ACIL ALLEN

25 May 2023

Report to Energy Security Board

EV charging insights

International literature review

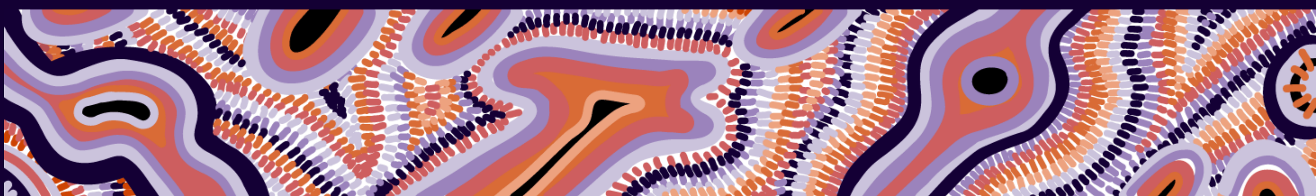
About ACIL Allen

ACIL Allen is a leading independent economics, policy and strategy advisory firm, dedicated to helping clients solve complex issues.

Our purpose is to help clients make informed decisions about complex economic and public policy issues.

Our vision is to be Australia's most trusted economics, policy and strategy advisory firm. We are committed and passionate about providing rigorous independent advice that contributes to a better world.

ACIL Allen acknowledges Aboriginal and Torres Strait Islander peoples as the Traditional Custodians of the land and its waters. We pay our respects to Elders, past and present, and to the youth, for the future. We extend this to all Aboriginal and Torres Strait Islander peoples reading this report.



Goomup, by Jarni McGuire

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The Customer Insights Collaboration was established by the Energy Security Board to provide feedback from a customer perspective on the transition to a future of diverse sources of non-dispatchable generation, demand response, storage, and consumer energy resources. The current release of the Customer Insights Collaboration is focused on enhancing consumers' experiences with, and value from, charging their electric vehicles (EVs).

ACIL Allen was engaged to support the Customer Insights Collaboration by undertaking a review of recent international research to gather insights about:

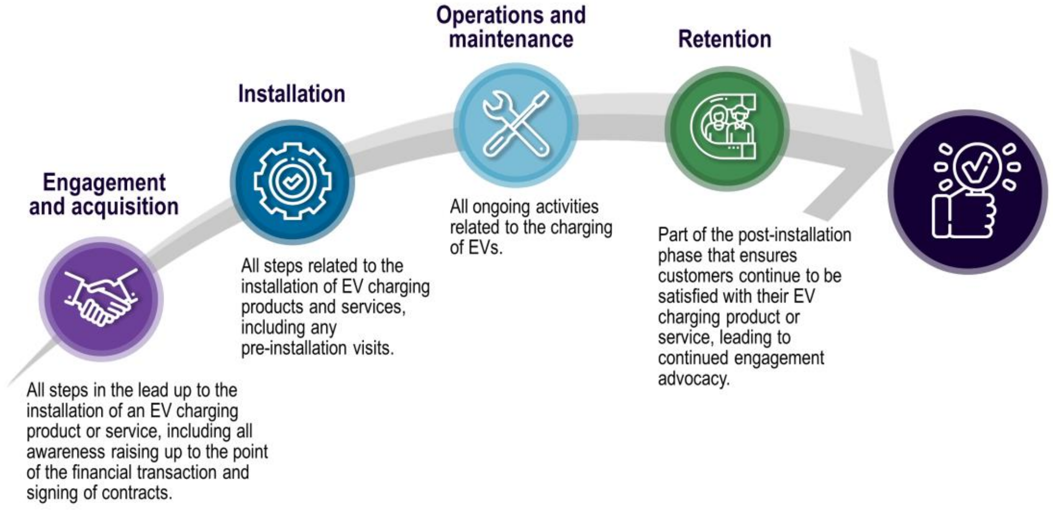
— the end-to-end customer journey for EV charging products and services (as illustrated in Figure ES 1)

— key customer enablers and pain points that have emerged along the customer journey for EV charging

— policy, regulatory and industry initiatives to support and manage the charging of EVs.

The literature review excluded any literature from Australia or New Zealand, as these insights are expected to be provided as an input to the Customer Insights Collaboration by members of the Stakeholder Steering Group.

Figure ES 1 Customer journey for EV charging products and services



Source: ACIL Allen based on (Australian Renewable Energy Agency, 2020)

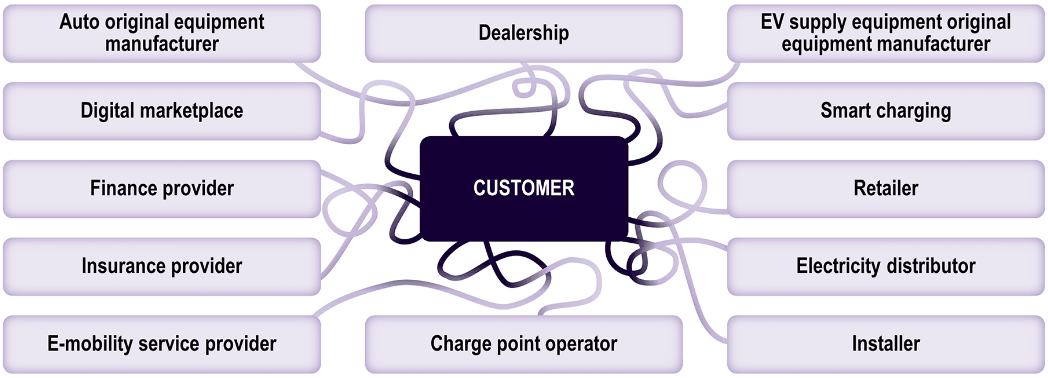
The relevant international literature is summarised in Appendix A. It is largely based on the experiences of EV charging by early adopters, with some more recent research, particularly in Norway, also including early majority consumers. Early adopters are mostly male, highly educated, with a relatively high income and are older (over 40 or 50 years, depending on the study) (for example (Anderson, Bergfeld, Nguyen, & Steck, 2022), (Chakraborty, Hardman, & Tal, 2020), (Haugneland & Kvisle, 2015) and (Westin, Jansson, & Nordlund, 2018)). They are generally more motivated by the environment and technology than financial considerations. (Anderson, Lehne, & Hardinghaus, 2017) and (Axsen, Goldberg, & Bailey, 2016) caution that the characteristics of early adopters do not mirror society more broadly.

Engagement and acquisition phase

The EV ecosystem, including charging, is complex as illustrated in Figure ES 2. The customer has multiple opportunities to 'drop off' the EV charger purchase pathway, due to the volume of additional actions required to be completed compared to purchasing a conventional internal combustion engine vehicle (ICEV). For example, (Kaluza, 2022a) identified that along this pathway, there needs to be consideration of things such as:

— Is a home charger needed[1] or will public charge points suffice[2]?
— What is the budget?
— What features are important?
— Technical evaluations such as: is the home currently capable of supporting a charge point?
— Which company should be chosen to complete the installation?

Figure ES 2 The complex EV ecosystem



Source: (Kaluza, 2022b)

Installation phase

EV users will normally charge their EV while the car is parked. Accordingly, charging of EVs by early adopters is generally dominated by home charging, with some work-based charging. Other forms of public charging are generally only used by those without home charging or professional users, to get to far-away destinations, and by occasional users for rare range problems.

With the high reliance by EV drivers in most countries on home charging, most EV drivers need to consider the installation of a home charging point, either a standard electricity socket or a dedicated home charge point. This is simpler for those that own a detached home with off-street

[1] While not specifically identified by (Kaluza, 2022a), the customer also has the option to use a standard electricity socket rather than install a dedicated charging point at home. Around a third of drivers across Europe and in the UK rely on a standard electricity socket (NewMotion, 2020), (U.K. Department for Business, Energy & Industrial Strategy, 2023).

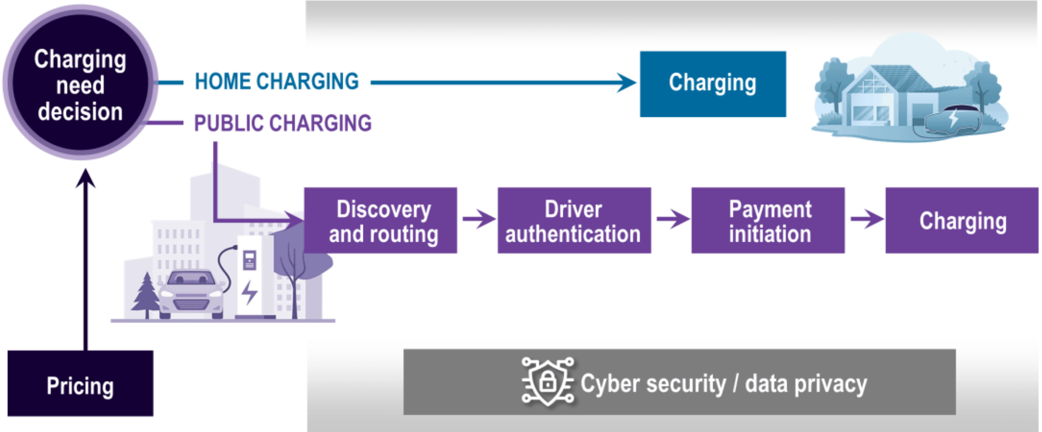
[2] We note from the literature that public charge points may include charge points at work, on the street, at a destination (e.g. a shopping centre) or en route (refer section 1.2.2).

parking than for those in rented or multi-unit accommodation, or do not have access to off-street parking.

Operations and maintenance phase

EV owners need to consider both home and public charging when using their EV. The EV charging journey during the operations and maintenance phase – for home and public charging – is illustrated in Figure ES 3.

Figure ES 3 EV charging journey – operations and maintenance phase



Source: ACIL Allen based on (Arthur D. Little, 2022)

The majority of drivers in a UK trial did not think that adapting to charging their EV would be a difficult task (73%). After experiencing the charging process for 3 months, significantly fewer drivers (88%) did not think that adapting to charging the vehicle had been difficult. It was often described as being as simple as plugging in a household appliance (Bunce, Harris, & Burgess, 2014).

However, the (Competition & Markets Authority, 2021) found that EV charging can be complex, confusing, and frustrating at times, particularly compared to the experience of refuelling an ICEV.

> *"Charging of a BEV should be just as simple as filling petrol. Drive to the station, insert the cable, and pay with a bank/credit card. I have never experienced that this succession differs between different petrol stations. It should be equal to use all public charging stations; it should be simple."*
>
> *Consumer quote in (Figenbaum, Wangsness, Amundsen, & Milch, 2022)*

(McKinsey & Company, 2022) found that customers' experiences with public charging are often unsatisfying, with the main shortcomings being the speed, cost, availability, and safety of charging locations. Drivers struggle to find chargers because information is limited and pricing systems can vary considerably. Finally, the design and operation of chargers differ greatly, and customer service isn't always prompt or helpful.

Retention phase

EV charging should be a seamless experience for customers. However, a number of studies have identified a level of dissatisfaction with the charging journey. These issues matter because current EV drivers can experience unacceptably poor service and they deter others from switching to an EV by contributing to 'range anxiety' (U.K. Department for Transport, 2022b), 'charging anxiety' and increasingly to 'parking anxiety'.

Key pain points and enablers along the customer journey

The international literature review has identified a range of pain points for customers along the EV charging journey. These pain points are summarised in Table ES 1, with enablers to facilitate a simpler customer journey.

Table ES 1 Key pain points and enablers along the EV charging customer journey, as identified by the international literature review

Customer journey phase	Pain points	Enablers
Engagement and acquisition	There is a chicken and egg dilemma: – the decision to purchase an EV charging product or service is secondary to the decision to purchase an EV – the decision to purchase an EV is dependent on the availability of charging infrastructure.	Improved information on the availability of public charging infrastructure, and on home charging options, to increase awareness and understanding by car dealerships and end customers.
	The EV ecosystem is complex with purchasers of an EV needing to interface with multiple parties, including a number of parties relating to home charging, if the potential purchaser has the option to install home charging.	
	There is currently low awareness and understanding of the different charging point options, and car dealerships may not be well placed to advise customers.	
	A dedicated home charge point may be expensive, and all costs associated with purchasing a dedicated home charge point may not be known upfront.	Obligations on suppliers and installers of dedicated home charge points to assess the supply adequacy for a dedicated home charging point so that the full costs for the supply and installation are quoted upfront.
Installation	There are reported safety issues associated with charging EVs at home using a standard electricity socket, including burnt sockets, blown fuses, overheating of long charging cables, and rain mixed with sockets.	Government recommendations related to the use of standard electricity sockets and dedicated charging points for charging EVs at home, including separate circuit and fuse, and ground fault detection.[3] Information on charging EVs safely at home using standard electricity sockets and dedicated EV chargers.
	There may be insufficient capacity to supply a dedicated home EV charging point.	Prior to installation of a home charge point, assess the adequacy of supply to ensure all costs are known before commencement of the installation.
	There may be significant additional costs to install a dedicated home charge point if the premises need re-wiring and/or the fuse upgraded to accommodate the charge point.	

[3] We note that current and emerging international standards for in-cable control and protection will mitigate some of the safety issues that have been identified internationally.

Customer journey phase		Pain points	Enablers
		Those living in rented, leased or multi-unit accommodation may find it difficult to get permission to install or decide who pays for home EV charging points.	Introduce a "right to charge" for those living in rented, leased or multi-unit accommodation.
Operations and maintenance	Pricing – home charging	An EV driver may not be aware of, understand and/or have switched to an EV-specific or TOU tariff.	Information and awareness raising of the benefits of EV-specific and TOU tariffs.
		A smart meter may be required to access an EV-specific or TOU tariff, and a separate meter may be required that applies only to EV charging.	Price comparison sites to include consideration of EV charging loads and EV-specific tariffs.
	Pricing – public charging	Pricing structures can be complex and difficult to understand.	Pricing offer to be clearly displayed to the consumer before charging commences.
		Pricing information may not be transparent, and may change during the charging process.	
	Home charging	There are reported safety issues associated with charging an EV from a standard electricity socket.	Limitations on the use of standard electricity sockets rather than dedicated home charging points, and government recommendations on minimum safety standards to apply. Information and awareness raising on the safety issues, including safe storage and use of connector cables.[4]
		There is a lack of standardisation of the charging point interface.	Standardise charging point interface.
	Public charging – discovery and routing	EV drivers need to plan where to charge an EV before embarking on a trip.	The need to plan will lessen with a greater proliferation of public charging points, and by addressing issues relating to reliability, queueing, and standardisation of public charging infrastructure.
		A range of apps are needed to find public charging points, and the information on these apps may be incorrect or out-of-date, and may be static in nature.	Facilitate a single app which contains the location of all public charging points, and includes dynamic data such as availability, charging speed, connector types, pricing and payment method.
	Driver authentication and payment initiation	Process to pre-register to access a public charging point may be difficult and time-consuming.	Facilitate a quick and accessible process for pre-registration.

