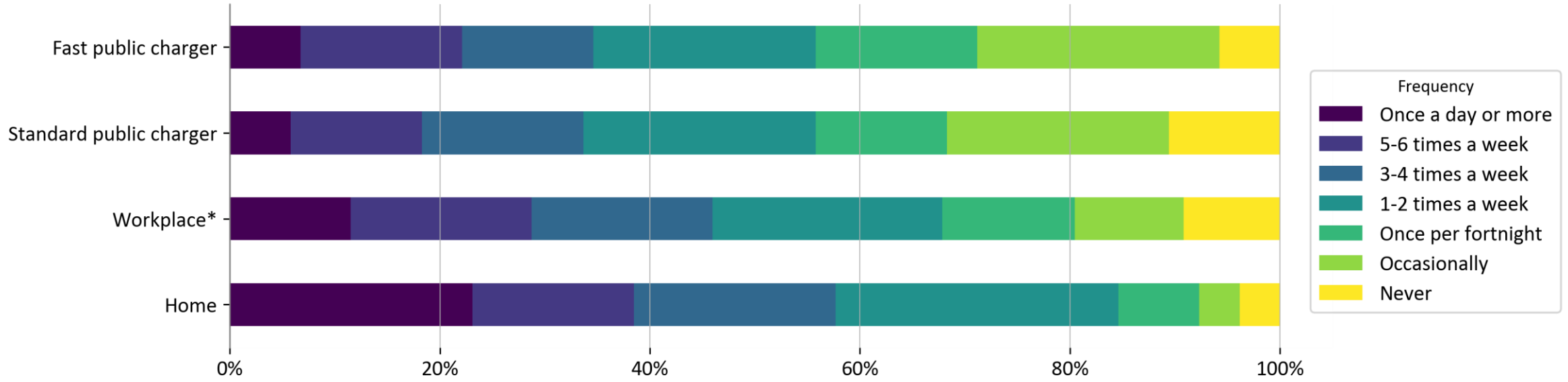
The frequency that EV drivers charge at home, work, and public chargers.

Why?

To understand charging demand at different locations.

Results

Residences are the most frequently used charging locations. Almost 60% of the sample charges at home at least 3 times a week. The distribution of charging frequencies is very similar for PEV and PHEV owners. Yet, charging the vehicle at least once a day is more common among PEV drivers. Considering all locations, on average, respondents charge their cars 4 times a week. Considering average weekly distances driven, each charging session would correspond to 78km of added driving range.



N=104, all respondents who are the main drivers of an electric vehicle

Decision to Charge

What?

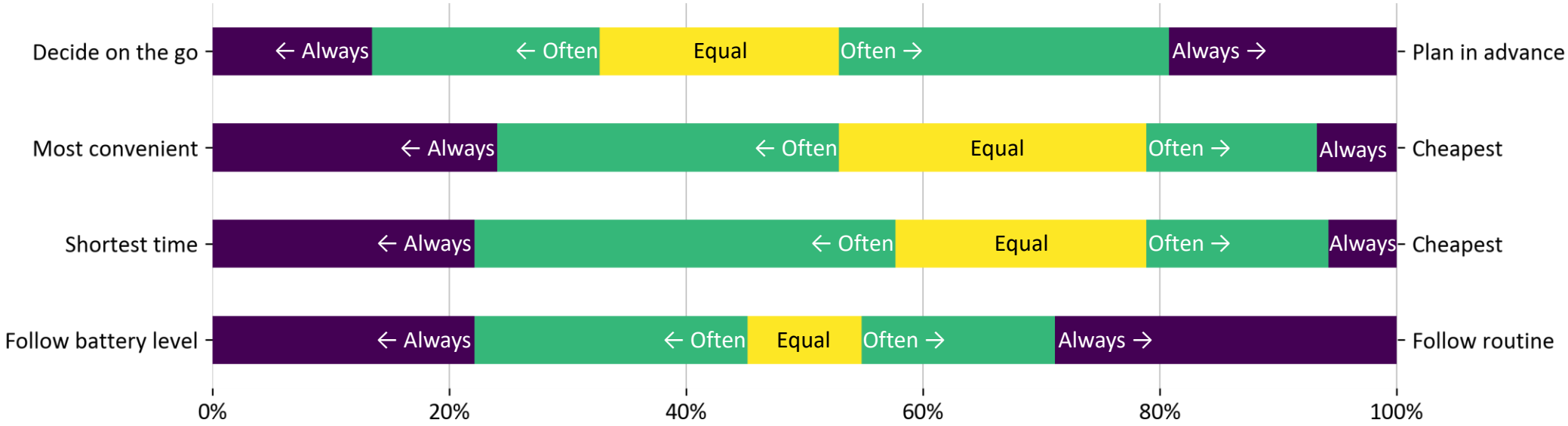
EV drivers reported on how often their decision to charge is planned and how they trade off convenience and time for cost.

Why?

Understanding how charging behaviour varies across individuals can help guide strategies for charging infrastructure deployment and demand management

Results

Planning charging sessions in advance is a more common behaviour than deciding on the go, especially for PEV drivers. Convenience and time seem to be more important than the price on most occasions, which is expected as current EV drivers are early adopters with high incomes. There is an even split between those that decide to charge based on the battery level or as part of an established routine.



N=104, all respondents who are the main drivers of an electric vehicle

Charging Routine Characteristics

What?

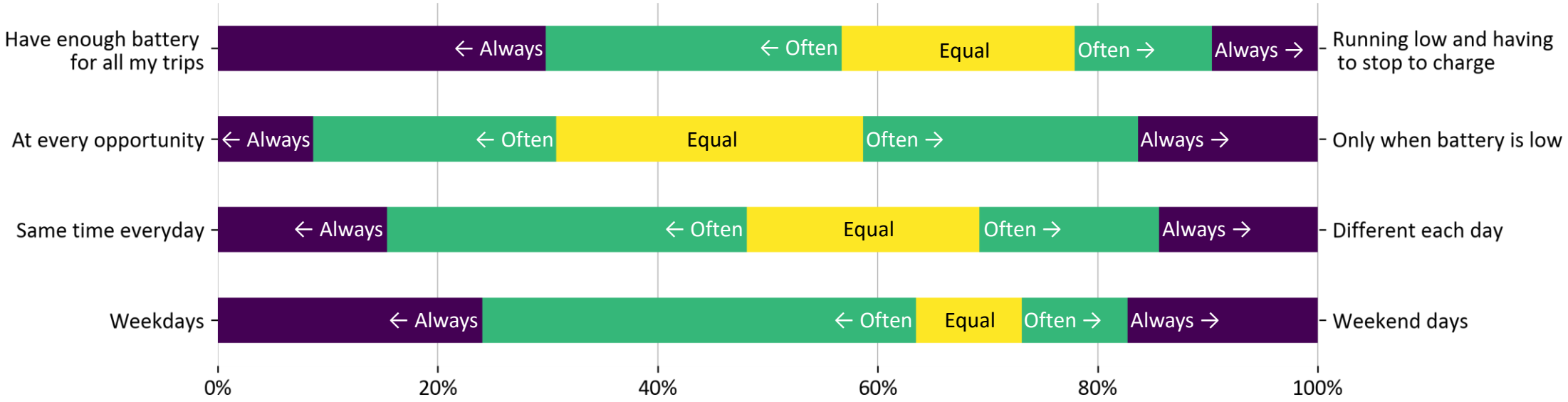
EV drivers reported their usual charging routine involving general frequency, time, and day of the week.

Why?

Understanding how charging behaviour varies across individuals can provide insights into charging related electricity demand and potential strategies for demand management.

Results

Only about 20% of the sample often need to stop to charge in order to complete their daily travel. There is an equal split between individuals who take advantage of every opportunity they have to charge and those who will only plug if the battery is low. Charging on weekdays at regular times is often the majorities' choice.



N=104, all respondents who are the main drivers of an electric vehicle

5. Would EV drivers accept supplier-managed charging?

EV Drivers Acceptance of Supplier-Managed Charging: Key Insights

- 46.2% of EV drivers would choose user-managed smart charging and 40.4% would choose supplier-managed smart charging instead of unmanaged charging.
  - PEV drivers are twice as likely to choose supplier-managed charging than PHEV drivers are.
- The general acceptance of supplier-managed smart charging is high.
  - The ability to use an App to override the external charging management does not have a major impact on acceptance.
  - Acceptance is higher among PEV drivers.
- EV drivers seem convinced about the advantages of supplier-managed smart charging systems over alternative systems.
  - Nevertheless, more than 75% of the sample think that it is somewhat likely that they would need to override the system at least once a week or use a backup plan to charge their vehicle.
  - 75% of respondents show some level of concern regarding data sharing and privacy issues with this system.
  - Even though innovators and early adopters tend to be risk-takers, it is unclear whether:
    - perceived benefits significantly outweigh risks to justify adoption,
    - or there is some degree of survey measurement error.