[4] We note that current and emerging international standards for in-cable control and protection will mitigate some of the safety issues that have been identified internationally.

Customer journey phase	Pain points	Enablers
	Multiple apps or cards may be needed to access and pay for public charging points, and may not include standard credit/debit cards or contactless payment methods.	Mandate minimum standards for payment methods which are not specific to a brand and do not require a payee's mobile or internet signal. Facilitate roaming that allows people to pay for charging via a single app or card.
	An internet signal may not be available to access apps.	
	The payment method may not be known in advance of using a charge point.	
Public charging – reliability	Public charger may be out of order or cannot be easily activated or connected to the vehicle.	Mandate minimum standards for the reliability of public charging infrastructure.
Public charging – speed of charging	Charging speed may be low because of the charging speed of the charging point or the vehicle's connector type.	Provide clear information on the speed of the public charging point. Information and awareness raising of the different connector types.
Public charging – queueing	Public charging points may not be available, particularly during peak travel times.	Provide real-time data on the availability of public charging points, and the ability to book a charger.
Public charging – lack of standardisation	Public charging stations vary greatly in terms of connector types, layout, user interfaces, payment solutions, charger activation, cable lengths and locations, and charging power levels.	Increase the level of standardisation of public charging infrastructure.
Public charging - accessibility	There may be additional barriers to those with disabilities to use public charging infrastructure due to the design and/or location of the charging point.	Minimum standards or guidelines for designing accessible public charging points that consider the needs of all users, including disabled and older people.
	There may be difficulties for non-EV users with disabilities navigating the streetscape with the installation of on-street chargers.	
Public charging – charging station etiquette	EV charging bays may be blocked by EVs not charging or vehicles that are not EVs.	Prohibit the use of EV public charging bays by vehicles that are not being charged.
	EVs may be unplugged by others during the charging process.	Increase awareness of the appropriate use of public charging bays.
Public charging – facilities	There may be a lack of amenities at or near public charging points.	Provide facilities, similar to those provided at petrol stations, that are appropriate to the type and location of the charging point.

Customer journey phase		Pain points	Enablers
	Public charging – lighting and security	EV drivers may feel vulnerable charging their EVs without adequate lighting and security. EV drivers may have difficulty charging their EVs without adequate lighting.	Provide a level of lighting and security features that are appropriate to the type and location of the charging point.
	Public charging - weatherproofing	Charging an EV during inclement weather is uncomfortable in the absence of a roof.	Provide roofing, similar to that provided at petrol stations, that is appropriate to the type and location of the charging point.
	Public charging – signage	A lack of road signs may make it difficult to find a public charging point.	Install road signage directing users to public charging infrastructure, similar to that provided for petrol stations, that is appropriate to the type and location of the charging point.
	Public charging – help and support	EV drivers experiencing difficulties with a public charging point may not be able to readily access the requisite help and support.	Provide ready access to help and support.

	Smart charging and V2G	EV owners may be concerned about using smart charging or V2G due to a lack of trust and loss of control resulting in:
		– the EV:
		  – being insufficiently charged
		  – taking longer to charge
		– uncertainty about charging speed and charging time
		– degradation of the EV's battery.
			Have a user-friendly interface which includes an override functionality.
			Provide simple and engaging rewards for using smart charging or V2G.
			Information and awareness raising of the benefits associated with smart charging and V2G.

	Cybersecurity	Potential for a cybersecurity attack resulting in an inability to charge or a loss of personal data.	Minimum security standards for home and public charging points and networks.
	Data privacy	Potential for the direct or indirect loss of personal data.	Robust protocols to prevent breaches and fraudulent activity.

Customer journey phase	Pain points	Enablers
Retention	There are many sources of dissatisfaction with the EV charging process, as discussed above. A US survey found that dissatisfaction with the convenience of charging and the absence of faster charging (level 2) at home were factors influencing EV owners to discontinue using an EV.	While a number of enablers have been identified above, a European study has revealed that the most important improvements required relate to: – faster charging – increased availability of public charger points – single charge card for any public charge point. Information and awareness raising of the overall charging experience.

Source: ACIL Allen

Introduction and background 1

The Energy Security Board (ESB) was established in 2017 to provide a whole-of-system oversight on energy security, reliability and affordability in Australia's National Energy Market (NEM) and facilitates better planning, co-ordination and action between governments, Energy Ministers and market bodies.

The ESB's post 2025 Project is taking a holistic look at what should change so the NEM can meet the needs of consumers in a future of diverse sources of non-dispatchable generation, demand response, storage, and consumer energy resources.

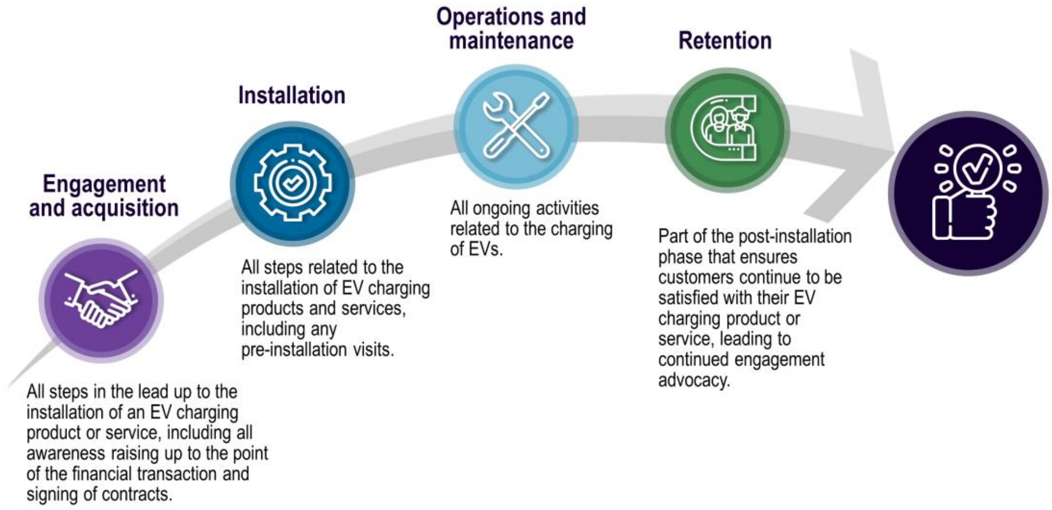
To inform the post 2025 Project, the Customer Insights Collaboration was established to provide feedback from a customer perspective as to how they need or intend to use their customer-owned assets. It is organised around six-month blocks of work on key customer issues relevant to ESB's Consumer Energy Resources (CER) Implementation Plan reform activities.

The current release of the Customer Insights Collaboration is focused on enhancing consumers' experiences with, and value from, charging their electric vehicles (EVs).

ACIL Allen was engaged to support the Customer Insights Collaboration by undertaking a review of recent international research, and conducting a small number of interviews with overseas experts, to gather insights about:

- the end-to-end customer journey for EV charging products and services, encompassing home and public charging (as illustrated in Figure 1.1)
- key customer enablers and pain points that have emerged in the roll-out of smart charging products and services, and the stage in the customer journey where these enablers/pain points have occurred
- policy, regulatory and industry initiatives to support and manage the roll-out of EV charging products and services and how these initiatives have been received by, and delivered outcomes for, customers, including in relation to, for example:
  - default charging and tariff arrangements
  - technical standards for interoperability
  - enhanced or EV-specific consumer protections.

Figure 1.1 Customer journey for EV charging products and services



Source: ACIL Allen based on (Australian Renewable Energy Agency, 2020)

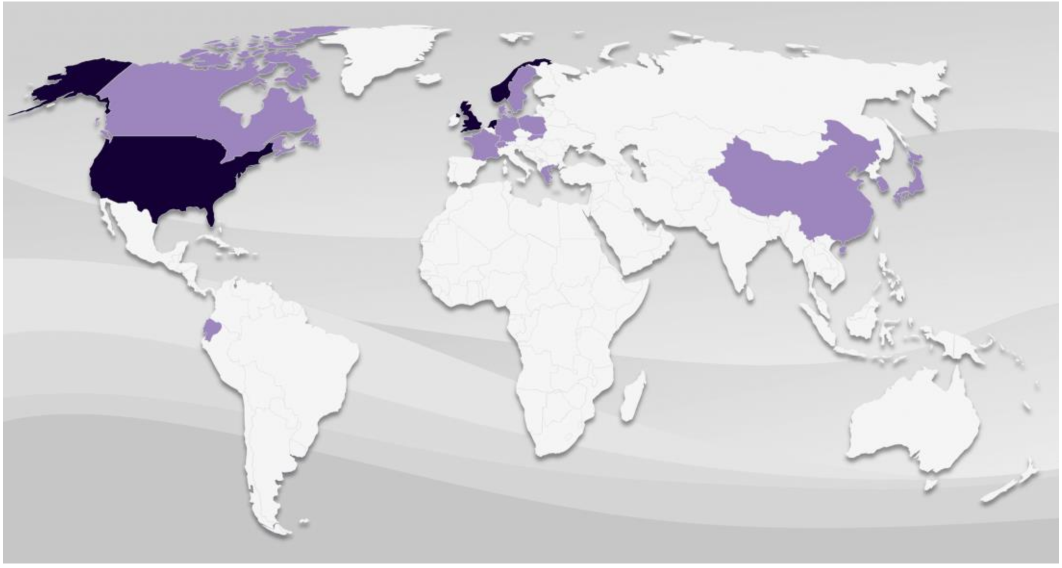
1.1 International research

ACIL Allen undertook a literature review to identify papers, reports and media releases on customers' experiences with EV charging that have been released by academia, governments, regulators, industry associations and consumer representatives over the last 10 years. The literature review excluded any literature from Australia or New Zealand, as these insights are expected to be provided as an input to the Customer Insights Collaboration by members of the Stakeholder Steering Group.

While there is extensive literature pertaining to EVs, there is less that specifically relates to EV charging, and only a portion of which is from a consumer perspective. Most of the relevant literature relates to the operations and maintenance phase of the customer journey, followed by literature that relates to the installation phase.

A summary of each of the relevant documents identified is provided as Appendix A. They are largely based on the results of qualitative and quantitative customer research, either stated or revealed preferences, or analysis of charging data. The research is predominantly based on consumers in the Netherlands, Norway, the United Kingdom and the United States, as well as consumers in Canada, China, Denmark, Ecuador, France, Germany, Greece, Hong Kong, Japan, Poland, Slovenia, South Korea, Sweden and Switzerland (refer Figure 1.2). The EV adoption rates for many of these countries are provided as Appendix B. The countries with the highest adoption rates at the end of 2021 are Norway (86% of car sales), Sweden (43%), the Netherlands (30%), Germany (26%), United Kingdom (19%) and France (19%).

Figure 1.2 Sources of EV charging insights



Source: ACIL Allen

The international research is largely based on the experiences of EV charging by early adopters, with some more recent research, particularly in Norway, also including early majority consumers.

Early adopters are mostly male, highly educated, with a relatively high income and are older (over 40 or 50 years, depending on the study) (for example (Anderson, Bergfeld, Nguyen, & Steck, 2022), (Chakraborty, Hardman, & Tal, 2020), (Haugneland & Kvisle, 2015) and (Westin, Jansson, & Nordlund, 2018)). They are generally more motivated by the environment and technology than financial considerations. (Anderson, Lehne, & Hardinghaus, 2017) and (Axsen, Goldberg, & Bailey, 2016) caution that the characteristics of early adopters do not mirror society more broadly.

1.2 Background information on EV charging

The following sections provide background information on levels of EV charging, location of EV charging and EV charging behaviour, as context for the rest of the report.

1.2.1 Levels of EV charging

There are a number of different levels of EV charging.

The slowest charging occurs when EVs are plugged into a standard alternating current (AC) electricity socket. This level of charging is typically used to charge plug-in hybrid EVs (PHEVs) and for home charging of battery EVs (BEVs), particularly older EVs with smaller batteries. The typical range added per hour of charging is 7-15 km.

Slow EV chargers typically have a dedicated circuit and bespoke connection. They are used to 'slow' charge BEVs, with the typical range added per hour of charging in the range of 50-80 km.

Fast EV chargers typically operate at 50 kiloWatts (kW) and upwards and are usually a direct current (DC) rather than an AC device. The typical range added per ten minutes of charging is 50-80 km. In Norway, fast chargers are used by:

— occasional users (30%) – for rare range problems
— frequent users (10%) – for those without home charging or professional users
— long distance trip users (rare) – to get to far-away destinations
— local users (common) – to solve every day needs (Institute of Transport Economics, Norwegian Centre for Transport Research, 2019a).

1.2.2 Location of EV charging

EVs are typically charged at:

— home, using a standard electricity socket or a dedicated slow EV charger
— work, generally using a slow EV charger
— a public EV charger, which can be a slow or fast EV charger, and is located:
  — on the street, for example, on bollards or lamp posts
  — at a destination, such as shops, restaurants, hotels, gyms and parking stations
  — en route.

1.2.3 EV charging behaviour

EV users will normally charge their EV while the car is parked. Accordingly, charging of EVs by early adopters is generally dominated by home charging, with some work-based charging. The proportion of time that an EV user charges at home will depend on the EV user's circumstances, in particular whether the user has a driveway in which to charge a vehicle.

Those living in apartment buildings will use public charging more and will use fast charging more frequently than those living in detached housing (Lorentzen, Haugneland, Bu, & Hauge, 2017).

In a 2021 survey (Electric Vehicle Association England, 2021), around 90% of EV drivers in the UK indicated they have access to off-street parking. Thirty-nine per cent indicated that they performed most of their charging at home while sometimes using public charge points and 36% performed almost all of their charging at home. Ten percent of drivers indicated that they performed all of their charging using public charge points, and 9% of drivers used an even split of home and public charging. Only 5% of drivers designated workplace charging as the primary location in which their charging events occurred.

Similarly, over 90% of Norwegians charge at home (Figenbaum, Wangsness, Amundsen, & Milch, 2022). In a 2018 Norwegian survey (Institute of Transport Economics, Norwegian Centre for Transport Research, 2019a), 80% of Norwegian EV users indicated that they charge 3 times or more per week at home. Eighteen per cent reported that they charged three times or more per week at the workplace, and 27% reported that they did this on a weekly basis. Few respondents reported using available public chargers. Only 13% used them on a weekly basis.

By way of comparison, approximately 75% of Dutch households do not have their own driveway in which to charge a vehicle. In a 2021 Dutch survey (de Brey, Gardien, & Hiep, 2021), 47% of the charging is completed at home, 19% takes place at work, 23% at a public charging point, and 11% of all kilometres are charged via a fast charger.

The charging habits of EV users vary widely between users, with some regularly charging overnight, and others plugging in during the day or more often on weekends (University of Oxford, 2019). Each EV driver has their own distinct charging patterns. The behaviour at the individual level is generally habitual, e.g. EV drivers generally charge at a limited number of locations and often around the same time (Wolbertus, van de Hoed, Kroesen, & Chorus, 2021).

There are considerable differences in the charging practices of BEV and PHEV users, with BEV drivers more reliant on chargers than PHEV drivers (University of Oxford, 2019). While more than two thirds of all PHEV users charge their EV (almost) daily, tending to charge every time upon arriving at home (Anderson, Bergfeld, Nguyen, & Steck, 2022), some PHEV drivers rarely charge their PHEV (Chakraborty, Hardman, & Tal, 2020).

Those that charge their EV at home predominantly do so in the evening on their return from work, while those that charge their EV at work generally plug in on their arrival at work. The rest of the EV users plug their vehicles in during different periods of the day (for example, (Clairand, 2020), (Helmus & van de Hoed, 2015)). As a result, the charging of EVs in aggregate follows a general pattern such as the following (Element Energy for National Grid ESO, 2019):

- Weekdays (Monday-Friday):
  - there is generally a large peak in the early evening, driven by residential charging when commuters plug into charge when they arrive home from work
  - there is a secondary peak in the morning, with a maximum between 9-10am, when commuters plug in to charge when they arrive at their workplace
  - there is a small peak in work charging, which coincides with EV drivers plugging in during their lunch break.
- Weekends – the demand for EV charging is approximately 25% less than during the week, with no morning peak, as there is considerably less demand from work charging, and the evening peak is shifted an hour earlier than on weekdays.

While this pattern is from the UK, similar patterns are observed in the Netherlands (Helmus, Lees, & van den Hoed, 2020), the US (University of California, Davis, 2020) and China (Wang, Xing, Chen, Zhang, & Liu, 2022).

1.3 Structure of this report

The rest of this report discusses key customer enablers and pain points that have emerged in the use of EV charging products and services, and the stage in the EV charging customer journey where these enablers/pain points have occurred, as revealed by the international literature review. The key customer enablers and pain points during the:

- engagement and acquisition phase are discussed in chapter 2
- installation phase are discussed in chapter 3
- operations and maintenance phase are discussed in chapter 4
- retention phase are discussed in chapter 5.

Chapter 6 summarises the key customer enablers and pain points that have emerged across each stage of the customer journey.

Engagement and acquisition 2

The engagement and acquisition phase is all steps in the lead up to the installation of an EV charging product or service, including all awareness raising up to the point of the financial transaction and signing of contracts.

On average, EV drivers do lots of research into driving electric before purchasing an EV. Ninety-two per cent of EV drivers say they do at least some specific research before their purchase (NewMotion, 2020). When people are buying an EV, they will generally put most of their time and effort into researching different EV models – which is a much larger purchase – rather than the charge point (Competition & Markets Authority, 2021).

"The information is there but there is an information overload trying to work it out"
(Ofgem, 2021d)

(NewMotion, 2020) found that the third most important research topic for potential European EV drivers, after car models and battery range, is around the charging options (35% of survey respondents). Over 80% of respondents in a US survey indicated that they were *generally* satisfied with finding the information they needed to buy or lease an EV, but only 40% reported that they could find *all* the information they needed without difficulty. Approximately 18% of respondents had difficulty accessing information on public charging options and 10% had difficulty accessing information on home charging requirements (Plug in America, 2022).

The importance of charging options when purchasing an EV varies by country. For example, in terms of barriers to purchasing an EV, it is rated as the:

— second most important factor in Germany after battery range (commonly referred to as 'range anxiety')
— third most important consideration in the US after battery range and purchase price
— the most important consideration in China (Marinescu, 2023).

In a survey of 2,000 car owners, 2 in 5 respondents said the top reason they weren't considering buying an EV was the perceived lack of charge points (Passingham, 2022).

"My fear when buying it was not having enough chargers around so I'd have wanted to know more about that"
(Ofgem, 2021d)

There is a symbiotic relationship between the purchase and acquisition of an EV and the purchase and acquisition of EV charging products and services, with the choice of EV dependent on the available EV charging options. There is also potentially a chicken-and-egg dilemma, with the decision to purchase an EV dependent on charging infrastructure, and the availability of charging infrastructure dependent on the take up of EVs.

2.1 Relative importance of home charging and public charging infrastructure when purchasing an EV

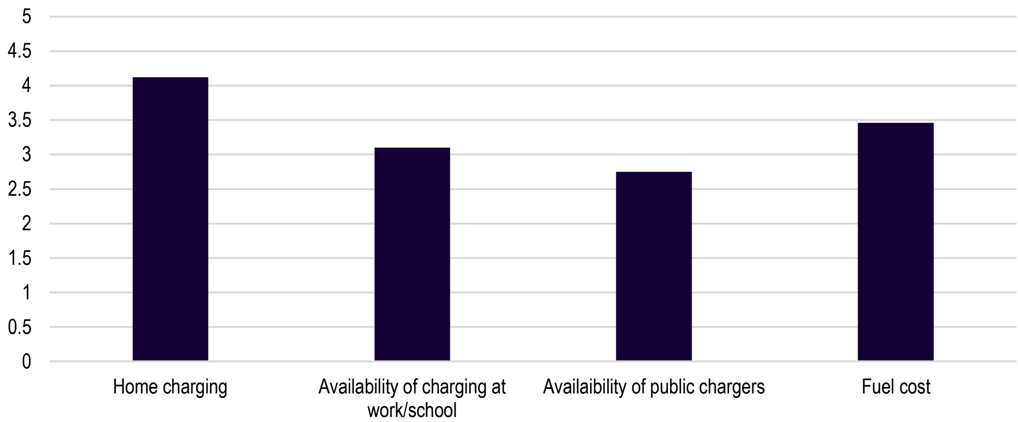
The importance of home charging relative to public charging during the engagement and acquisition phase varies on the way in which the EV is most likely to be charged. The absence of home charging was identified as a key barrier to purchasing an EV by (EY, 2022) based on a global survey and by (Ofgem, 2021c) based on a UK survey.

By way of contrast, the availability of public infrastructure was identified by (Kalthaus & Sun, 2021) as a key barrier based on an analysis of Chinese data and by (He, Luo, & Sun, 2022) based on a Hong Kong survey – countries in which a large proportion of the population lives in an apartment.

(Westin, Jansson, & Nordlund, 2018) identify that, while the availability of public charging infrastructure in Sweden is a psychological barrier before purchasing an EV, it is not an actual barrier due to the reliance on home and work charging.

The relative importance of the different forms of charging for EV drivers in the US is illustrated in Figure 2.1. The availability of home charging is rated as more important than the availability of charging at work or school, which is rated as more important than the availability of public chargers. Only the availability of home charging is rated as more important than fuel cost when purchasing an EV (U.S. Department of Energy, Transportation Secure Data Center, 2023).

Figure 2.1 Relative importance of factors when purchasing an EV



Source: (U.S. Department of Energy, Transportation Secure Data Center, 2023)

The relative importance of public infrastructure also depends on a consumer's housing arrangements, and whether they have access to off-street parking.

Approximately 75% of Dutch households do not have their own driveway in which to charge a vehicle (de Brey, Gardien, & Hiep, 2021). The Dutch government therefore introduced the "right to charge" as a demand-driven approach for charging infrastructure. It requires the municipalities to set up public charging points within 250 m of a home at the request of EV owners. This practically guarantees access to available charge points nearby, improving electric mobility attractiveness for consumers and ensuring equitable access for those without off-street parking. End-users are required to use a minimum of 2,000 kWh per year for charging, noting that the actual average consumption per charge point is growing and was over 7,000 kWh in 2020 in Rotterdam (Changing Transport, u.d.), (Guidehouse Inc., 2021).

(Competition & Markets Authority, 2021) found that a lack of off-street parking particularly impacts those in city and urban areas and especially those in social housing (57% of households in social sector houses in the UK do not have off-street parking and 86% of households in social sector flats in the UK do not have off-street parking).

(Narassimhan & Johnson, 2018) found that the importance of charging infrastructure in the purchase of an EV also depends on the type of EV – whether it is a BEV or a PHEV, and the range of the battery. They found that sales of the Tesla Model S and Prius were not affected by the availability of charging infrastructure. They speculated that:

— unlike long-range BEV owners, short-range BEV owners may be more range anxious and consider public charging availability seriously when making purchase decisions
— PHEV drivers with a significant electric driving range may base their purchase decision more on total cost of ownership, which would include utilising low-cost/free electric power from public charging stations whenever possible.

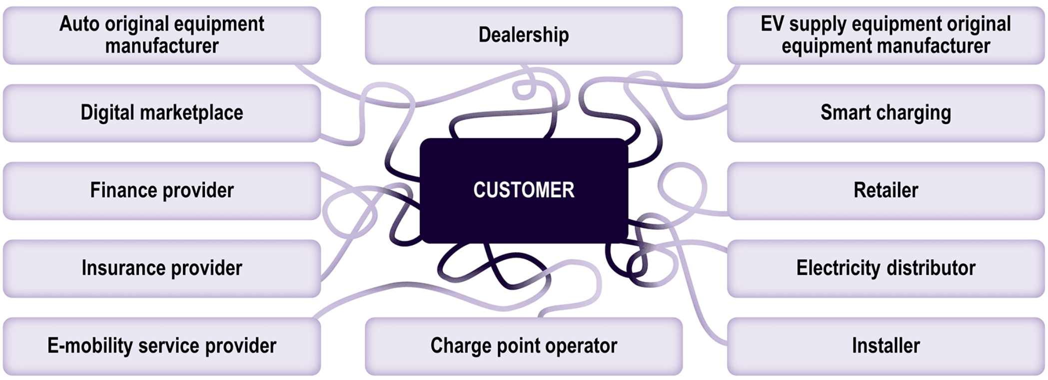
2.2 Purchasing an EV charging product or service

"They left out the need for the charger at purchase"
(Ofgem, 2021d)

Charging tends not to be a consideration until the purchasing phase is well underway, or even completed. There is generally the option to buy a dedicated EV home charger when buying an EV.

Since vehicle providers – both dealers and the automakers themselves – tend to be different from the charger providers, there are multiple touchpoints to deal with in this phase of the journey, compared to just one party with the purchase of a traditional Internal Combustion Engine (ICE) vehicle (ICEV). The complexity of the EV ecosystem makes EV acquisition and ownership overwhelming for many customers. An average EV customer needs to interface with at least 6 different parties to receive the full EV experience (Kaluza, 2022b), as illustrated in Figure 2.2.

Figure 2.2 The complex EV ecosystem



Source: (Kaluza, 2022b)

The customer has multiple opportunities to 'drop off' the EV charger purchase pathway, due to the volume of additional actions required to be completed. For example, (Kaluza, 2022a) identified that along this pathway, there needs to be consideration of things such as:

— Is a home charger needed[5] or will public charge points suffice[6]?
— What is the budget?
— What features are important?
— Technical evaluations such as: is the home currently capable of supporting a charge point?
— Which company should be chosen to complete the installation?

Almost half (45%) of the participants in a UK survey chose to get a dedicated charge-point rather than use a standard electricity socket for a safe home charging option, 44% needed faster charging than a standard electricity socket, 43% to make it more convenient to charge at home, while 26% said that saving money was a motivator for purchasing it and 19% stated that it was recommended by their EV car dealer. Fourteen per cent were informed by an independent advice website (U.K. Department for Business, Energy & Industrial Strategy, 2023).

"We didn't find out about the different types of chargers until we got the car. So we had a mad 'what's going on?'"
(Ofgem, 2021d)

People currently have a low awareness and understanding of the charge point options and may rely on EV manufacturers and car dealerships for information and advice when making decisions about home charge points. Car dealerships themselves have limited knowledge of the different charge points and therefore may not be in a position to support and advise customers (Competition & Markets Authority, 2021). As a result, dealers typically put those who are looking for a home charge point in contact with a charge point seller (Ofgem, 2021d).

The (U.K. Department for Business, Energy & Industrial Strategy, 2023) found that potential EV drivers in the UK appear to acquire their dedicated charge points through the most convenient means, with 31% of drivers acquiring one for free as part of their vehicle purchase, 26% purchasing their dedicated charge point directly from the manufacturer and 14% from an electrician/installer company while only 7% purchased it from their vehicle's dealership and 7% from their home energy provider.

A survey of Norwegian EV drivers revealed that the preferred channel for purchasing a home charging point was an electrical contractor (31%), the vehicle's dealership (20%), online (18%), and energy supplier (4%). The remaining respondents nominated other or didn't know (Norsk elbilforening, 2017).

For those who own a dedicated home charge point, they clarify ease of use as being most important when choosing their solution, with more than half citing this as their main purchasing driver. A third say the price of the charge point is important, while a quarter say that a recommendation from a third party such as a lease company, a car dealer or employer, is most influential to their decision.

The main decision driver for respondents' preferred charge point provider is ease of use (35% of survey respondents), while 24% of the respondents say that technical specifications of the hardware is an important factor towards their choice (NewMotion, 2020).

When considering what they value most in their charge point provider, 46% of respondents mention reliability of the product, while 19% of EV drivers indicate smart functionalities (such as automatic

[5] While not specifically identified by (Kaluza, 2022a), the customer also has the option to use a standard electricity socket rather than install a dedicated charging point at home. Around a third of drivers across Europe and in the UK rely on a standard electricity socket (NewMotion, 2020), (U.K. Department for Business, Energy & Industrial Strategy, 2023).

[6] We note from the literature that public charge points may include charge points at work, on the street, at a destination (e.g. a shopping centre) or en route (refer section 1.2.2).

reimbursement of the energy usage by the employer or remote start-and-stop functionality) as most important. Eleven per cent feel that customer service quality is key (NewMotion, 2020).

2.3 Pain points when purchasing a dedicated home charge point

"In the meantime of getting my house setup for a charge point the price went up, we're talking £600."
(Ofgem, 2021d)

The pain points in the acquisition of a dedicated home charge point include that:

- not all costs are clear upfront, e.g. rewiring in the home to be able to install a dedicated home charge point
- it is not made clear what essential items need to be purchased separately (Ofgem, 2021d).

A 2017 survey of Norwegian EV drivers revealed that a home charging point had not been installed because it was too expensive (48%), there was too little information (11%) or the ordering process is difficult (3%). The remainder didn't have the need (35%), didn't know / had no opinion (7%), or had another reason (15%) (Norsk elbilforening, 2017).

Similarly, a survey of EV drivers across a number of European countries identified that more than 40% of electric vehicle (EV) drivers did not have a dedicated home charging point to charge their car. Almost a quarter of these indicated that they were planning to get one installed soon while 14% believed that there is no need as a standard electricity socket is sufficient, and 14% stated that a dedicated charger is too expensive (Peachey, 2022).

Other reasons identified in a UK study for not installing a dedicated home charging point were that there was not enough space or it was too complex to install, upgrades were needed to their home electricity system, and location issues such as living above the ground floor or being unable to park directly outside their house (U.K. Department for Business, Energy & Industrial Strategy, 2023).