Definitions

Survey respondents were presented with definitions of smart charging and charging management options:

Types of chargers

Conventional chargers: don't include a data connection.

Smart chargers: include a data connection.

Options for controlling the charging, and managing your costs and electricity demand

Unmanaged conventional charging: Charging is monitored and controlled only by you. Your car is charged from the moment it is plugged in (or based on a simple timer). The rate of charge is fixed based on your charging point specification (ex: 20km per hour of charge) and costs depend on your electricity plan and the times you choose to charge.

User-managed smart charging: Charging is optimised by an automatic system that is monitored and controlled only by you. You provide the system with the desired level of charge and your next departure time, and the system will automatically select the cheapest time to charge your car based on time-of-use tariffs. The rate of charge may be lower than your charging point specification to minimise costs. If you need to use your car before your set departure time, it may not have the desired level of charge.

Supplier-managed smart charging: Charging is optimised by a centralised system that communicates and coordinates with the electricity supplier to determine the best schedule for your charge considering real-time electricity demand in your area. You provide the system with the desired level of charge and your next departure time, and the system will automatically select the cheapest time to charge your car based on discounts that vary to help balance the overall demand for power in your area and increase the share of renewable energy used. The rate of charge may be lower than your charging point specification to minimise costs and balance the demand. If you need to use your car before your set departure time, it may not have the desired level of charge.

Preferred Type of Charging Management

What?

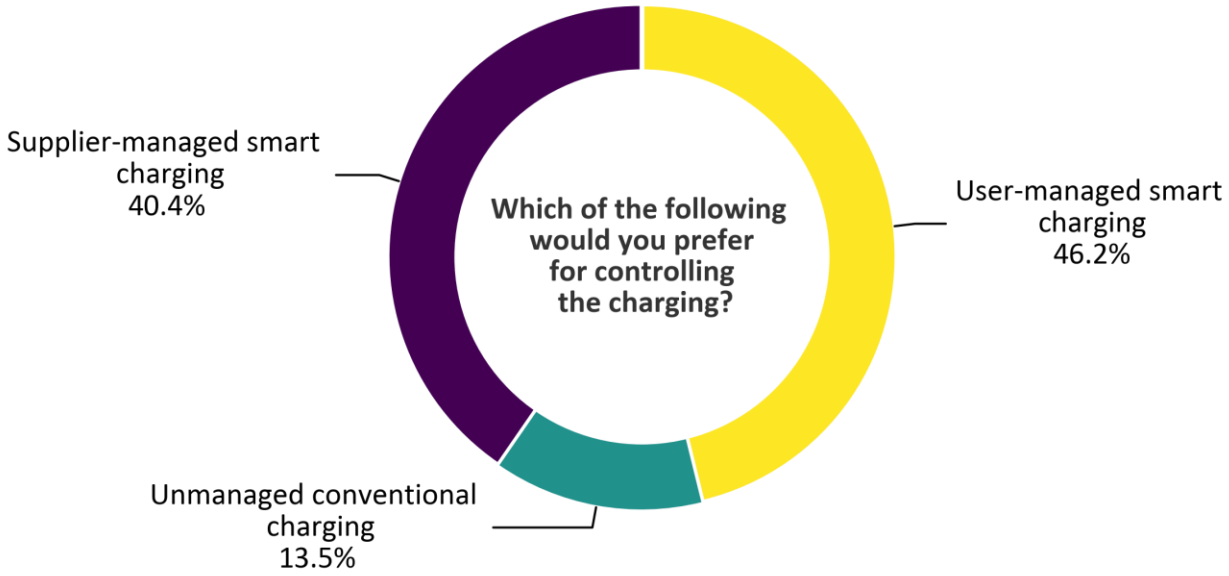
Preferred type of charging management based on definitions provided.

Why?

To understand the acceptance of smart charging and user willingness to give electricity suppliers the ability to control charging.

Results

The use of an automated system to minimise costs based on ToU tariffs is the preferred option of most EV drivers in the sample (86.6%). However, only 40.4% would have the supplier-managed option as their preferred alternative. PEV drivers are twice as likely to choose supplier-managed charging than PHEV drivers are. Among men, the choice between supplier and user managed charging is evenly split, while women are more likely to choose user-managed charging.



N=104, all respondents who are the main drivers of an electric vehicle

Acceptance of Supplier-Managed Charging

What?

Willingness to accept supplier-managed smart charging to avoid peak surges considering the risk of not having the vehicle fully charged.

Why?

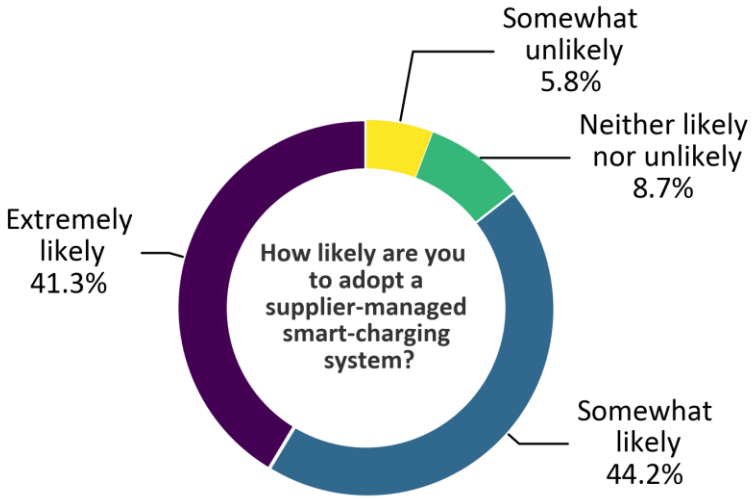
To understand the general acceptance of supplier-managed charging when considering potential benefits and risks.

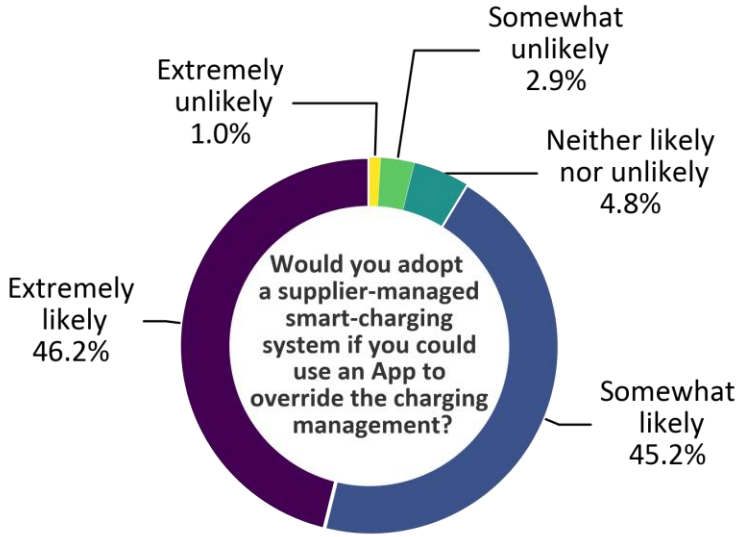
Results

Even though supplier-managed charging is not the majorities' preferred option, general acceptance of this concept is high among EV drivers. For this group, the ability to use an App to override the external charging management when needed causes a marginal increase in acceptance. PEV drivers are more prone to accept supplier-managed charging than PHEV drivers are. Acceptance is higher among men than women and the App has little impact on this difference.

Description

"In a future where the majority of cars are electric, balancing the overall demand for electricity becomes important to avoid potential peak surges that may lead to a power outage. Between the moment you plug in your car and your chosen departure time, a supplier-managed smart-charging system selects the charging time and speed that minimise your costs, balances the overall demand for electricity, and increases the use of renewable energy. However, there is a chance that in sporadic occasions your car won't be charged to your desired level by the end of the charging session."





N=104, all respondents who are the main drivers of an electric vehicle

Perceived Benefits Associated with Supplier-Managed Charging

What?

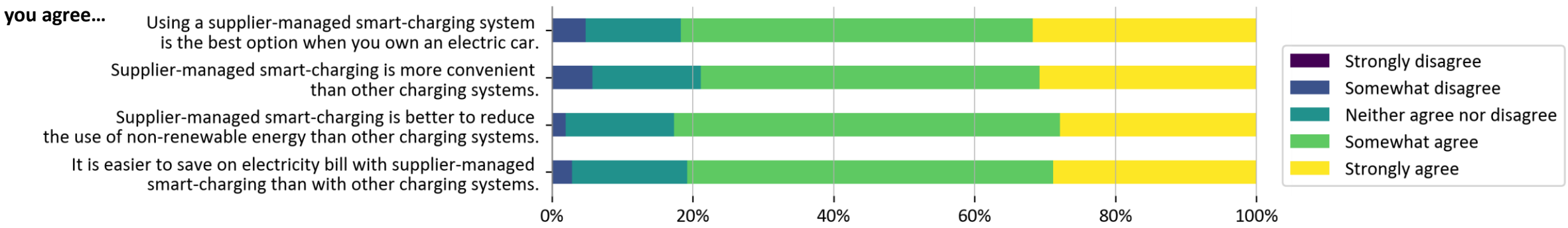
User appreciation of supplier-managed smart charging in terms of convenience, reduction in the use of non-renewable energy, cost efficiency, as well as general appreciation compared to other systems.

Why?

To understand how perceptions of benefits may drive supplier-managed smart charging acceptance.

Results

All four benefits are evaluated in a similar manner by EV drivers. Around 80% of the sample at least somewhat agrees that supplier-managed smart charging systems are better than the alternative systems.



N=104, all respondents who are the main drivers of an electric vehicle

Perceived Risks Associated with Supplier-Managed Charging

What?

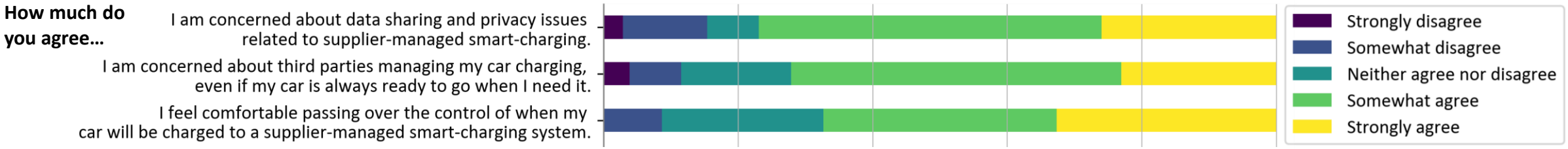
Concerns and perceived risks associated with the use of supplier-managed charging systems.

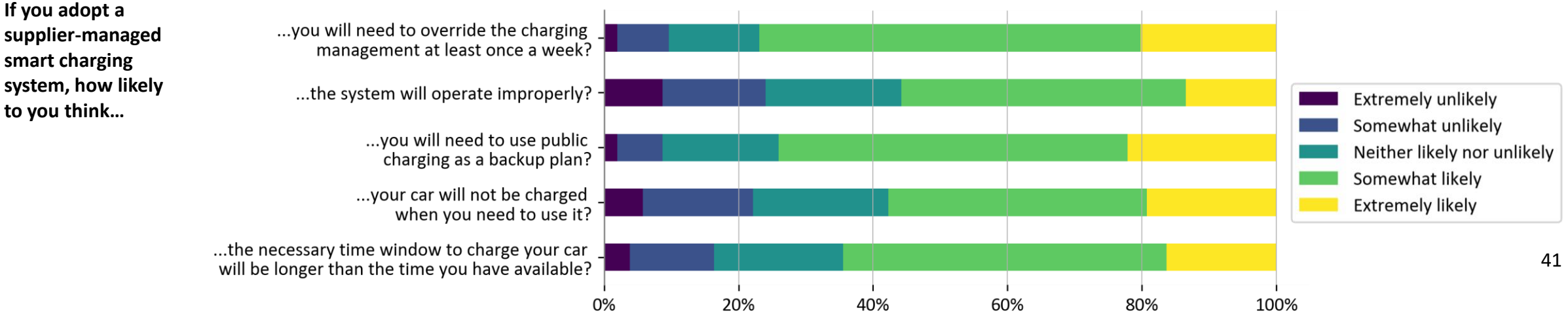
Why?

To understand how perceptions of risks may hinder supplier-managed smart charging acceptance.

Results

All risks are considered somewhat likely by at least half of the sample. However, it is interesting to note that the general acceptance of this management system is high despite these perceptions. The highest perceived risks are associated with the need to override the supplier managed system or use a backup plan, which is considered somewhat likely by more than 75% of the sample. 75% of respondents show some level of concern regarding data sharing and privacy issues with this system.





6. Where and when would potential EV consumers prefer to charge?

Charging Preferences of Potential EV Consumers : Key Insights

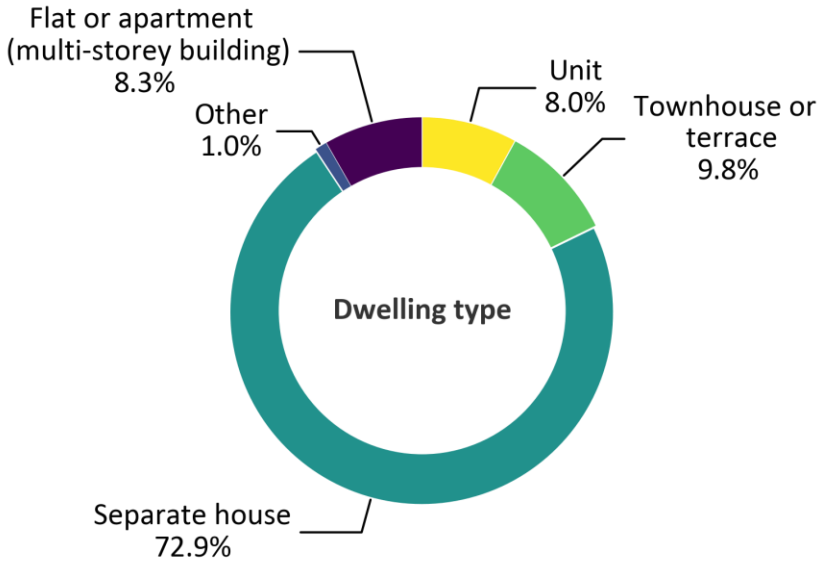
- 70% own their dwellings, 80% live in houses, and 85% have off-street parking.
  - 79% of the parking spots are less than 10 m away from a power point.
- 20% have ToU tariff plans and almost 30% have solar panels.
- Perceived ability to charge is lower than expected: 52.2% think they would be able to charge at home, while 31.5% state that they are unsure.
- Almost 80% of those who commute by car, park their vehicles in places other than street parking.
- 75.6% claim that EV charging is not available in their workplace parking location.
- Interest in using free work charging instead of home charging is high.
- Charging at home is perceived as the most convenient location by most potential EV consumers, followed by dedicated fast-charging facilities.
- Those who commute tend to prefer workplace charging over dedicated fast-charging facilities.
- On average, sample respondents expect to charge their vehicles at home around 2 to 3 times a week.
- Close to 55% of the sample reported they would start charging during evening peak (38% between 17h-20h) or shoulder times (17% between 20h-22h).
- A 50% tariff discount after 11pm could attract up to 75% of the consumers who prefer different times.
- A 20% mid-day (10am-2pm) tariff discount would potentially shift the charging times of 23% of the consumers who prefer different times.
- Saving money seems to be a priority over time and convenience, which is expected as mainstream consumers tend to be more cost-sensitive than early adopters.
- Regular charging start times and charging on weekdays are preferred by more than half of the consumers.

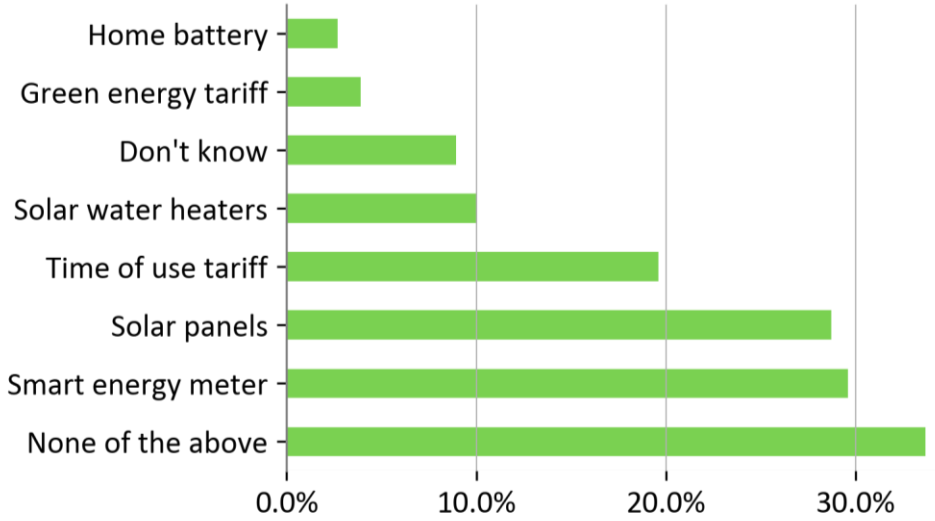
Residential Characteristics

What?
Dwelling ownership and type, electricity plan and the availability of solar panels.

Why?
Determine the potential for residential charging installation. The current adoption of ToU tariffs is indicative of acceptance of demand response mechanisms, while solar energy indicates potential grid independence.

Results
Almost 70% of respondents own their dwellings, while more than 80% live in houses, which are attributes usually associated with the potential for home charging installation. ToU tariffs are more popular than green energy tariffs but still are adopted by less than 20% of the sample. Solar panels are available in almost 30% of the residences, which is compatible with the current national average[11].