2.4 Consumer Code for home charging points

In 2020, the Association for Renewable Energy and Clean Technology in the UK developed a Consumer Code to facilitate the correct specification, installation and maintenance of home charging points. It applies to suppliers and installers of home charging points that are Code members, to foster confidence by consumers to install a home charging point. The Code includes a number of provisions that are relevant to the engagement and acquisition phase for dedicated home charging points including provisions relating to customer service, data privacy, pre-sale activities, sales visits, pre-sale surveys, permissions, approvals and notifications, after-sale activities and a dispute resolution process. Further details are provided in Box 2.1.

Box 2.1 Excerpts from the UK's Electric Vehicle Consumer Code for Home Charge points that are relevant to the engagement and acquisition phase

- **Customer service** – Code Members are required to deal with consumers politely and quickly, and take steps to make sure that important information is passed to them clearly. Code Members are required to provide extra care and support to vulnerable consumers or consumers in vulnerable circumstances to ensure they understand key documents, including the quotation, contract and guarantee arrangements. This may, for example, mean involving a trusted friend or relative in any contacts with the consumer, and arranging for such a person to be present during a visit to the consumer's home.
- **Data privacy** – Code Members must comply with their legal obligations in the collection and processing of the personal data of consumers.
- **Pre-sale activities** – Code Members must act with integrity in all their sales and marketing activities, when visiting a consumer, and particularly during sales visits. Code Members must not mislead consumers in any way.
- **Sales visits** – Code Members must not use any selling techniques designed to pressurise a consumer into making an immediate decision. Prohibited techniques include staying more than two hours at the consumer's home to keep trying to close a sale; offering a consumer an artificially inflated initial price followed by a discount, or equivalent for signing on the day, agreeing to provide testimonials, and providing customer referrals; and claiming untruthfully that there is limited availability of a discount or of the proposed charge point or of any grant or other incentive in order to pressure for a quick signature.
- **Pre-sale surveys** – a Code Member must carry out a pre-sale site survey (which may be done remotely) and an assessment of the consumer's property and the adequacy of the electricity supply for installing a charge point. Where the supply adequacy assessment indicates that there is an issue with the supply, the Code Member must make clear to the consumer what action will be necessary to address any inadequacies (which may include uprating the incoming supply); and the potential costs and benefits of such actions, or point the consumer towards objective information on them, so that the consumer can choose whether or not to go ahead.
- **Permissions, approvals and notifications** – Code Members must make consumers aware accurately and in writing of all the permission and approvals that may be needed for the charge point they offer, including planning permission, building regulations and connection requirements before any contract is agreed.
- **After-sale activities** – Code Members must provide contact details for after-sale queries, manufacturers guarantees, clarity about any paid-for extended guarantees, a workmanship guarantee for a minimum of three years, and details of any regular servicing or maintenance requirements.
- **Dispute resolution process** – which is a two phase process, the second phase of which is an independent arbitration service provided by the Code Administrator (Renewable Energy Assurance Ltd).

Source: (The Association for Renewable Energy and Clean Technology, 2022)

2.5 Summary of key pain points and enablers

The key pain points and enablers during the phase to engage and acquire an EV charging product or service, as revealed by the international literature review, are summarised in Table 2.1.

Table 2.1 Key pain points and enablers – engagement and acquisition phase

Pain points	Enablers
There is a chicken and egg dilemma: – the decision to purchase an EV charging product or service is secondary to the decision to purchase an EV – the decision to purchase an EV is dependent on the availability of charging infrastructure.	Improved information on the availability of public charging infrastructure, and on home charging options, to increase awareness and understanding by car dealerships and end customers.
The EV ecosystem is complex with purchasers of an EV needing to interface with multiple parties, including a number of parties relating to home charging, if the potential purchaser has the option to install home charging.	
There is currently low awareness and understanding of the different charging point options, and car dealerships may not be well placed to advise customers.	
A dedicated home charge point may be expensive, and all costs associated with purchasing a dedicated home charge point may not be known upfront.	Obligations on suppliers and installers of dedicated home charge points to assess the supply adequacy for a dedicated home charging point so that the full costs for the supply and installation are quoted upfront.

Source: ACIL Allen

Installation 3

The installation phase is all steps related to the installation of EV charging products and services, including any pre-installation visits.

With the high reliance by EV drivers in most countries on home charging, most EV drivers need to consider the installation of a home charging point, either a standard electricity socket or a dedicated EV charger. For example, the research indicates that 77% of EV drivers in Europe had a charge point at home in 2019 (NewMotion, 2020) and 91% of EV drivers in the US had a charge point at home (California Center for Sustainable Energy, 2012).

3.1 Standard electricity socket or dedicated home charge point?

In the early days of EVs, most EV drivers charged their EVs at home using a standard electricity socket. However, EV drivers have increasingly installed a dedicated EV charger. For example, 85% of EV drivers in Norway used a standard electricity socket in 2013 (Haugneland & Kvisle, 2015) but this decreased to 63% in 2017 (Norsk elbilforening, 2017) and 35% in 2018 (Institute of Transport Economics, Norwegian Centre for Transport Research, 2019b).

The change was driven by safety concerns associated with using a standard electricity socket. In a 2017 survey, 2% had experienced a burnt socket (Lorentzen, Haugneland, Bu, & Hauge, 2017) and 10% had experienced a blown fuse (Norsk elbilforening, 2017). Additionally, while a 10 A fuse was sufficient in many cases for charging an EV, the impedance associated with long charging cables could result in them overheating and eventually catching fire. (NewMotion, 2020) identified additional safety issues associated with rain mixed with sockets and an overused electricity network in the street.

In response to growing concerns regarding the safety issues associated with home charging, the Norwegian Government recommended installing a dedicated EV charger:

— with built in ground fault detection and circuit breakers
— which is connected to the fuse box with a dedicated circuit and fused separately, usually with a 16 A or 32 A fuse, but which could be up to a 63 A fuse in some cases.

An additional benefit of using a dedicated EV charger is that it charges faster than using a standard electricity socket.

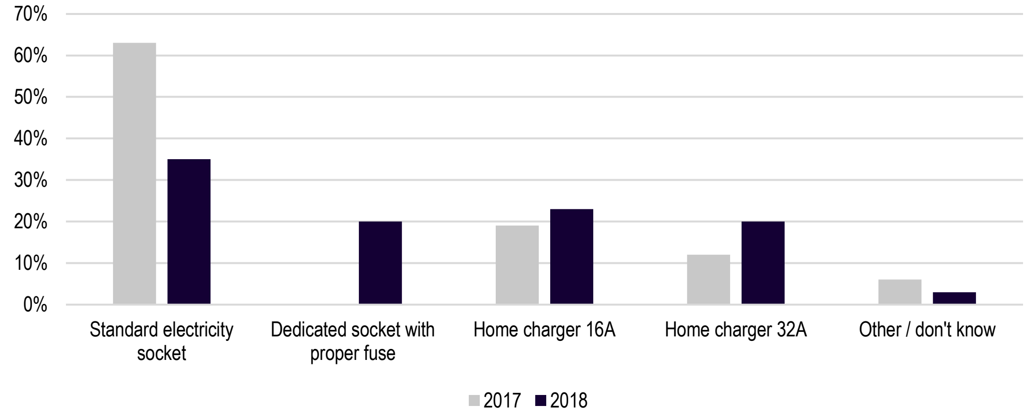
In cases where a standard electricity socket continues to be used, the Government recommended that it:

— be earthed
— be on a separate circuit with at least a 10 A fuse
— has ground fault detection.

Additionally it recommended that the connector (which usually comes with the car as standard equipment) be hung on a hook or stored in a basket so that it is not damaged due to its weight (Henriksen, Thorsden, Ryghaug, & Skjolsvold, 2021), (Institute of Transport Economics, Norwegian Centre for Transport Research, 2019a).

Figure 3.1 illustrates the increased uptake of dedicated home chargers in Norway from 2017 to 2018 in response to the Government's recommendations, as well as the increased uptake of dedicated electricity sockets with proper fuses.

Figure 3.1 Change in home charging in Norway from 2017 to 2018



Source: (Institute of Transport Economics, Norwegian Centre for Transport Research, 2019b), (Norsk elbilforening, 2017)

Around a third of drivers continue to rely on a standard electricity socket for home charging across Europe (NewMotion, 2020) and in the UK (U.K. Department for Business, Energy & Industrial Strategy, 2023). In Sweden, the proportion of EV drivers relying on a standard electricity socket is higher (two thirds) (International Energy Agency, 2018), but it is noted that power outlets are used to heat motors in Sweden, and these can be used for charging EVs (Westin, Jansson, & Nordlund, 2018).

3.2 Installing a dedicated home charge point

According to a 2018 Norwegian survey, the cost to install a dedicated home charging unit was about US$1,200 – 1,800 (Institute of Transport Economics, Norwegian Centre for Transport Research, 2019b).

"We got a free installation of a charger, but we had to pay £250 for the wiring to be done in the house". (Ofgem, 2021d)

However, the (Competition & Markets Authority, 2021) noted that there is a lack of standardisation in the quoted cost for installing home charge points with some experiencing additional costs which may not be clear at the time of purchase (e.g. fees for fuse upgrade or rewiring). A 2019 Californian survey identified that 51% of EV drivers incurred an expense to upgrade their electrical system, with an average cost of US$1,060 (U.S. Department of Energy, Transportation Secure Data Center, 2023).

While the process for installing a home charging point in detached houses is relatively simple, the process is more complex for those living in rented, leased or multi-dwelling buildings, and for faster and larger home EV charge points. (Ofgem, 2021d) noted that some EV users perceived a lack of awareness of installers for more bespoke charge point set-ups.

3.2.1 Multi-dwelling buildings

Those living in rented, leased or multi-unit accommodation can find it difficult to get permission to install, or decide who pays for, home EV charge points.

In the Netherlands, apartments may have a garage or parking lot with dedicated parking spaces, or a parking lot with non-dedicated spaces, or may not have parking at all. Installing charging infrastructure for such buildings has a capital cost or gives rise to other problems. According to the research, of consumers who apply for a charging station via their Homeowners' Association or comparable collective, 31% did not experience any problems finding an available parking point, while almost 70% did (de Brey, Gardien, & Hiep, 2021).

The regulations were recently changed in Norway so that everyone in an apartment building has a right to access a charging point. The decision to install charging points for an apartment is made at the annual meeting of the board of the apartment building. The typical solution comprises:

— basic infrastructure such as installing extra cabling and electricity capacity, which is jointly owned and paid for by everyone, similar to the use of an elevator
— charge points, which are bought by individual flat owners who are then billed for the electricity that is used.

The common cost is around $US1,000 per flat, and the charger cost is around US$1,500 per flat. Load shedding equipment is installed as part of the basic infrastructure to ensure there is sufficient supply to meet demand (Institute of Transport Economics, Norwegian Centre for Transport Research, 2019a), (Institute of Transport Economics, Norwegian Centre for Transport Research, 2019b) (The Fast Charge, 2022).

The use of standard electricity sockets for EV charging are less common in Norwegian apartment buildings than for detached houses as the board of the apartment building will require a safe solution to be used (Institute of Transport Economics, Norwegian Centre for Transport Research, 2019a).

Most Chinese urban households live in apartments in multi-family buildings. As a result, many households do not have a dedicated parking space for a home charging point or face restrictions to install charging points for the building. The community property management firms generally reject residents' requests to install charging points due to concerns regarding electricity safety or insufficient electricity capacity. In response, Chinese urban households use their air-conditioning socket to charge at home, leading to problems with overloaded circuits and the inability to connect the charging cable to the socket located on a high floor (Qian, Grisolia, & Soopramanien, 2019), (Wang Y. , Chi, Xu, & Yuan, 2022).

Households in Hong Kong face similar issues. Given the potential disputes with incorporated owners pertaining to the limited power reserved for alternative electricity uses, and insufficient space available at standard parking lots, installing a private charger in one's parking bay is not a common practice. If the owners' corporation or property management company consents to the installation of charging points, the electricity provider requires applications for electricity supply that specify the estimated loading, wiring diagram and charger position (He, Luo, & Sun, 2022).

Regulations have been introduced in California to facilitate the installation of EV charging points for those living in rented, leased or multi-dwelling buildings:

— **EV charging station policies for multi-unit dwellings**: A common interest development, including a community apartment, condominium, and cooperative development, may not prohibit or restrict the installation or use of EV charging stations or EV-dedicated time-of-use (TOU) meter in a homeowner's designated parking space or unit. These entities may put reasonable restrictions on EV charging stations, but the policies may not significantly increase the cost of the EV charging stations or significantly decrease its efficiency or performance. Restrictions may be placed on TOU meter installations if they are based on the structure of or available space in the building.

If installation in the homeowner's designated parking space or unit is not possible, with authorisation, the homeowner may add EV charging stations or a EV-dedicated TOU meter in a common area. The homeowner must obtain appropriate approvals from the common interest development association and agree in writing to comply with applicable architectural standards, engage a licensed installation contractor, provide a certificate of insurance, and pay for the electricity usage, maintenance, and other costs associated with the EV charging stations or TOU meter. The homeowner and each successive homeowner of the parking space or unit equipped with EV charging stations or a TOU meter is responsible for the cost of the installation, maintenance, repair, removal, or replacement of the equipment, as well as any resulting damage to the EV charging stations, TOU meter, or surrounding area.

— **EV charging station policies for residential and commercial renters**: The lessor of a dwelling or commercial property must approve written requests from a lessee to install an EV charging station at a parking space allotted for the lessee on qualified properties. Certain exclusions apply to residential dwellings and commercial properties.
— **Mandatory EV charging station building standards**: the California Building Standards Code, which applies to all new construction, sizeable repairs, demolitions and remodels/renovations, requires pre-wiring for an EV charging station installation in parking spaces at one- and two-family dwellings with attached private garages, multi-family dwellings, commercial facilities, and public buildings (U.S. Department of Energy, 2023).

3.2.2 Faster charge points

Faster chargers may require more expertise to install then slower chargers. In the US, installing a faster 240 V charging station, rather than using the standard voltage (120 V) that is slower, requires permits, a licensed electrician and sometimes service upgrades (U.S. Department of Energy, 2014).

3.2.3 Larger charge points

In the UK, there are significant barriers for developers requiring larger scale charge point connections, including the costs to connect to the network (47%); and the pace and difficulty of the process of connection time to connect (11%).

Prior to a recent reform, if the network required reinforcement to enable a non-domestic consumer to connect to the network, they were required to pay for that reinforcement. This could result in prohibitively high costs for larger scale charging infrastructure, such as blocks of flats, car parks, and vehicle depots, resulting in customers delaying or deciding against installing EV charging infrastructure (Ofgem, 2021a).

From 1 April 2023, non-domestic customers in the UK are not required to pay to reinforce the network in these circumstances. The costs will be recovered from all electricity customers instead (Ofgem, 2022a).