N=899, all respondents who drive an ICEV

[11]Australian PV Institute, 2021. Mapping Australian Photovoltaic installations. (Accessed 16/08/2021)

Residential Parking and Perceived Ability to Charge an EV at Home

What?

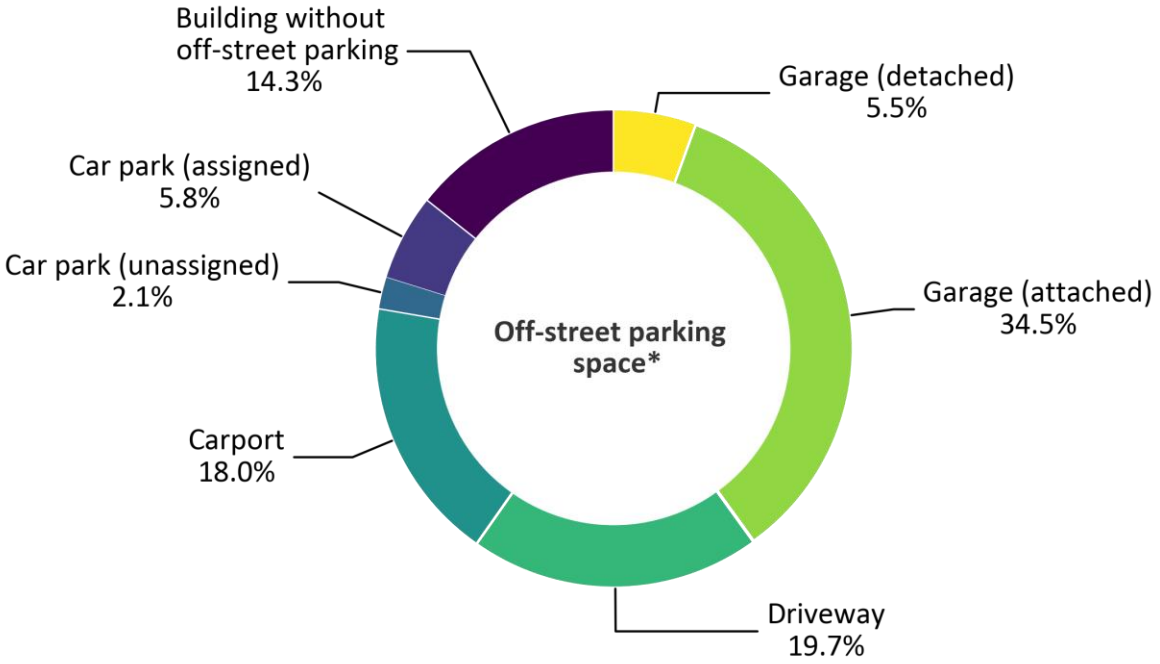
Off-street parking availability, type, and distance to a power point. Perceived ability to charge an EV at home.

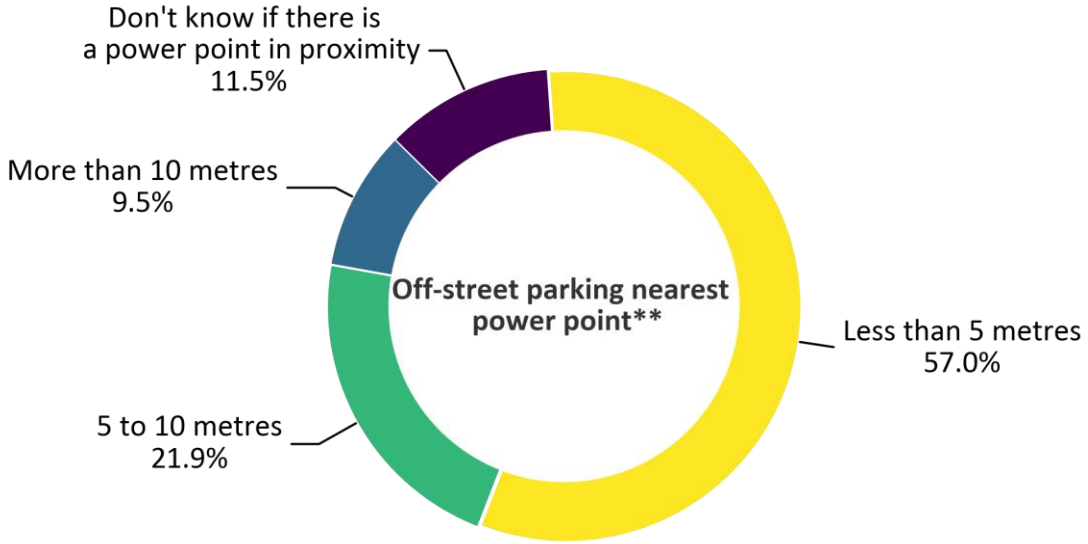
Why?

The ability to charge at home can significantly impact EV purchase intention and the need for public charging infrastructure.

Results

Around 85% of ICEV drivers have off-street parking in their residences, with attached garages being the most common setup. Access to a power point is also high, as almost 79% of those who park off-street are less than 10 m away from an outlet. Considering these factors, the perceived ability to charge is lower than expected. 52.2% of the ICEV drivers think they would be able to charge at home, while 31.5% state that they may be able but are unsure.





*N=899, all respondents who drive an ICEV

**N=777, respondents who have access to off-street parking

Workplace Charging Availability

What?

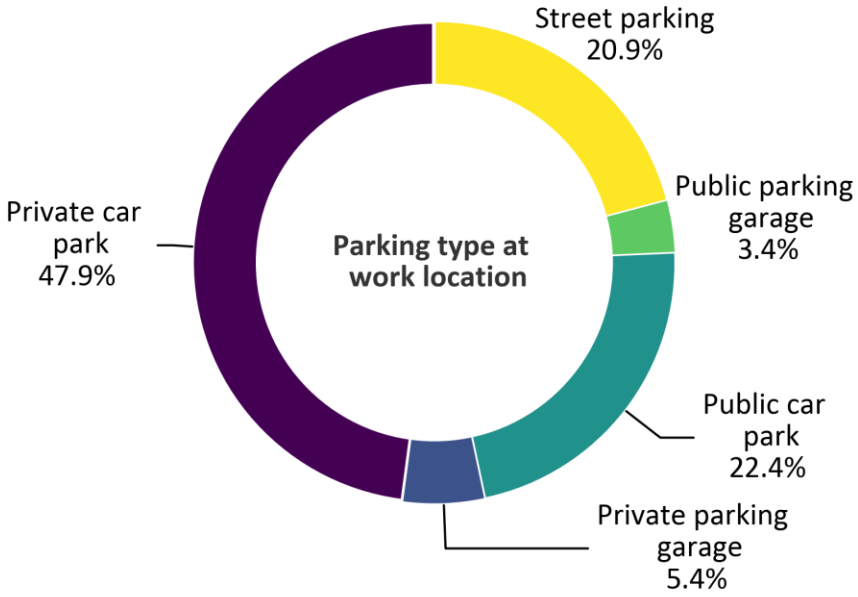
ICEV owners who drive to work reported parking type, access to EV charging, and intention to charge if free charging is available. Those who do not drive to work reported on their intention to change their commute mode to take advantage of free charging.

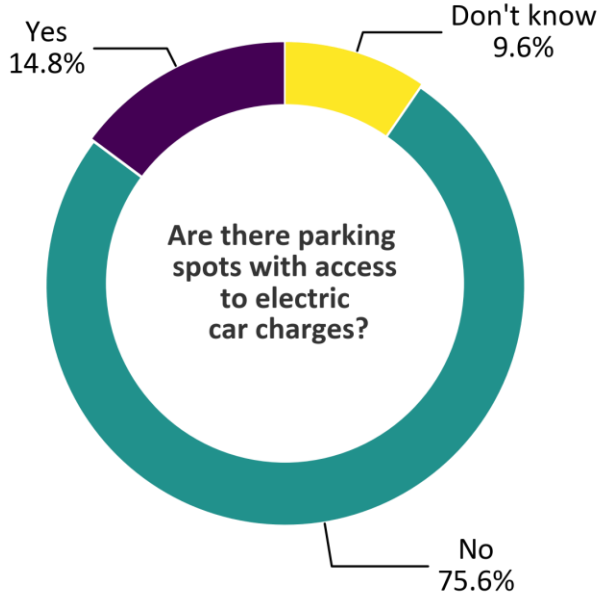
Why?

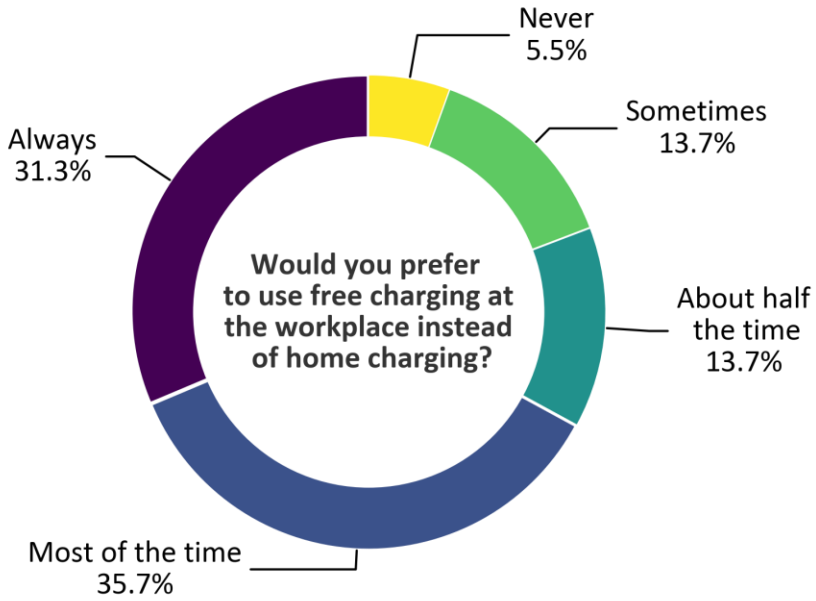
To understand the potential for workplace charging to complement or substitute residential charging.

Results

Almost 80% of those who commute by car park their vehicles in places other than street parking. Yet, 75.6% claim that electric car charging is not available in their parking location. Interest in using free work charging instead of home charging is high, with 67% saying that they would do that most of the time or always. 45% of those who do not drive to work would consider switching their mode to take advantage of free charging on a regular basis.







N=422, ICEV drivers who currently drive to work or who used to drive to work prior to the COVID-19 pandemic

Hypothetical Scenario

The remainder of this section and Section 7 present the compilation of answers that ICEV drivers gave based on the following hypothetical scenario:

For the remainder of the survey, please consider that you are the owner or regular user of a **plug-in electric car.** A car that **NEEDS** to be plugged into an electrical outlet to recharge and does not use traditional fuel such as petrol or diesel.
Also, consider that your parking arrangements allow you to charge your car at home.

Charging an electric car may take from less than 1 hour to more than 12 hours, depending on the battery size, level of charge, and type of charger. Cars can be charged overnight at home, but residential chargers usually require longer charging periods than public chargers.

Usual charging rates available at different locations:
1- Dedicated fast-charging facility: 225 km per hour of charge
2- Regular public chargers at car parks of shopping, dining, recreational, and sporting facilities: 45 km per hour of charge
3- Regular public chargers at workplace car parks: 45 km per hour of charge
4- Residential chargers: 20 km per hour of charge

Preferred Charging Location and Home Charging Frequency

What?

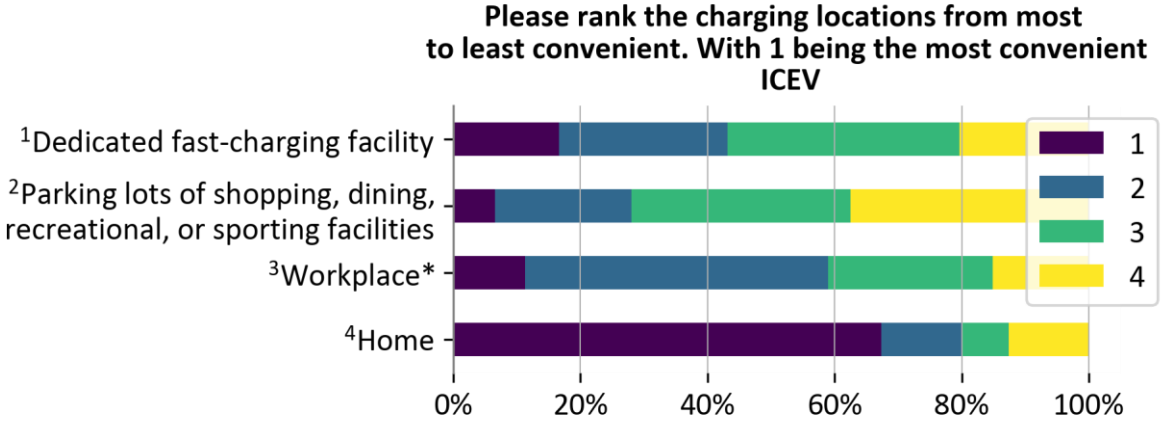
Perception of convenience of different charging locations and frequency that ICEV drivers would charge at home.

Why?

To understand charging demand at different locations and expected changes in residential charging loads.

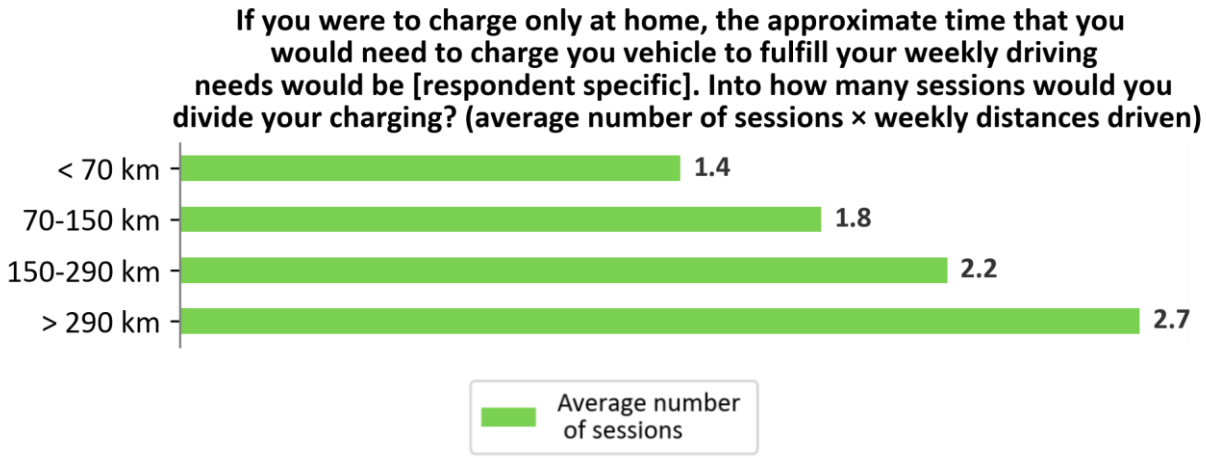
Results

Charging at home is perceived as the most convenient location by most potential EV consumers, followed by dedicated fast-charging facilities. However, those who commute tend to prefer workplace charging over dedicated fast-charging facilities. However, fast-charging facilities are preferred over standard chargers located at destinations of interest, such as shopping facilities. On average, sample respondents expect to charge their vehicles at home around 2 to 3 times a week.



Charging rates provided to respondents:

1- 225 km per hour of charge
2- 45 km per hour of charge
3- 45 km per hour of charge
4- 20 km per hour of charge



N=899, all respondents who drive an ICEV
*N=523, respondents who commute

Home Charging: Preferred Start Time

What?

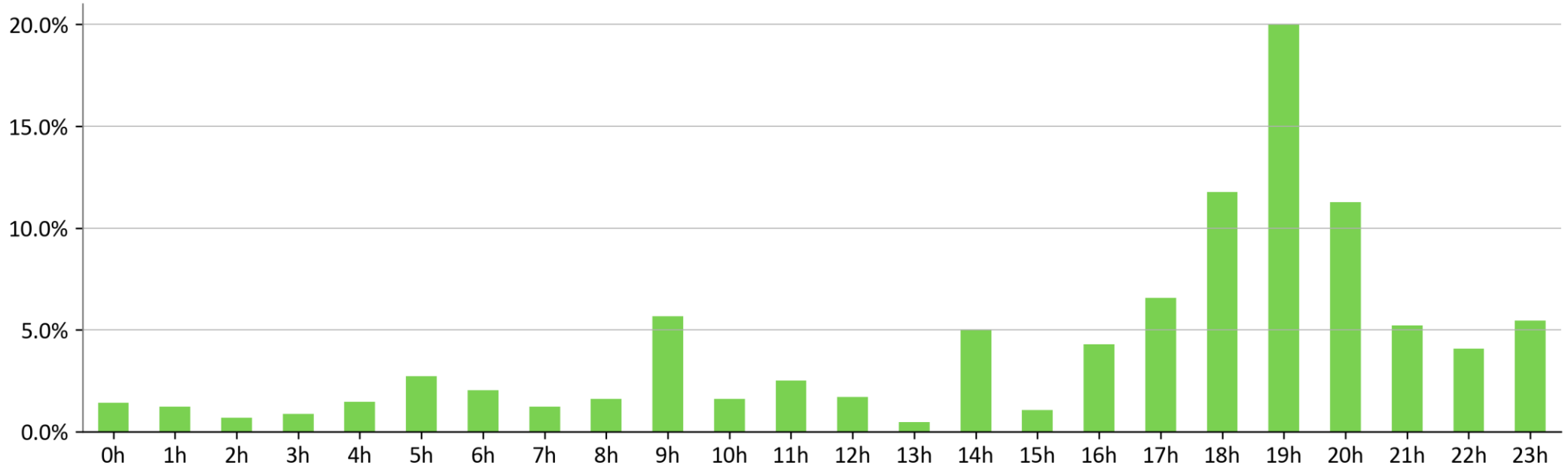
Preferred time to start charging an EV at home.