Other barriers that are experienced when installing larger charge points are lack of capacity (9%), uncertainty in the regulatory regime (5%), lack of capacity and time to connect (3%), inconsistency between electricity distributors (3%), and lack of response from distributors (2%) (Ofgem, 2021a).

3.2.4 Solar panels

"I wanted to understand how it could integrate with my solar panels but they just wanted to bung it in."
(Ofgem, 2021d)

In an early Californian study, 39% of owners indicated that they had also invested in home solar PV systems to help "fuel" their vehicles with renewable solar energy, with an additional 17% indicating they were planning to install a solar PV system within the next year. On average, 60% of the respondents who did not initially size their solar PV system for their EV stated that they planned to expand their system within the coming year (California Center for Sustainable Energy, 2012).

3.2.5 Consumer Code for home charging points

To facilitate a quality installation of home charging points, the UK's Electric Vehicle Consumer Code for Home Chargepoints includes a number of provisions that are relevant to the installation of home charging points. These provisions relate to notifying the electricity distributor of the installation, installing the charge point, post-installation (testing and commissioning, information, notifications, grant application), and workmanship guarantees. Further details are provided in Box 3.1.

Box 3.1 Excerpts from the Electric Vehicle Consumer Code for Home Charge points that are relevant to the installation phase

— **Distributor notification** – the Code Member must notify the electricity distributor of the installation. If the maximum demand of the charge point is more than 13.8 kVA, or if there is an issue around the adequacy or safety of the existing safety equipment, the installer must contact the electricity distributor prior to installation.

— **Installation** – the final installation must be in accordance with all applicable regulations and standards. In particular, a Code Member must provide a separate dedicated final electrical circuit for the EV charging equipment protected by a suitable Residual Current Device (RCD).

— **Information** – the Code Member must provide the consumer with:
  - a demonstration of the correct operation of the charging equipment including, where applicable, an explanation of any default charge setting and how this can be altered
  - written evidence that the electricity distributor has been notified
  - details of all guarantees in place.

— **Workmanship guarantees** – the Code Member must make sure that consumers are provided with a guarantee, for a minimum of 3 years, against any faults that might arise as a result of the installation process and workmanship applied. The workmanship guarantee remains with the charge point when a consumer moves home.

Source: (The Association for Renewable Energy and Clean Technology, 2022)

3.3 Summary of key pain points and enablers

The key pain points and enablers during the phase to engage and acquire an EV charging product or service, as revealed by the international literature review, are summarised in Table 3.1.

Table 3.1 Key pain points and enablers – installation phase

Pain points	Enablers
There are reported safety issues associated with charging EVs at home using a standard electricity socket, including burnt sockets, blown fuses, overheating of long charging cables, and rain mixed with sockets.	Government recommendations related to the use of standard electricity sockets and dedicated charging points for charging EVs at home, including separate circuit and fuse, and ground fault detection.[7] Information on charging EVs safely at home using standard electricity sockets and dedicated EV chargers.
There may be insufficient capacity to supply a dedicated home EV charging point.	Prior to installation of a home charge point, assess the adequacy of supply to ensure all costs are known before commencement of the installation.
There may be significant additional costs to install a dedicated home charge point if the premises need re-wiring and/or the fuse upgraded to accommodate the charge point.	

[7] We note that current and emerging international standards for in-cable control and protection will mitigate some of the safety issues that have been identified internationally.

Pain points	Enablers
Those living in rented, leased or multi-unit accommodation may find it difficult to get permission to install or decide who pays for home EV charging points.	Introduce a “right to charge” for those living in rented, leased or multi-unit accommodation.

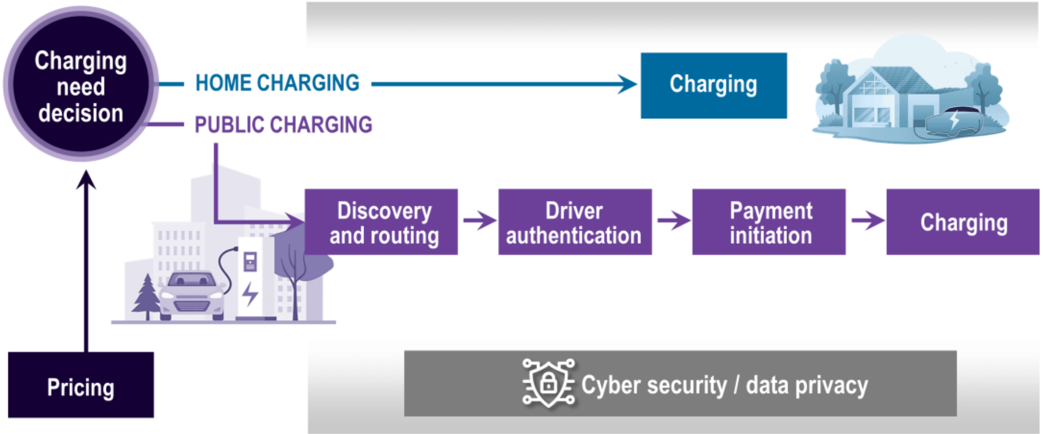
Source: ACIL Allen

Operations and maintenance 4

The operation and maintenance phase is all ongoing activities related to the charging of EVs.

Charging of EVs by early adopters is generally dominated by home charging, with public charging infrastructure used when parking at work, destinations, or en route. The EV charging journey during the operations and maintenance phase– for home and public charging – is illustrated in Figure 4.1.

Figure 4.1 EV charging journey – operations and maintenance phase



Source: ACIL Allen based on (Arthur D. Little, 2022)

The majority of drivers in a UK trial did not think that adapting to charging their EV would be a difficult task (73%). After experiencing the charging process for 3 months, significantly fewer drivers (88%) did not think that adapting to charging the vehicle had been difficult. It was often described as being as simple as plugging in a household appliance (Bunce, Harris, & Burgess, 2014).

However, the (Competition & Markets Authority, 2021) found that EV charging can be complex, confusing, and frustrating at times, particularly compared to the experience of refuelling an ICEV.

> *"Charging of a BEV should be just as simple as filling petrol. Drive to the station, insert the cable, and pay with a bank/credit card. I have never experienced that this succession differs between different petrol stations. It should be equal to use all public charging stations; it should be simple."*

Consumer quote in (Figenbaum, Wangsness, Amundsen, & Milch, 2022)

(McKinsey & Company, 2022) similarly found that customers' experiences with public charging are often unsatisfying, with the main shortcomings being the speed, cost, availability, and safety of charging locations. Drivers struggle to find chargers because information is limited and pricing systems can vary considerably. Finally, the design and operation of chargers differ greatly, and customer service isn't always prompt or helpful.

"There is a ridiculous amount of apps and networks and cards". (Ofgem, 2021d)

(Kaluza, 2023) identified that at least eight apps are likely to be needed on a phone to set up and manage the EV on a day-to-day basis across the EV charging journey. Each app gives some information on a specific aspect of EV use – such as where it can be charged, when best to charge, how much it's costing and battery health – but there is no single app that can give this holistic view.

There will likely be at least one EV-related app for locating, accessing and paying for public charging. Across the UK, there are over 80 charging networks, each with their own apps and subscriptions. Across the US, almost all of the charging networks (of which there are at least 35) require their own app or card. Many automakers, roaming platforms and even car parks are now also offering their own apps. EV drivers are therefore faced with a bewildering array of apps and cards for public charging offered by a number of vendors.

Tesla drivers are generally more satisfied with their charging experience than drivers of other models of EVs. This is due to the larger driving range, free fast charging locations in some countries and the overall user experience. This is possible as Tesla has complete control over the whole process from the car to the charging (Visaria, Jensen, Thorhauge, & Mabit, 2022). However, Tesla's network is designed to work only for its own EVs. It uses a proprietary connector so non-Tesla vehicles need an adapter to access the company's Superchargers. Tesla is expected to begin opening up its chargers to non-Tesla EVs at the end of 2023 (Hawkins, 2022).

Further details on consumers' experiences during the operations and maintenance phase of the EV charging journey, as revealed by the international literature review, are described in the following sections, noting that a difficult charging experience will undermine trust and put people off EVs (Competition & Markets Authority, 2021).

4.1 Charging need decision

There are three factors that influence the need to charge an EV, namely:

— **driver related** – experience with EV charging and the nature of the trip

— **infrastructure related** – whether the EV is being charged at home or using public charging infrastructure, and if using public charging infrastructure, the availability, charging power and cost of charging, and the distance to the infrastructure with an acceptable distance being around a 5-10 minute walk

— **vehicle-related** – the vehicle type (BEV or PHEV), battery size, range relative to travel distance, and consumption (Anderson, Bergfeld, Nguyen, & Steck, 2022), (Bunce, Harris, & Burgess, 2014), (Chakraborty, Hardman, & Tal, 2020), (Helmus & van de Hoed, 2015), (U.S. Department of Energy, 2014).

Charging behaviour develops from an unsteady state of charging behaviour to a more steady, consistent behaviour as users gain more experience with EV charging (Bunce, Harris, & Burgess, 2014).

Participants generally prefer charging their cars overnight at home (U.S. Department of Energy, 2014), with 59% of UK EV users usually charging at home (Ofgem, 2021b).

In terms of public charging, (Ge & MacKenzie, 2022) hypothesise that, for home-based trips, EV drivers are confident about finding public chargers outside of the planned destinations if necessary, and the cost of having to make a mid-trip stop to charge is not very high. Whereas on a long-distance trip, it might be rather difficult or costly to find a charger off the route. It is also likely that

BEV owners tend to be more cautious and conservative than PHEV drivers when they are on long-distance trips, as they are totally reliant on the battery charge.

PHEV drivers often use public charging stations—especially where free public charging is available—before returning home. All-electric drivers more often choose to wait and charge their depleted batteries at home, in large part because of the longer times required to charge the all-electric vehicle batteries (U.S. Department of Energy, 2014).

Weather also has an impact on charging decisions at public charging stations. (Kim, Yang, Rasouli, & Timmermans, 2017) found that, in the Netherlands, when the mean temperature is lower than 0 deg C, an EV user's charging rate increases by 5%. This may reflect an EV user's charging behaviour as well as factors affecting battery consumption such as parasitic load (e.g., heating) and battery performance at low temperatures. In contrast, when the temperature is above 20 deg C, there is a 14% decrease in the charging rate on the corresponding day suggesting good performance of the battery at this temperature. *Heavy wind speed* and *Heavy precipitation* have high negative effects on inter-charging times of EV users at public charging stations, and lower the charging rate by 5% and 4%, respectively.

As a result of these influencing factors, drivers in a UK trial said that they had developed a predominant charging routine, based on:

1. routine
2. state of charge (SOC), or
3. opportunity.

However, they sometimes recharged on the basis of different criteria depending on the circumstances (Bunce, Harris, & Burgess, 2014).

Regardless of the predominant driver of charging need, some EV drivers avoid topping up the battery to 100%, due to a belief this might damage the battery (Delmonte, Kinnear, Jenkins, & Skippon, 2020).

4.1.1 Routine charging

In a UK trial, 49% of drivers agreed that they recharged at a regular interval regardless of the state of battery charge, and this was usually at home overnight or at work during the day (Bunce, Harris, & Burgess, 2014).

> *"We've got a very set routine which is that we come in and we charge it up overnight because we know if we're going to be at home for 10, 8 h, that sort of thing, so whilst we're asleep the car is charging, no worries."*
>
> *"Each time I used it, each day I charged it overnight, after using, that was the general routine […] it would always be ready to go, that was my routine."*
>
> *"So, you know, it's like treating it like your mobile phone and just plugging it in every night before you go to bed and then when you get up in the morning, unplugging it and driving off to work."*
>
> *Consumer quotes in (Bunce, Harris, & Burgess, 2014)*

Around 25% tend to charge after every journey they make (Ofgem, 2021b). Some drivers saw positive similarities between this recharging habit and the habit of charging their laptop or mobile phone (Bunce, Harris, & Burgess, 2014).

While (Anderson, Bergfeld, Nguyen, & Steck, 2022) found that more than two thirds of all PHEV users charge their EV (almost) daily, (Chakraborty, Hardman, & Tal, 2020) found that owners of older PHEVs are more likely to not plug-in their vehicles, which can be due to low battery performance and consequently lower potential cost savings from plugging in.[8]

German EV drivers rated being close to their usual charging site as the most important reason for recharging an EV on a routine basis (3.44 on a 5 point scale). This rated more highly than recharging after finishing a particular trip (2.80), recharging at a certain time of day (1.88) and recharging after a particular time period had elapsed (1.01) (Philipsen, Brell, Brost, Eickels, & Ziefle, 2018).

4.1.2 Recharging based on state of charge

In a 2021 survey, (Ofgem, 2021b) found that around 23% of EV drivers in the UK only charge their EV when the SOC is low. Drivers who recharged according to when they felt that the battery had a low SOC usually calculated future journey requirements to decide whether or not they needed to recharge (Bunce, Harris, & Burgess, 2014). For example, at least one participant in a UK trial made sure they reached 90% battery capacity the day *before* a long journey to minimise the scope for things to go wrong (Evergreen Smart Power, 2021).

> *"It's not too much of a pattern because you're looking at the car at the end of the day thinking there's 30% [charge] left and that's fine for tomorrow, so it's not a regular 'bring it in and charge it every night'. You just plug it in and charge it when you know you're going to need that much more the next day".*
>
> *"What I don't like is sticking it on charge everyday … um … because that is bad, so what I think I'll carry on doing is … so let's say 60 miles, yes, I'll have to charge it, or right I'm going to do three round trips of 20 miles over three days, therefore, I'll charge it in three days' time, it's just sort of doing that little calculation in your head."*
>
> *Consumer quotes in (Bunce, Harris, & Burgess, 2014)*

Based on an analysis of US charging data, (Ge & MacKenzie, 2022) is of the view that the battery SOC and the ability to reach the next station without deviating from the original plan are the primary factors influencing charging decisions. The probability of charging increases when the charging infrastructure has a restroom, dining, and Wi-Fi, and as the SOC decreases (Sun, Yakamoto, & Morikawa, 2016).

A German study identified that EV drivers rated having sufficient charge for the next planned trip as the most important reason to charge (4.33 out of 5), more than the battery dropping to a certain level (3.49), the battery being discharged (3.45) or falling below a minimum SOC (3.10) (Philipsen, Brell, Brost, Eickels, & Ziefle, 2018).

Some drivers in an early UK trial recharged their EV when the SOC was 'low' (54% of drivers). There was considerable variation among drivers about what constituted a low SOC. Approximately half the drivers (46%) felt that 21–40% level of remaining battery charge was 'low' and 46% felt that 10–20% was low (Bunce, Harris, & Burgess, 2014).

Survey data from the US reveals that 35% of BEV users recharge when the SOC is more than half, 40% at half, 55% at quarter, 25% at an eighth and 5% when the warning light comes on (U.S. Department of Energy, Transportation Secure Data Center, 2023).[9] The average SOC for EV drivers charging in China is less than half (45.6%) (Lu, Zhang, Yuan, & Tong, 2020).