Why?

This variable can help determine whether future consumers may contribute to peak electricity demand once they buy EVs.

Results

Close to 55% of the sample reported they would start charging during evening peak (38% between 17h-20h) or shoulder times (17% between 20h-22h).



N=899, all respondents who drive an ICEV

This question requested respondents to report their charging start time based on a 24h clock, which may have caused some measurement error.

Home Charging: Willingness to Change Start Time

What?

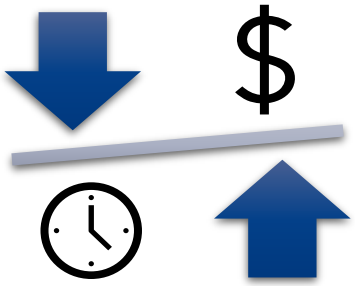
Willingness to delay home charging start time to 11pm or to change it to between 10am and 2pm

Why?

The 11pm scenario provides insights into the acceptance of traditional demand response programs based on ToU tariffs. While the mid-day charging scenario represents demand response programs that aim to use EVs to absorb excess solar power generation.

Results

Marginal benefits in terms of participation increase in both programs are the highest when 20% discounts are offered. Increases in acceptance of the night ToU are rather linear and a 50% discount would be able to reach almost 75% of the consumers. Acceptance of mid-day charging is constrained by the car location during this time window as almost 18% of the sample stated that their vehicles are never at home during this time.



Discount Level	Change to 11pm*	Change to between 10am and 2pm**
No discount	7.9%	4.6%
10% discount	15.9%	10.5%
20% discount	32.0%	22.7%
50% discount	74.8%	50.6%

*N=756, respondents who charge at home and whose charging start time in between 7am and 10pm

**N=797, respondents who charge at home and whose charging start time is not between 10am and 2pm

Factors Affecting the Decision to Charge

What?

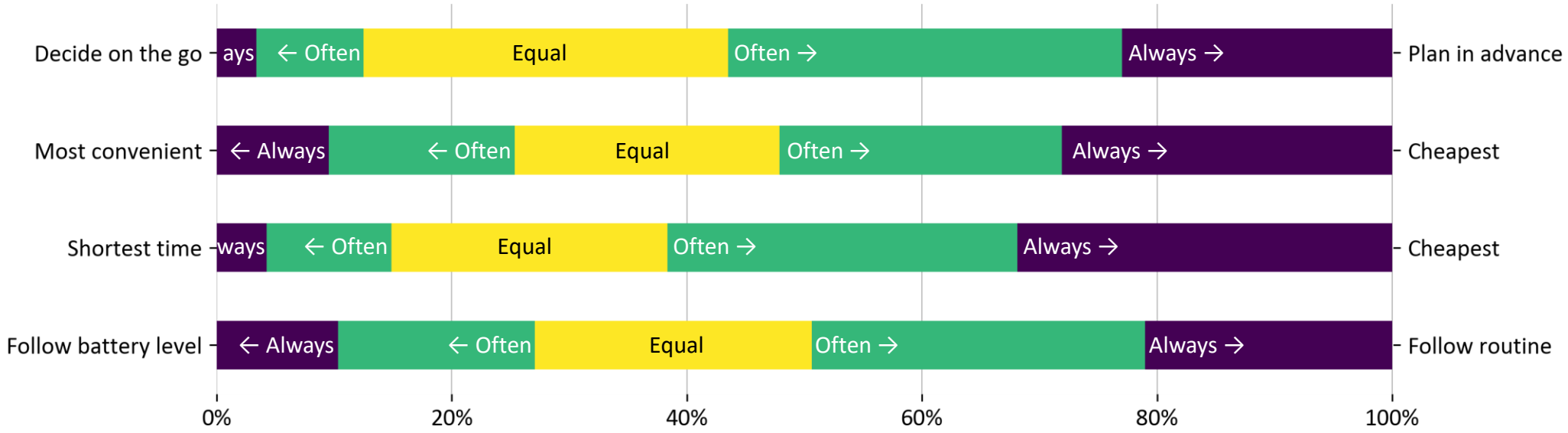
ICEV drivers reported how frequently they would base their charging decision on several factors.

Why?

Understanding how charging behaviour may vary across potential consumers can help guide different strategies for charging infrastructure deployment and demand management.

Results

Potential EV consumers indicate a general preference toward planning charging sessions in advance and following a routine. Saving money seems to be a priority over time and convenience, which is expected as mainstream consumers tend to be more cost sensitive than early adopters.



N=899, all respondents who drive an ICEV

Potential Charging Routine Characteristics

What?

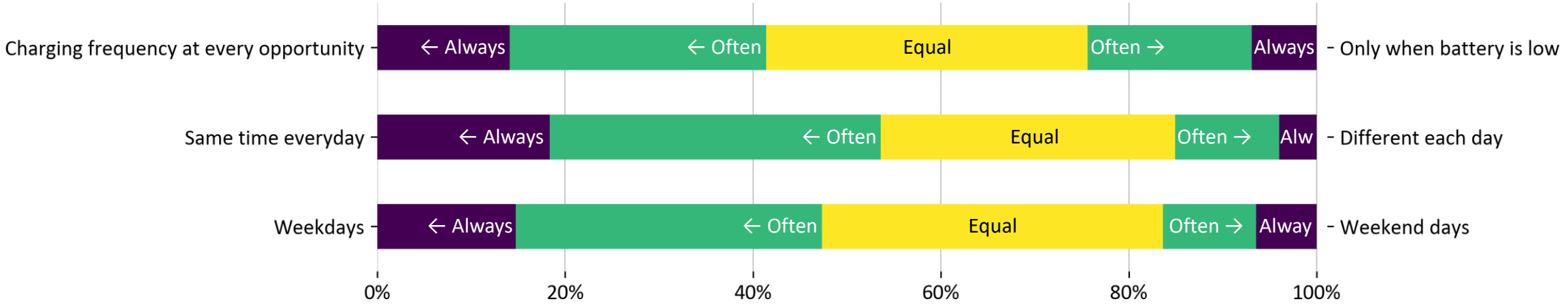
ICEV drivers reported their preferred charging routine in terms of frequency, time, and day of the week.

Why?

Understanding how charging behaviour may vary across potential EV consumers can provide insights into charging related electricity demand and potential strategies for demand management.

Results

There is a clear preference for consistent charging start times as more than half of respondents stated that they would often or always charge at the same time. Charging on weekdays also tends to be preferred over weekend charging. There is a slight tendency toward basing the decision to charge on the opportunity rather than battery level. However, this could change as these consumers get real world experience with EV technology.



N=899, all respondents who drive an ICEV

7. Would potential EV consumers accept supplier-managed charging?

Acceptance of Supplier-Managed Charging by Potential EV Consumers: Key Insights

- 45.8% would choose user-managed smart charging and 25.0% would choose supplier-managed smart charging instead of unmanaged charging.
  - Consumers who are currently doing research to purchase an EV are more likely to choose supplier-managed smart charging.
- Almost 40% are 'somewhat likely' to adopt supplier-managed smart charging.
  - The ability to use an App to override the external charging management increases this share to 58.7%.
- Consumers seem unsure about the benefits of supplier-managed charging.
  - Information campaigns may be necessary to convince potential EV owners.
- Most consumers do not think that supplier-managed charging systems will operate improperly.
- They think it is somewhat likely that their vehicles will not get charged to the desired level or during a suitable time window, and that there will be a need to override management frequently or use public charging.
- Around 60% of respondents show some concern about data sharing and privacy issues related to supplier-managed charging.
- Almost 40% would feel uncomfortable passing over the control of when their vehicles are charged.
  - This seems to be more associated with the risk of not having their vehicles charged than with concerns about third-party management.

Preferred Type of Charging Management

What?

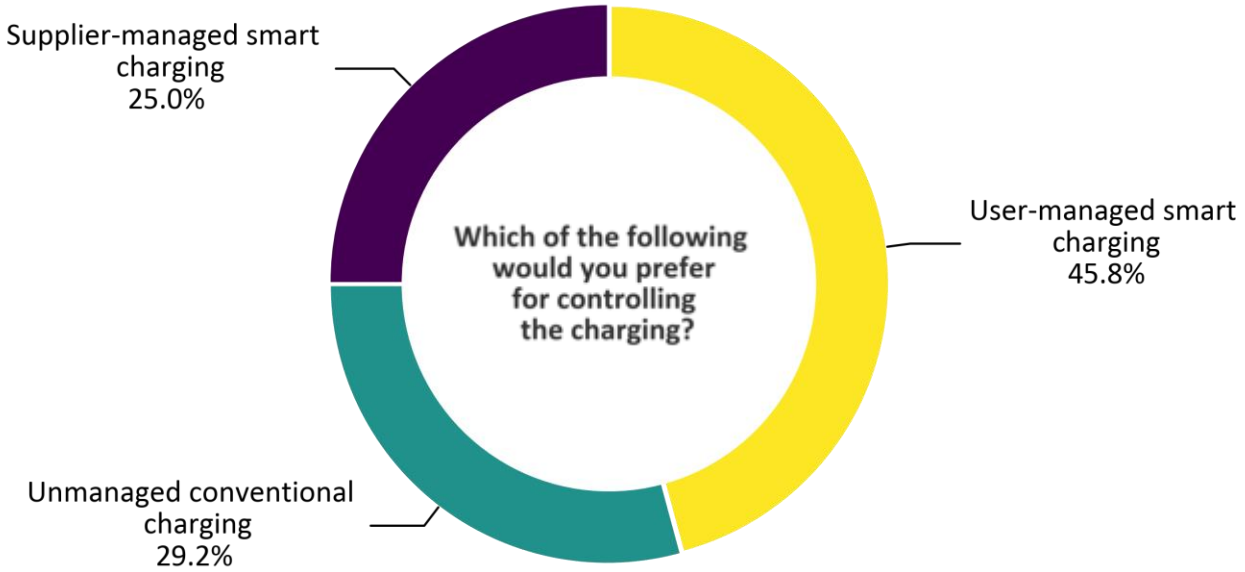
Preferred type of charging management based on definitions provided.

Why?

To understand the acceptance of smart charging and consumer willingness to give electricity suppliers the ability to control charging.

Results

The use of an automated system to minimise costs based on ToU tariffs is the preferred option of most potential consumers in the sample (70.8%). However, only one-fourth of the respondents would have the supplier-managed option as their preferred alternative. Preference for this option is 10% higher among consumers who are currently doing research to purchase an EV compared to the remaining sample. The preference for supplier-managed charging is higher among men compared to women.



N=899, all respondents who drive an ICEV

Acceptance of Supplier-Managed Charging

What?

Willingness to accept supplier-managed smart charging to avoid peak surges considering the risk of not having the vehicle fully charged.

Why?

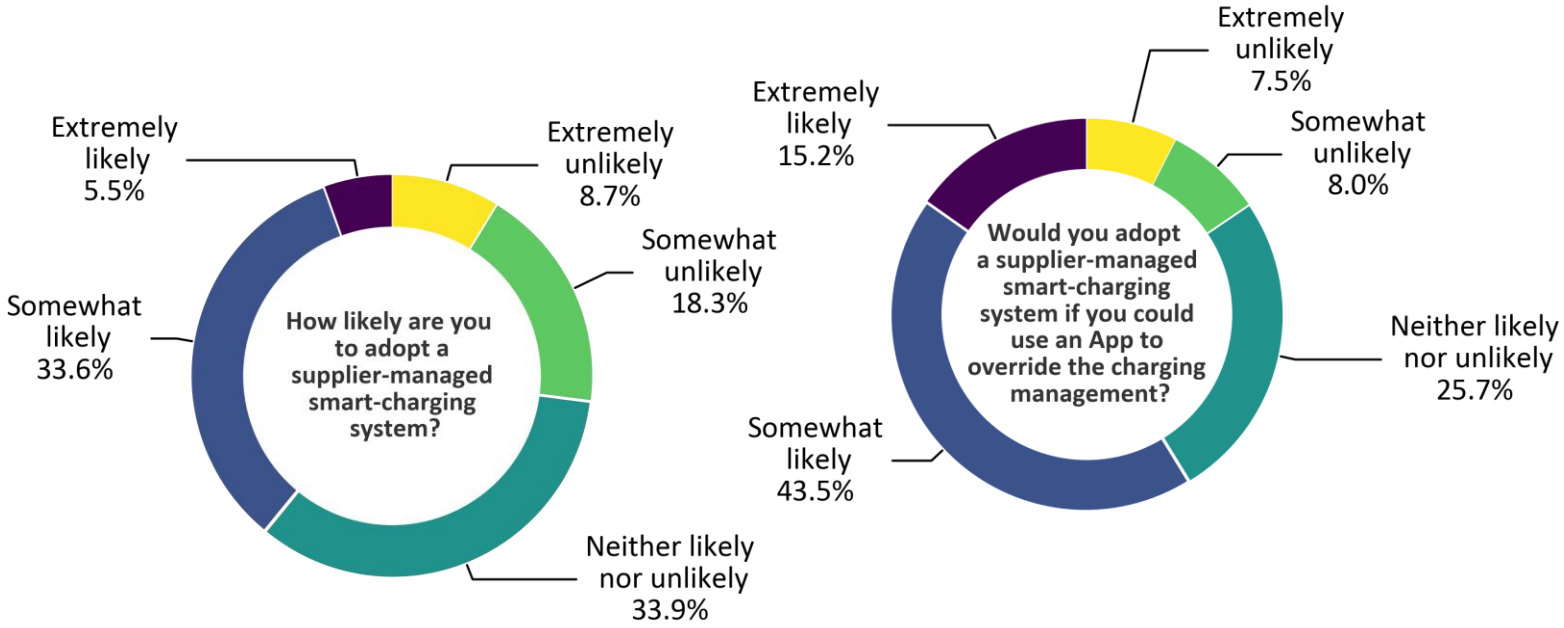
To understand the general acceptance of supplier-managed charging when considering potential benefits and risks.

Results

The general acceptance of supplier-managed charging is higher than the preference for this option. Almost 40% of the respondents are 'somewhat likely' to adopt it. The ability to use an App to override the external charging management when required can significantly increase acceptance among this group (58.7% of the sample would be somewhat likely to adopt if overriding is available). Supplier-managed charging acceptance levels are positively correlated with the intention to purchase an EV. Acceptance is higher among men than women but the App reduces this difference.

Description

"In a future where the majority of cars are electric, balancing the overall demand for electricity becomes important to avoid potential peak surges that may lead to a power outage. Between the moment you plug in your car and your chosen departure time, a supplier-managed smart-charging system selects the charging time and speed that minimise your costs, balances the overall demand for electricity, and increases the use of renewable energy. However, there is a chance that in sporadic occasions your car won't be charged to your desired level by the end of the charging session."



N=899, all respondents who drive an ICEV

Perceived Benefits Associated with Supplier-Managed Charging

What?

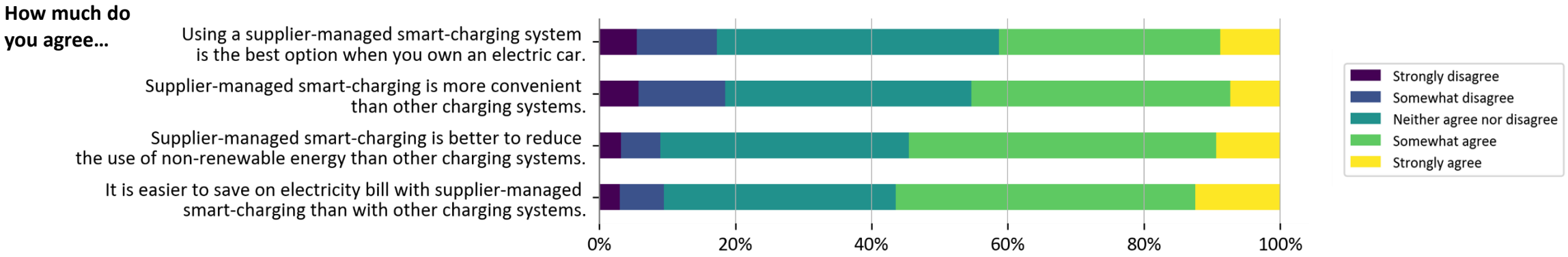
User appreciation of supplier-managed smart charging in terms of convenience, reduction in the use of non-renewable energy, cost efficiency, as well as general appreciation compared to other systems.

Why?

To understand how perceptions of benefits may drive supplier-managed smart charging acceptance.

Results

Around one-third of the respondents neither agree nor disagree with the supplier-managed smart charging benefits, which indicates that consumers may need more information to make up their minds. The convenience brough by this system may still be unclear, while there is a slightly higher understanding of the potential for reducing the use of non-renewable energy and saving money.



N=899, all respondents who drive an ICEV

Perceived Risks Associated with Supplier-Managed Charging

What?