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[8] Under these circumstances, they will operate the PHEV as an ICEV.

[9] The same survey indicated that 89% of users have the capability of recharging at home, and that they use a public charger 2.85 times per month on average (with a range of 0-33 times per month).

4.1.3 Opportunistic charging

Some EV drivers have a desire to keep the battery topped up whenever possible (Delmonte, Kinnear, Jenkins, & Skippon, 2020). Fifty-five per cent of drivers in an early UK trial charged the vehicle whenever the opportunity arose (Bunce, Harris, & Burgess, 2014) and the importance of using every available opportunity to charge was rated 3.43 out of 5 by German EV drivers (Philipsen, Brell, Brost, Eickels, & Ziefle, 2018).

> *"I do plug it in when I get back into the office in case I have to go … it does extend my range, so my routine is just plugging it in everywhere I can really, and because all my work is in private substations in big sites, I can always find a socket … so my routine is just everywhere really I can …"*
>
> *Consumer quote in (Bunce, Harris, & Burgess, 2014)*

(Albert, 2022) recommends charging opportunistically when travelling. As charging stations may not be available due to technical breakdowns or long queues, it is better to top up a little at an available charging station when the battery is at 55%, than be 100% dependent on making it to a specific fast-charging station.

The cost of charging is less of a driver for recharging an EV than refuelling an ICEV. (Philipsen, Brell, Brost, Eickels, & Ziefle, 2018) found that the spontaneous discovery of a favourable price as the basis for charging an EV was rated 1.38 out of 5, while for refuelling an ICEV was rated 2.94, and the active search for favourable prices in the run-up to a charging/ refuelling stop was rated as 1.36 for EV drivers and 2.08 for ICEV drivers.

Those with solar panels at home tend to charge their vehicles when their panels are generating energy (Delmonte, Kinnear, Jenkins, & Skippon, 2020), although some worry about charging too much – they may want to leave space for solar in an expected forthcoming heat wave (Evergreen Smart Power, 2021).

4.2 Pricing

Fuel costs play an important role in the cost of using EVs. While the cost of gasoline and diesel is quite transparent to consumers (i.e. the pump price at gas stations), EV charging costs to consumers are not as straightforward; they depend on a variety of factors including charging location, charging speed, time of charging, or even other pricing mechanisms such as charging subscription packages (Lanz, Noll, Schmidt, & Steffen, 2022).

4.2.1 Home charging

The cost to charge an EV at home depends on the vehicle's battery size and the price of electricity. The price of electricity can be a specific EV-tariff or the same rate as used for the rest of the household's energy use.

While over two thirds of drivers are aware of the advantages of switching to an EV-specific tariff and have considered doing so, most have not yet taken the leap; they may be unaware of tariffs that offer the right incentives to switch. Switching also requires more work from EV drivers at the set-up stage so many do not move tariff even when they are aware of their options (Kaluza, 2023).

Most utilities in the US offer time-of-use (TOU) rates, either as an EV-specific rate or applied to all of a household's electricity use. These greatly reduce costs associated with charging a vehicle at home by charging during off–peak hours (California Clean Vehicle Rebate Project, 2023). A 2019 Californian survey revealed that the electricity provider offered different rates for peak and off-peak usage to 81% of EV users (6% were not offered and 13% were not sure or didn't know) and 76% took advantage of these rates. Thirty-three per cent received a special rate for charging their EV (51% did not and 16% were not sure or didn't know). For 88%, the special rate applied to all electricity usage, and for 12% it only applied to what is used on a separate EV meter (U.S. Department of Energy, Transportation Secure Data Center, 2023).

A survey of 1,169 EV owners undertaken across eight European markets revealed that less than 50% of people have a TOU tariff, which would enable them to take advantage of cheaper overnight electricity prices. Additionally, just three in 10 EV owners had a specific EV tariff with their energy provider (Peachey, 2022).

EV-specific tariffs and TOU rates may be more complex for consumers to understand and compare than traditional electricity supply tariffs. Ofgem is working with the UK Government to consider the role of third-party intermediaries (such as price comparison websites) and to improve the use of data, to give consumers the right tools to help them make the right choices for their circumstances (Ofgem, 2021a).

Home charging costs can be offset by hosting the charger on a home charging sharing network. EV drivers can earn money by sharing their home chargers or connect with other hosts to find convenient charging on the go (California Clean Vehicle Rebate Project, 2023).

Residential charging options are enticing for EV users capable of installing home-charging infrastructure. For users with access to energy from a solar PV system, charging costs can be further reduced, particularly in countries with high capacity factors of solar PV or high grid electricity costs (Lanz, Noll, Schmidt, & Steffen, 2022).

(Ofgem, 2021a) notes that:

> *EV charging at home will change the nature of domestic consumers' electricity usage, which may lead to the creation of new situations in which consumers find themselves vulnerable.*

Bundling of tariffs and charges

Emerging developments like bundling of tariffs and charges could create more problems in the future – they could make it even more confusing for people, harder for them to understand and compare deals, and make it difficult to exit. Some bundles, which include home charging, that are starting to be offered include energy tariffs bundled with discounted public charging, and energy tariffs bundled with the home charge point (Competition & Markets Authority, 2021).

4.2.2 Public charging

Residential charging options are typically available only to house owners—EV users in city apartments mostly rely on public charging infrastructure, which often comes at a higher cost. For countries with low population shares living in owner-occupied dwellings, such as Switzerland (42.5%), Germany (51.7%), Austria (55%), Denmark (61.7%) and the UK (63.4%), EV users, in particular those in lower-income groups, may rely exclusively on commercial charging and thus face much higher charging costs (Lanz, Noll, Schmidt, & Steffen, 2022).

Pricing structure

Public charging stations can be free, pay-as-you-go or subscription-based (California Clean Vehicle Rebate Project, 2023).

Free public charging infrastructure

During the early adoption phase of EVs, there were a number of public charging stations that did not charge a fee. For example, an early Californian study revealed that about 90% of those that had access to public and workplace charging infrastructure had access to free charging (California Center for Sustainable Energy, 2012). Some vehicle manufacturers, such as Hyundai, Nissan and

Tesla continue to provide complimentary public charging (California Clean Vehicle Rebate Project, 2023).

Pay-as-you-go public charging infrastructure

Where public charging infrastructure is available on a pay-as-you-go basis, different pricing structures are used, which can make it hard to understand and compare prices. There are currently around 160 pricing models in the UK – while most offer variable pence per kilowatt hour (kWh) pricing based on the charge point's energy usage, some structure their prices as per hour or per minute usage of the charge point (Competition & Markets Authority, 2021). In Europe, some operators charge based on the charger rating (in kW) and some differentiate between the charging time and the time attached to the charging station (Emobicity, 2019). Some charge point operators charge on a time basis to avoid users charging slowly past 80% battery SOC (Figenbaum, Wangsness, Amundsen, & Milch, 2022).

Around a third charge connection fees on top of the charging cost, and some charge additional fees such as minimum payments, overstay charges (Competition & Markets Authority, 2021) or parking costs (Hardman, et al., 2018).

"It's really complicated to work out the pricing structures on the public ones"
(Ofgem, 2021d)

Over 90% of UK drivers surveyed said that standardised pricing would make it easier to use public charge points (Competition & Markets Authority, 2021). A 2021 UK survey of EV drivers revealed that respondents overwhelmingly preferred a pence per kWh format for paying for a charge (94%), with 2% preferring a charge for time spent charging (pence per minute), 2% a flat rate for a charging session and 2% a membership fee (Electric Vehicle Association England, 2021).

A discrete choice experiment conducted in Germany identified that the preferred pricing scheme for EV charging is pay-per-kWh (47%) followed by a flat rate for a fixed monthly fee (42%). The two other pricing schemes, pay-per-minute and monthly subscription (fixed costs & pay-per-minute), were preferred equally (5% each) (Institute for Future Energy Consumer Needs and Behavior (FCN), 2019).

Many in Norway were of the view that paying by the minute is unfair because the important part is how much energy is received (Figenbaum, Wangsness, Amundsen, & Milch, 2022). This is particularly the case during the four to five months of the year in Norway when fast charging of cold batteries is slower (Haugneland & Kvisle, 2015).

To facilitate price comparisons, all fast charging stations in Norway changed to pricing per kWh during 2022 (Figenbaum, Wangsness, Amundsen, & Milch, 2022). The UK will similarly be regulating that all public charge points are charged on a pence per kWh basis (U.K. Department for Transport, 2022a).

All EV charging stations in the US must price based on a per MegaJoule (MJ) or per kWh rate. Additionally, all EV charging stations must be able to indicate the billing rate at any point during a transaction. The requirements are being phased in, with all new charging stations required to meet this obligation upon installation, and all existing charging stations required to meet it in the early 2030s (U.S. Department of Energy, 2023).

Subscription-based public charging infrastructure

Subscription based fees are payable in some European countries for public charging.[10] For example, packages are available in Slovenia which include a monthly fee and then a price per minute or price per kWh (Emobicity, 2019).[11]

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[10] For example, the Netherlands, Greece and Slovenia.

[11] The price per minute decreases as the subscription price increases.

Users on a flat-rate fee are not incentivised to move their vehicles after the rate of charge significantly deteriorates. Occupying a fast charging station after the rate of charge diminishes considerably may defeat the purpose of fast charging and is time costly to other users who may need to recharge their vehicles (Lanz, Noll, Schmidt, & Steffen, 2022).

Subscriptions could potentially lead to harmful traps that exploit people's inertia and make it difficult to exit (Competition & Markets Authority, 2021).

Willingness to pay for public charging

Many commented in a UK survey that prices for public chargers were too high especially when compared to the costs to charge at home. This disproportionately impacts those without access to off-street parking and therefore without access to home charging (Electric Vehicle Association England, 2021).

Notwithstanding, in an early Californian survey, EV owners indicated that they were willing to pay 40%-70% more for public charging compared to standard residential electricity rates, and were prepared to pay 2.5 to 3 times more for "critical need" public charging[12] than they were for daily charging (California Center for Sustainable Energy, 2012).

A German study found that drivers with high annual mileage and BEV users are willing to pay more for additional charging power, and that a BEV user's willingness to pay increases with the range of their EV (Anderson, Bergfeld, Nguyen, & Steck, 2022).

Transparency of charges for public charging

Pricing information for EV charging can be hard to find (Competition & Markets Authority, 2021) and the costs of charging are often unknown (de Brey, Gardien, & Hiep, 2021).

More than 60% of respondents in a Dutch survey indicated that they did not know, at least once or more in the year prior to the survey, what the costs were of charging at a public charging station. Those who are paying for the charge most frequently want to understand pricing in advance (de Brey, Gardien, & Hiep, 2021). Similarly, most respondents in a Norwegian survey found it difficult to understand in advance how much the charging would cost. Price information was often lacking or difficult to understand. BEV users were often not provided with price information until the charging had finished (Figenbaum, Wangsness, Amundsen, & Milch, 2022). Furthermore, two out of five respondents in a European study say they've had at least one instance where the actual price of a charging session turned out to be different to the price shown beforehand at the charge point (NewMotion, 2020).

> *"The problem is lacking information about how fast I'm charging; how much I'm charging and how much it costs. These three things tend to be hidden at most charging stations. It's normally when you have finished charging that you know how much you've spent, unless you've brought a calculator and do the math yourself".*
>
> *"It's like going to a petrol station where they've covered all the prices with white tags. You can't see the price before after you've charged. That really sucks'."*
>
> *"It is hopeless that precise pricing is not available, like at petrol stations. I would prefer information about actual costs and received kWh during the charging session. Ideally, I could indicate the wanted charging percentage at the beginning, and the charging session would automatically stop when this percentage is achieved."*

[12] The paper did not explain what was meant by "critical need".

> *"I wanted to be able to pay by credit/debit card, get information on the price before I start the charging, and receive information about the actual cost after the charging session is ended."*
>
> *Consumer quotes in (Figenbaum, Wangsness, Amundsen, & Milch, 2022)*

This is significantly different from refuelling a conventional vehicle where consumers are aware of exactly what they are paying, and how much each unit of fuel costs (Hardman, et al., 2018).

A number of jurisdictions have introduced obligations to increase transparency and consumer choice.

In the US, all fees associated with a public charging session must be disclosed at the point of sale (California Air Resources Board, 2023a), (California Air Resources Board, 2023b), (U.S. Department of Energy, 2023).

As part of the Europe Fit for 55 package, new infrastructure will have to clearly inform users about pricing options (European Council, Council of the European Union, 2023). This is in addition, to an earlier obligation that prices for public charging infrastructure are required to be reasonable, easily and clearly comparable, transparent and non-discriminatory (European Parliament and Council, 2014).

In the UK, the Government will be regulating that the pricing offer is clearly displayed to the consumer before charging commences, either on the charge point, or through a separate device such as an app or website. Additionally it will regulate that the price cannot increase once charging has commenced (U.K. Department for Transport, 2022a).

4.3 Home charging

The (International Energy Agency, 2018) noted that home charging has proven to be reliable for most households; almost 90% of Norwegian electric car owners have never experienced issues with it. Similarly, (de Brey, Gardien, & Hiep, 2021) note that about 90% of respondents in a Dutch trial were also satisfied with their home charging point.

The vast majority of drivers in a UK trial (85%) indicated a preference for 'plugging-in' at home rather than refuelling by visiting a petrol station. The reasons for this preference included convenience, cleanliness, independence (from oil companies), time and cost effectiveness, and not paying for the cost upfront (Bunce, Harris, & Burgess, 2014).

> *"You come back home and you just charge it up again."*
>
> *Kevin, (Axsen, Langman, & Goldberg, 2017)*
>
> *"… the fact that I haven't had to go to a petrol station for a couple of months, you know, that's just been brilliant, … yes just the convenience of knowing that I get home, I can plug it in, I don't have to factor in a diversion to a petrol station on my way to work because well my house is the petrol station now … um… I think that's been a real bonus … the convenience."*
>
> *"You know, you do have a sense of independence, you can just come home, plug it is, … overnight, get up in the morning, go where you want to go, it's nice, it's a nice feeling, you feel good, I do like that, you don't have to go to a petrol station you know, you don't have to pay money out again … you've already, you pay it through your electricity bill."*
>
> *"I don't find that a chore, I find it quite easy, I think it's quite liberating to do that … because I don't have to go to a petrol; station."*
>
> *Consumer quotes in (Bunce, Harris, & Burgess, 2014)*

However, while participants in the UK trial identified the convenience of home charging, others are of the view that it is inconvenient.

> *"And then, of course, when I get home, I have to plug it in. So it's just like for me, inconvenient."*
>
> *Mr. Young, (Axsen, Langman, & Goldberg, 2017)*

> *"It was quite a cumbersome bit of kit to plug it in […] I can just imagine a young mother in one arm and trying to get this thing out and unclip the latch and put it in and in the rain it would be just ridiculous to try and do that."*
>
> *Consumer quote in (Bunce, Harris, & Burgess, 2014)*

As discussed in chapter 3, there are a number of reported safety issues associated with charging an EV from a standard electricity socket. These include experiencing:

— a burnt socket
— a blown fuse
— overheating of long connection cables
— rain mixed with sockets.