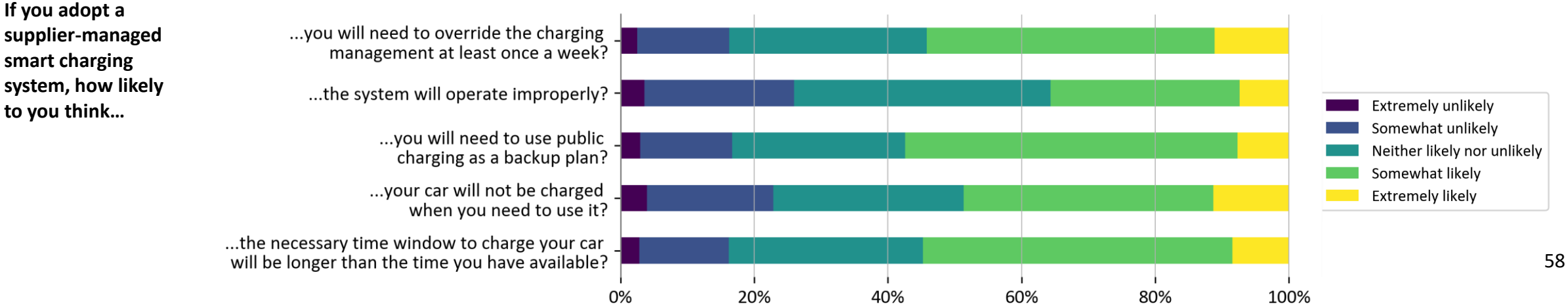
Concerns and perceived risks associated with the use of supplier-managed charging systems.

Why?

To understand how perceptions of risks may hinder supplier-managed smart charging acceptance among potential EV consumers.

Results

With the exception of improper system operation, all other risks are considered somewhat likely by at least half of the sample. Around 60% of respondents show some concern about data sharing and privacy issues. Almost 40% would feel uncomfortable passing over the control of when their vehicles are charged, which seems to be more associated with the risk of not having their vehicles charged than with concerns about third-party management.



8. Comparing charging preferences of EV owners and potential consumers

Setting the Comparison

- This section compares currently EV owners and potential consumers in terms of:
  - the perceived ability to charge an EV at home;
  - the perceived ability to charge an EV at work; and
  - the charging management preferences.
- Charging preferences of current EV owners may differ from those of potential consumers simply because of their level of experience using the technology.
- Other sources of variability can be differences in socio-demographic characteristics and differences in personality traits and lifestyle preferences.
- The sample of EV drivers has a significant overrepresentation of men between the ages of 35 and 44 years.
- To create a more even field to compare EV drivers and potential consumers, subsamples of EV drivers and ICEV drivers formed only by men between the ages of 35 and 44 years were drawn.
- The subsamples were compared to the main samples to see if the observed variables of interest significantly differed.
- Even though some degree of variation between the subsamples and the samples were observed, they were not sufficient to justify limiting the comparison to the subsamples.
- For the above reason, the next slides provide a summary of the major differences found between the complete samples of EV drivers and ICEV drivers.
- It is important to bear in mind that the sample of potential consumers (ICEV drivers) is representative of the driving-age population of Australia. However, the EV driver sample is not representative in terms of PEV and PHEV split and the degree of representativeness regarding individual socio-demographic characteristics is unknown.

EV Owners vs. Potential Consumers (1)

Ability to Charge at Home

- The proportion of respondents living in houses is higher among potential consumers than EV owners. However, access to off-street parking and garages is higher among the second group.
- 18.0% of potential consumers, compared to 16.3% of EV owners, park more than 10 m away from a power point or do not know if there is power in proximity.
- 16.3% of potential consumers claim that they would not be able to charge an EV at home and another 31.5% are unsure. Only 7.7% of EV owners are unable to charge at home.
- Potential consumers currently doing research to buy an EV are more confident about their ability to charge at home than the remaining sample.
- Based on the above, it is possible that potential consumers underestimate their ability to charge at home.
- Home would be the preferred charging location of most potential consumers and it is also the most frequently used location by the majority of EV owners.

Ability to Charge at Work

- 75.6% of potential consumers who drive to work say that there is no charger available and another 9.6% does not know. In contrast, 75.9% of EV commuters can charge at their work parking location.
- Even though there is a higher share of potential consumers that use street parking, it is possible that this group underestimates charging availability.
- Most EV commuters do use workplace charging at least weekly and there is similar interest among potential consumers. Both groups also perceive free workplace charging as an appealing alternative to home charging.

EV Owners vs. Potential Consumers (2)

Home Charging Start Time

- The distribution of residential charging start time for EV drivers is similar to potential consumer's preferences.
- Potential consumers are more responsive to ToU discounts than EV owners, which is expected since mainstream consumers tend to be more sensitive to monetary costs than innovators and early adopters.
- Indeed, potential consumers demonstrated that saving money would be often a priority over increased convenience and reduced charging time, while current EV owners demonstrated the opposite.

Supplier-Managed Charging

- Preference for and acceptance of supplier-managed smart charging is higher among EV drivers compared to potential consumers. Those planning to purchase an EV within the next year show stronger preferences for supplier-managed charging. These results indicate the clear separation between consumer types (early adopters and the majorities).
- Among EV owners and potential consumers, men show greater acceptance of supplier-managed changing than women do. Yet, an App that allows for management overriding, has greater potential to increase acceptance among female mainstream consumers.
- EV drivers tend to agree more with statements about supplier-managed charging benefits than potential consumers do. However, they also tend to find risks associated with this system to be more likely to occur.
- Considering the differences in perceived risks and benefits, there are a couple of potential explanations for higher acceptance of this system among EV owners:
  - innovators and early adopters tend to be risk-takers, and thus, the perceived risks do not discourage this group;
  - perceived benefits significantly outweigh risks and justify adoption; or
  - the significantly smaller sample of EV drivers is more susceptible to survey measurement error than the ICEV driver sample.

9. Conclusions and recommendations

Conclusions and Recommendations (1)

The results of the survey described in this report corroborate and complement the findings from the literature review in a previous report from this project. In this section we summarise conclusions and recommendations based on these findings.

Current EV owner profile: Like in Europe and the USA, we observed that most EV owners are men, approaching middle age, with high income and education.

- PHEVs are more likely to be the only household vehicle than PEVs.
- EV owners drive almost two times the national average distance travelled per car per year and there are no significant differences between PEV and PHEV drivers.

Prospective buyers: Those intending to buy an EV within the next year also driver longer distances than the national average. This indicates that the higher purchase cost of EVs may be appealing only to those who will benefit the most from lower running costs.

- From a utility provision standpoint, it is interesting to note that weekly charging needs per individual are likely to decrease as the adoption curve reaches the majorities.

Adoption timeline: Among those considered mainstream consumers, 44% do not consider purchasing an EV within the next 10 years. Skepticism is higher in regional areas.

- Marketing campaigns and changes in the current policy scenario seem necessary to accelerate EV dissemination in Australia.

Home is the preferred charging location for current owners and potential consumers. However, workplace charging is also frequently used by current owners.

- All consumers who commute show significant interest in using workplace charging if it leads to monetary savings. This can be an opportunity to balance EV charging demand both temporally and spatially.

Potential consumers seem to underestimate their ability to charge at home and at work.

- Initiatives that increase consumer knowledge about EV charging may be necessary to increase technology acceptance.

Fast-charging service stations are perceived to be more convenient than standard chargers located at destinations of interest, such as shopping facilities. However, this is just a perception of convenience and actual choices will be influenced by differences in costs.

- Current users of free public-charging would continue to use it if a fee was introduced. However, mainstream consumers will likely be more sensitive to cost changes.

Conclusions and Recommendations (2)

Residential charging is likely to take place during evening peak if unmanaged.

- Even though most EV drivers can set a timer to start charging their vehicles, 51% begins charging between 5-10pm. 55% of the potential consumers would also charge during this time.
- Half of the EV owners adopt EV specific, and/or ToU tariffs, and/or residential solar panels. PEV owners are two times more likely than PHEV owners to adopt those.
- Less than one-fifth of potential consumers currently consider that special tariffs and solar panels would be necessary if they purchased an EV.
- These results emphasize that charging management to nudge consumers into different charging times will be necessary together with measures to increase awareness about ToU benefits.

Mainstream consumers are more responsive to ToU discounts than current EV owners.

- A 50% residential tariff discount after 11pm could attract up to three-quarters of the consumers who prefer different times.
- A 20% mid-day (10am-2pm) discount could shift the charging times of around one-fifth of those who prefer different times.
- The demand shift is constrained by cars not being parked at home during this time.

Preference for and acceptance of supplier-managed smart charging is higher among EV early adopters (both EV owners and those planning to buy an EV in the near future).

- Less than one-fourth of mainstream consumers would prefer supplier-managed smart charging over user-managed or unmanaged charging.

To increase supplier-managed smart charging acceptance:

- Monetary savings need to be evident and clear to consumers, even if tariff structure is dynamic and complex.
- Third-party management and control need an interface via App that increases users' sense of control over charging and decreases their feeling of uncertainty.
- Clarity in data sharing and user privacy policies is required.
- Consumer awareness about environmental and community benefits need to be addressed in campaigns.
- Public charging needs to be perceived as an easy and accessible backup plan.

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