Some stakeholders in the UK noted that open standards and data can help to improve people's experience of home charging by ensuring they are not 'locked in' to the charge point operator's interface. Without open standards and data, people are restricted to using the interface that comes with their charge point, which can be costly and difficult (Competition & Markets Authority, 2021).

4.4 Public charging

The public charging experience is more complex than the home charging experience. It includes:

— discovery and routing
— driver authentication and payment initiation, in addition to
— charging the EV.

4.4.1 Discovery and routing

As the network of public charging infrastructure for EVs is not as well established as the network of traditional petrol stations, there are significant additional challenges for EV drivers in planning and finding suitable available public charging infrastructure, particularly in areas that are not familiar to them and on busier days, than for drivers of ICEVs.

Planning trips

A survey of Danish EV users identified that most of them took long trips with their EV at varying frequencies in a year. For these long trips, they needed to plan ahead and identify their charging options on the route taken. Key factors that they took into account while selecting suitable charging locations were the charging speed, charging cost and surrounding facilities.

A few of the users commented on how using EVs had improved their driving behaviour. Long trips had become a more pleasant experience by taking breaks for charging, driving at moderate speeds to maximise battery efficiency, and the overall EV experience (Visaria, Jensen, Thorhauge, & Mabit, 2022).

(Albert, 2022) identified that when planning an itinerary, EV drivers need to see if there are convenient spots where they can combine a stop (lunch, sightseeing, hike) with a charging session, and to stay only at hotels that offer overnight charging. Since the battery generally won't get to

100% from fast charging, they had to be more aware that the only time the EV is likely to be at full range is at the start of the day after slow/medium charging overnight.

While planning a trip is particularly important for long road trips, it is also necessary on shorter trips. A participant in a Canadian trial stated that:

> *"[With a EV] you've got to map out the city and decide, 'Okay, well, I'm going over here but if I plug in here that means I've got to walk 15 blocks …'"*
>
> *Al, (Axsen, Langman, & Goldberg, 2017)*

Almost half of the respondents in a UK survey said that their nearest public charger was more than a 20-minute walk away, making dropping the car off for a charge and picking it up again a slog if they don't (or can't) have a charger at home. One in 5 survey respondents who no longer use public charge points said they were put off by the lack of availability (Passingham, 2022).

Sixty-two per cent of respondents in a US survey reported that they "always" or "frequently" feel anxious about their vehicles' ranges and adjust their travel plans to suit (Utility Dive, 2022). Furthermore, (Kuby, 2019) found that EV drivers take larger detours compared with ICEV drivers to recharge – 18% of EV drivers recharged at a location that took them away from or past their destination.

(Sun, Yakamoto, & Morikawa, 2016) found that the length of the detour for Japanese EV drivers is different for private and commercial users, on working and nonworking days. Generally, private users are willing to detour by up to about 1750 m to charge their vehicles on working days and 750 m on non-working days, while commercial users are willing to detour up to 500 m on both working and non-working days.

Finding a public EV charging point

Many EV drivers have difficulty finding an available charge point, with nearly half of the drivers in a UK survey saying that finding charging infrastructure actually working is a significant hurdle. One respondent in that survey was forced to spend the night in a hotel due to being unable to charge their vehicle while on the road (Passingham, 2022). The inability for Chinese EV drivers to find public charging stations in time to recharge during travel or during periods of high energy consumption caused by air conditioning is the main reason for consumers' range anxiety (Wang Y.-Y. , Chi, Xu, & Li, 2021).

When looking for a charge point, respondents in a UK survey indicated that the primary factor was the location of the charge point, followed by the charge point network and lastly the cost to charge their vehicle.

Ninety-four per cent of participants in that survey indicated that they experienced concern at some time or another about finding public charge points. That said, 45% of drivers agreed or strongly agreed that they found it easy to locate public charge points with 34% neither agreeing nor disagreeing.

All participants in the survey either used an app or website to locate charge points (83%) or their vehicle's onboard map information (17%) (Electric Vehicle Association England, 2021). However, (Albert, 2022) notes that Google Maps contains information about many charging stations, but since the data often comes from the users themselves, it may not always be up to date. The different apps provided by charge point operators have maps but only of their own stations, and the car's own navigation system may not be entirely up to date (more stations may exist than it knows about). (de Brey, Gardien, & Hiep, 2021) found that 38% of respondents in a Dutch survey experienced one or more times in the 6 months prior to the survey that the charging station could not be found; the location in the app does not always correspond to the actual location.

> *"Having all these apps is confusing, because if I'm planning a trip, I can't just use Google Maps and find all the different charger services there. My experience is that I'm unable to get a full overview, and that I'm forced to use each app individually to locate charging stations, and get information about the terms and so forth, and then I'm not even sure if I have the right app."*
>
> *Consumer quote in (Figenbaum, Wangsness, Amundsen, & Milch, 2022)*

Ninety-eight per cent of respondents believed that having access to real-time data ahead of a charging event would save them time. Such information could include the working order of a charge point, the availability of a charge point, time until charging completes and peak usage times (Electric Vehicle Association England, 2021), (Figenbaum, Wangsness, Amundsen, & Milch, 2022). However, not all charge point operators make live data on availability and working status freely available, and the live data that is available can be limited, inconsistent or difficult to access. Furthermore, consistent aggregated cross-network data would make it easier and more convenient for EV drivers to find charge points (Competition & Markets Authority, 2021).

A number of jurisdictions have implemented actions to facilitate EV drivers more readily finding available public charge points. However, to date many of these actions relate to static data rather than dynamic real-time data.

In the US, charging point operators must report new, current and decommissioned charging point locations as well as access information to the government to ensure accurate and up-to-date data is available to consumers (California Air Resources Board, 2023a), (California Air Resources Board, 2023b). In California, charging point operators must disclose the EV charging station geographic location, schedule of fees, accepted methods of payment, and network roaming charges (U.S. Department of Energy, 2023).

Additionally, the funding requirements of the US's National Electric Vehicle Infrastructure (NEVI) program state that charging stations must be capable of communicating their functional status via web applications to drivers on the road so they can confidently make decisions about where to pull over and recharge when needed (Utility Dive, 2022).

In Norway, cooperation between the governmental entity Enova and the Norwegian EV Association resulted in the development of an open, publicly owned database that allows everyone to build services using standardised data free of charge. This has provided BEV users with up to date information about the charging infrastructure, and the data is being used by several in-car navigations systems as well as by charging maps and apps (Lorentzen, Haugneland, Bu, & Hauge, 2017).

The UK Government is opening up data so that drivers can access real time information about charge points across the public network (U.K. Government, 2022). It is mandating the adoption of Open Charge Point Interface Protocol (OCPI), mandating that all static and some dynamic data are made openly available, and progressing its open data workstream to understand how this data should be opened and specified in technical guidance (U.K. Department for Transport, 2022a).

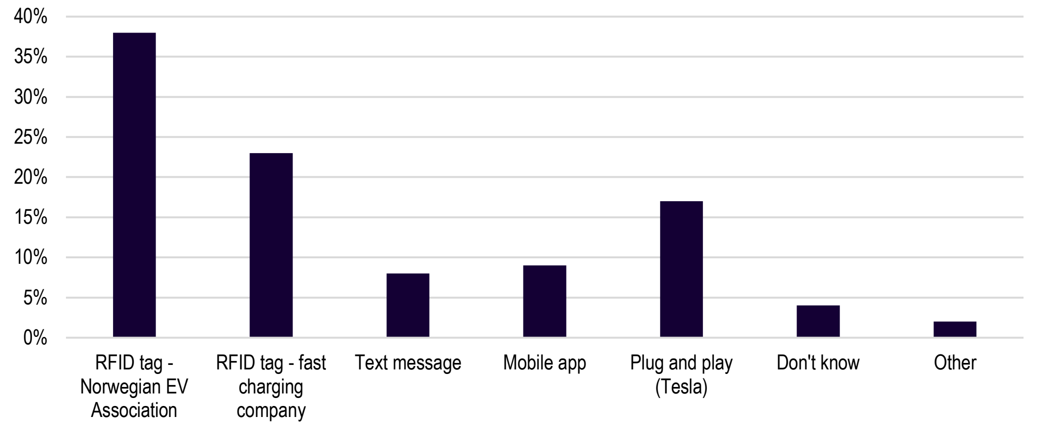
4.4.2 Driver authentication and payment initiation

Driver authentication

(Kaluza, 2023) noted that 90% of public chargers in the EU are not equipped with a credit card reader. As a result, EV drivers typically need to be pre-registered with a charge point operator. When registered, the customer identification can then operate the charger via an app or a radio frequency identification (RFID) tag (Figenbaum, Wangsness, Amundsen, & Milch, 2022). Consequently, not all public charge points can be accessed at the point of need (Ofgem, 2021d).

A 2017 Norwegian survey identified that most EV drivers in Norway started fast charging sessions using an RFID tag issued by the Norwegian EV Association or a fast charging company (60%). Alternatively, they used a text message, a mobile app or plug and play on Tesla superchargers (refer Figure 4.2).

Figure 4.2 Method for driver authentication



Source: (Norsk elbilforening, 2017)

"I'd say I have 10-15 apps on my phone for that and RFID cards for some of these."
(Ofgem, 2021d)

Currently there are sometimes more than 20 different charging infrastructure providers in a region. If consumers wish to access all charging stations, they may be required to hold a membership card for each company and/or use 20-30 apps. This situation can cause difficulties for consumers and can be a barrier to them purchasing a EV (Hardman, et al., 2018), (Nordic Road and Transport Research, 2022). About 75% of participants in a 2021 Norwegian survey agreed with the statement that "*It is inconvenient when charging operators operate with different apps"* (Figenbaum, Wangsness, Amundsen, & Milch, 2022).

To reduce complexity, policymakers and charging infrastructure companies are finding ways to ensure EV owners can access any charging station, regardless of membership status (Hardman, et al., 2018). The Europe Fit for 55 package requires that all new charging infrastructure allows ad-hoc charging (European Council, Council of the European Union, 2023).

In the US, a public charging point must be accessible to drivers regardless of membership in a charging point operator's network. EV drivers must not be required to pay a subscription fee or become a member to use a charging station (California Air Resources Board, 2023a), (California Air Resources Board, 2023b).

An ISO standard, referred to as "plug and charge" (*Road vehicles – Vehicle to Grid communication interface*) is in development. The standard will eliminate the manual authentication required when plugging into a public charging station. Instead, authentication data will be stored in the vehicle and automatically communicated to a charger when plugged in. The charger will be able to determine who to bill without user input (van Barlingen, 2022).

Payment initiation

Very few public fast chargers have bank terminals, so users must pay via apps, operator-specific payment cards, SMS messaging, or other means (Figenbaum, Wangsness, Amundsen, & Milch, 2022). A charge card or token is the main payment method at public charging sessions (80%). Eight per cent pay via ad-hoc charging (via a credit card or payment link), while 36% of the respondents said their public charging sessions were free (NewMotion, 2020).

(Figenbaum, Wangsness, Amundsen, & Milch, 2022) found that more than 50% of EV owners found the payment method at public fast charging stations inconvenient. Even among EV owners who use the chargers more than 20 times a year, the level of dissatisfaction was relatively high. In a January 2021 survey of EV drivers in the UK, 49% thought that paying at public charge points is too complicated and 61% thought that too many apps are required to use the public charging network. The lack of information on charge points can also mean it is difficult for people to know the payment method for a charge point in advance.

"You're very reliant on your phone."
(Ofgem, 2021d)

In many cases, a consumer needs a smartphone with internet and signal to pay for a charge. This means that paying for a charge is often frustrating to drivers who are used to paying with a bank card (credit or debit card) at petrol stations. In the worst case, some consumers may be unable to pay for a charge at a specific charge point, which is a particular issue if they do not have the battery range to reach an alternative charge point (U.K. Department for Transport, 2022a).

Around 8 in 10 EV owners who have used public charge points said they wanted to be able to pay using a bank card, avoiding the hassle of multiple apps and network payment (RFID) cards (Passingham, 2022), and the need to set something up beforehand (Ofgem, 2021d).

> *"An opportunity for simpler payment would be nice. To be able to pay with credit card […] An elderly person who uses fast chargers on rare occasions would want to do it as simple as possible."*
>
> *"It should have been a common method for payment at all public charging stations, without having to download an app to the phone. Should be possible to pay with debit or credit card. Not everyone is comfortable with apps, especially the elderly."*
>
> *Consumer quotes in (Figenbaum, Wangsness, Amundsen, & Milch, 2022)*

The (Competition & Markets Authority, 2021) noted that some of the payment options are more challenging for some cohorts, for example:

— people aged 65+ are less likely to own a mobile phone and more likely not to use the internet compared to the UK average, which may limit their ability to use pay-as-you-go options
— those living in or travelling through remote/rural areas can experience connectivity issues when paying for charging
— those without bank accounts and/or smartphones may struggle to pay for charging, at those charge points which largely only offer cashless payment options which can require a smartphone (e.g. Quick Response (QR) code, app) or bank account card.

"It got to the point where your purse is just full of all these cards you might never use."
(Ofgem, 2021d)

Although many EV drivers (37%) own just one charging card, a lot of EV drivers admit to needing multiple charge cards, particularly for longer journeys. Forty-five per cent say they own 2-4 charge cards while 15% require 5 or more charge cards. The average number of charge cards that EV drivers own is 2.5. The average number of cards varies by country, with the lowest average number in the Netherlands (1.82). This is most likely because most charge points in the Netherlands are interoperable and because of the high volume of charge points, which is the highest in Europe (NewMotion, 2020).

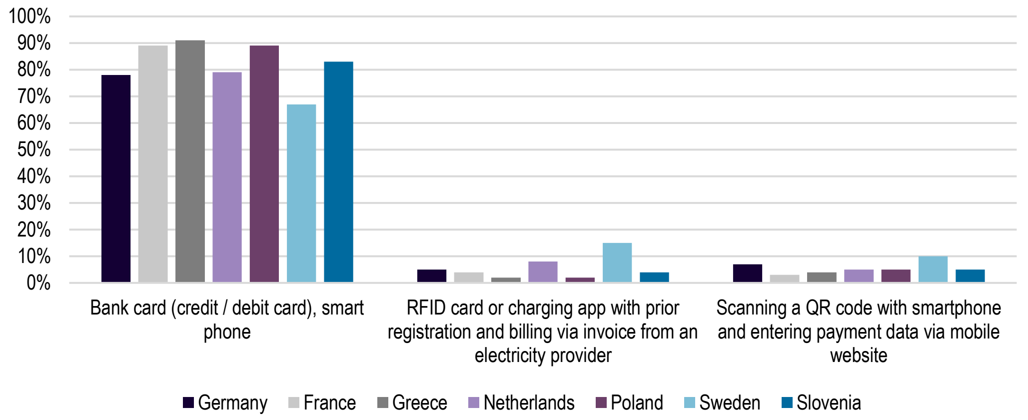
The (Nordic Road and Transport Research, 2022) found that the overall charging market becomes dysfunctional for users when 13 different payment solutions are in use, but not credit card payment. There are only a few public chargers in Norway which have contactless payment options, with everything done through apps (The Fast Charge, 2022).

There is also a lack of credit card readers at public charging stations in the US (Plug in America, 2022).

Preferred payment methods

Across a number of surveyed countries in Europe, the preferred payment method is overwhelmingly by debit or credit card or by smart phone, as illustrated in Figure 4.3.

Figure 4.3 Preferred method of payment for consumers in selected European countries



Source: (Initiative Deutsche Zahlungssysteme e.V., u.d.)

While 96% of drivers in a January 2021 survey said that contactless payments at all public charge points would make it easier to charge, currently only 9% of public charge points have contactless bank account payment. Eighty-seven per cent said that having access to all public charge points via a single smartphone app or membership card would make it easier. Some pay-as-you-go options can be less convenient than others as they require an additional setup to access (e.g. signing up to a RFID card or downloading an app) (Competition & Markets Authority, 2021).

"I don't understand why I can't just use my credit card like I do in the shops." (Ofgem, 2021d)

The (Electric Vehicle Association England, 2021) found that the payment method deemed the easiest for accessing a charge point was a contactless credit or debit card with 46% of participants preferring a contactless card. This was followed by a smartphone app (31%), a membership (RFID) card (29%) and other contactless forms of payment such as Apple Pay (22%). Respondents generally would not welcome a call or text-based option to pay for a charge (84%).

The (U.K. Department for Transport, 2022a) noted that payment via smartphone can be easier for wheelchair users than accessing chip and pin or contactless payment interfaces.

Emerging new payment methods are roaming, and plug and charge. Roaming is a cross-network payment method that allows people to pay for charging via a single app or card, and will support fleet electrification. 'Plug and charge' technology may offer a quick and convenient option by automating payment (Competition & Markets Authority, 2021), (U.K. Government, 2022).

The (Electric Vehicle Association England, 2021) found that most EV drivers would prefer to use their preferred payment method across all charge points (94%). Eighty-seven per cent of survey participants would welcome the ability to use one smartphone app across all public charge point networks, while a smaller percentage (71%) would welcome the ability to use one RFID card across all public charge point networks. Respondents generally would not welcome the option to access public charge points via QR code (59%).

The concept of roaming is more established in Norway. From 2015, the Norwegian EV Association issued RFID cards to their members that can be registered with the main charging infrastructure providers and used at any location. It was found that 61% of EV owners preferred this method of payment, believing it was easier than other solutions (Hardman, et al., 2018). Users prefer the RFID-tags over other payment methods like SMS or phone apps due to its ease of use, and that it is not necessarily very desirable to use a phone outside in adverse weather conditions (Lorentzen, Haugneland, Bu, & Hauge, 2017).[13]

Tesla, with their plug and play system, is by far the easiest system to use for Tesla owners, and is preferred by them (Lorentzen, Haugneland, Bu, & Hauge, 2017).

Regulating payment methods

The Europe Fit for 55 package requires that new charging infrastructure will have to accept electronic payments (European Council, Council of the European Union, 2023). Consistent with this directive, all charging stations installed in Norway after 1 January 2023 must offer payment via debit or credit card, and the government will set a deadline for card payment on those already in service (Berglund, 2022). In September 2021, Germany's federal parliament passed a bill that requires every EV public charging point to have a debit or credit card reader from June 2023 (Appunn, 2021).

In the UK, the Government is mandating a payment method that is not specific to a brand and does not require a payee's mobile or internet signal, to be available at:

— newly installed charge point sites (above 7.1 kW)
— retrofitting at existing rapid sites (50 kW and above).

In addition, the Government will mandate industry-led payment roaming, with enforcement to come into effect from 24 months after the legislation comes into force, and include a provision for the Government to designate approved providers if industry does not demonstrate sufficient progress in this timeframe (U.K. Department for Transport, 2022a).

In the US, charge point operators must operate credit card readers and mobile payment device options on public chargers so that all drivers have the choice to pay with credit card or mobile pay or both. This ensures more universal charging access by requiring public chargers to accept payment using chip-enabled credit cards, which are the most ubiquitous form of credit card payment currently, while also requiring contactless payment for mobile payment methods.

Additionally, the interoperable billing standard Open Charge Point Interface must be installed on each public charger. The protocol facilitates automated roaming for EV drivers across several EV charging networks (California Air Resources Board, 2023a), (California Air Resources Board, 2023b).

4.4.3 Charging the EV

While most consumers are generally satisfied with their experience of charging their EV with public charging infrastructure, the international research has identified a range of consumer pain points. These include:

— the reliability of the charger and the charging process
— speed of charging
— queueing to use public charging infrastructure
— lack of standardisation
— accessibility
— charging station etiquette
— facilities at public charging stations
— lighting and safety

[13] While noting that the authors of this paper are from the Norwegian EV Association.

— weather proofing
— signage
— ability to get help and support.

Reliability

The flip side of range anxiety is “charging anxiety”. Charging anxiety comes from knowing that even if a charger can be located – which may be tucked away in a corner of a parking lot with very little signage – and even if that charger isn’t blocked by another vehicle, it may be broken (Utility Dive, 2022).

Reliability of public charging is critical, particularly for BEVs – both in terms of the reliability of the public charging stations and the reliability of the charging process itself. In 2019 and 2020 surveys, reliability was ranked as the most important factor for a public network, particularly for en route charging (Competition & Markets Authority, 2021).

The most common reliability issue experienced by EV drivers was that a charge point was out of order (Electric Vehicle Association England, 2021). This could be due to issues with the charge point hardware and/or software, or faulty communication between the charge point and back office system (e.g. payment or software provider) (Competition & Markets Authority, 2021). This was followed by not being able to easily activate the charge point or that the charge point would not connect with the vehicle (Electric Vehicle Association England, 2021).

In a UK trial of on-street EV chargers in Oxford, stakeholders were surprised by the number of instances of vandalism and breakdown of the chargers during the trial, which led to lengthy periods in which a few chargers were non-operational (University of Oxford, 2019).

On average 1 in 25 charge points and 1 in 10 rapid charge points are out of service in the UK (Competition & Markets Authority, 2021). In one UK survey, 4 out of 10 said that they’ve personally experienced non-working chargers (Passingham, 2022), and in another survey, 62% of drivers disagreed or strongly disagreed that public charge points are typically in good working order with only 14% of survey participants finding charge points in good working order (Electric Vehicle Association England, 2021). Roughly 50% of EV drivers in Norway find that the fast charging network doesn’t work ‘occasionally or more often’ (The Fast Charge, 2022).

In the US, 43% of respondents in a Forbes survey had encountered broken public charging stations (Utility Dive, 2022). One out of five respondents in a US survey ended up not charging their EV after locating a public charger. Of those that didn’t charge, 72% indicated that it was due to the station malfunctioning or being out of service (Hawkins, 2022).

Participants in an early UK trial experienced a period of learning to use public charging infrastructure through trial-and-error. During this period, among successful recharges, some attempts were unsuccessful. Reasons for unsuccessful charging included the charging station having tripped, incompatibility between the rate of charging for the vehicle and charging station, or the electrical connection not having been made. Drivers indicated they would have welcomed confirmation that the electrical connection had been made, and the ability to find out remotely how the charging was progressing, for example, via a message sent to their mobile phone (Bunce, Harris, & Burgess, 2014).

In the UK, the Government is regulating to ensure that public charge points are reliable. It considered a minimum reliability standard for public charging points or for public charging networks. It decided that, by the end of 2023, a public charge point network will need to meet a 99% minimum reliability standard for all its publicly available rapid charge points of 50 kW and over (U.K. Government, 2022). In a 2021 survey, 99% of drivers believed that charge point operators should be required to meet a certain threshold of reliability and 93% of drivers believed that a 99% reliability standard would be fair (Electric Vehicle Association England, 2021).

In the US, there will be a requirement that chargers be functional nearly 100% of the time and adhere to technical standards for communicating with vehicles (Hawkins, 2022). The funding requirements of the US's National Electric Vehicle Infrastructure (NEVI) program state that charging stations must be operable at least 97% of the time (Utility Dive, 2022).

Speed of charging

Participants in a Canadian study raised a concern that charging an EV takes too much time. For example, one stated:

> *"Or road trips or something – do you literally take your family and you sit there and you charge your car and you try and entertain your kids for three hours?"*
>
> *Christine, (Axsen, Langman, & Goldberg, 2017)*

The speed at which an EV charges is influenced by the charging speed of the public charging infrastructure and the vehicle's connector type.

"I had to wait until 6 in the morning waiting for it to charge. After that experience I'm hesitant to use it."
(Ofgem, 2021d)

In a Dutch survey, 55% of the respondents indicated that they had experienced the charging speed at public charging stations as "too low" in the past 6 months. It was almost never clear what the charging speed (at that time) was with public charging stations (de Brey, Gardien, & Hiep, 2021).

An early on-line survey found that 51.4% of EV owners were equipped with fast-charging compatible plugs, like CCS, CHAdeMO, or Tesla-Supercharger, while 38.6% were limited to slow charging speeds (Philipsen, Schmidt, & Ziefle, 2016).

In the US, public charging stations must have a sticker informing drivers of voltage and amperage capabilities of the unit to help drivers understand how fast their battery may be charged (California Air Resources Board, 2023a).

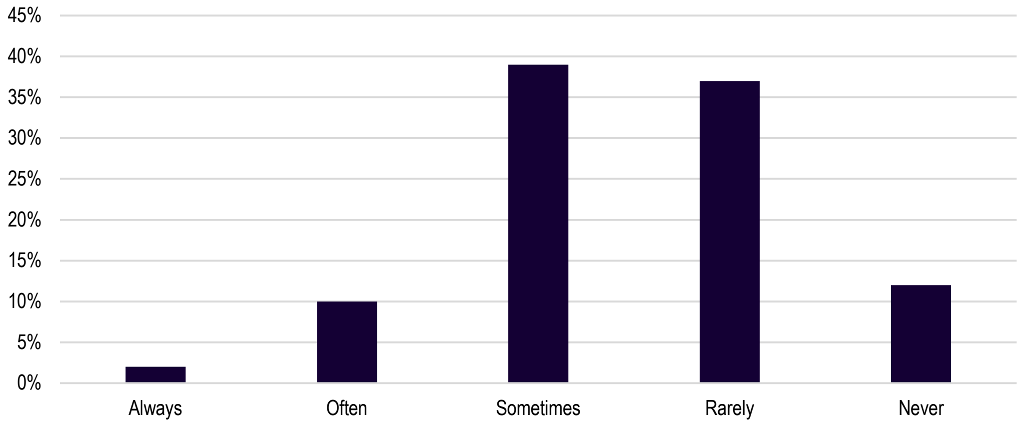
Queueing

(Hardman, et al., 2018) found that most cases of low dependability of public chargers are due to congestion at the chargers, rather than from missing infrastructure or low technical reliability.

> *"I have experienced that there are no available charging points when arriving at a charging station. It's difficult to know how long others plan to charge and where to park in the meantime."*
>
> *Consumer quote in (Figenbaum, Wangsness, Amundsen, & Milch, 2022)*

A 2017 Norwegian survey revealed that about half of the respondents always, often or sometimes experienced queues at fast charging stations, refer Figure 4.4.

Figure 4.4 Frequency of queueing at fast charging stations



Source: (Norsk elbilforening, 2017)
Note: Do you often experience queues at the fast charging stations?

In a UK survey, 9% of respondents had abandoned their attempt to charge their vehicle because of a long queue. Fifty-two per cent of survey participants either disagreed or strongly disagreed that there are typically enough available charge points to use, 29% agreed that there are enough available charge points to use, while only 5% strongly agreed there are enough charge points (Electric Vehicle Association England, 2021).

The proportion of EV users unable to access public charging stations was higher in a 2019 Californian survey. While public charging facilities are generally available for EV users (82%), charging stations at a work or school location are generally not available for the 70% of participants that park there in a typical week. Only 10% of EV users had always been able to access public charging, while 15% indicated they couldn't access them most or all of the time, 36% couldn't access them about half of the time, and 39% couldn't access them less than half the time (U.S. Department of Energy, Transportation Secure Data Center, 2023).

One EV owner in a UK survey noted that, as more people start to use EVs, it will become a pain to find a charger that isn't in use, so the half-hour recharge stop could be an hour while waiting for a charger to become available (Passingham, 2022).

'Parking anxiety', in addition to 'charging anxiety', is emerging in the UK with the installation of on-street chargers. EV drivers are becoming anxious that they will be unable to find a parking spot on the street which has access to on-street charging.[14]

EV owners in a Norwegian survey seemed to accept between 1-3 stops and 5-20 minutes of charge queues on days when many people are travelling. About half of users were willing to change travel time on peak travel days to avoid charge queues, but mainly within the same day. EV owners reported a variety of activities while charging, such as checking/sending e-mails, looking at social media, taking a stroll or using the facilities at the charge station (kiosks, cafés, toilets etc.) (Institute of Transport Economics, Norwegian Centre for Transport Research, 2019a).

Some EV owners may not risk driving their EV if they perceive charge point congestion to be an issue or if they think charge points could be inoperable (Hardman, et al., 2018).

[14] Discussion with Energy Systems Catapult on 23 March 2023.

"A form of booking/queue handling system should be available, to avoid arguments and "pointed elbows" on popular weekends."

"I get that all charging points are busy sometimes, but the fact that you're not provided with any information regarding when it will be available, creates a sense of uncertainty."

Consumer quotes in (Figenbaum, Wangsness, Amundsen, & Milch, 2022)

Lack of standardisation

"I didn't realise there were different cable types. I thought it was like petrol pumps one size fits all."
(Ofgem, 2021d)

There are different connectors for charging which means charge points with only one connection type cannot be used for all EVs. The different connections can also add confusion to the charging experience. There is also one closed charging network in the UK which can only be used by Tesla cars. This can restrict the charging options available and make it more complex and difficult to charge and switch to different charge points (Competition & Markets Authority, 2021).

Public charging stations also vary greatly in terms of layout, user interfaces, payment solutions, and charger activation, which comes on top of the different types of connectors, the cables with different lengths and locations, and different charging power levels associated with the EV technology and chargers in general. Consequently, several of the respondents in a Norwegian survey were dissatisfied with public fast charging services and emphasised the need for standardisation of all public charging stations. To avoid having to learn the operation and payment system of other charge point operators, 55% of the survey respondents stated that they deliberately used the same charge point operator each time they use public chargers. Almost half of the respondents stated that they had bought a BEV with a large battery to avoid having to use public chargers (Figenbaum, Wangsness, Amundsen, & Milch, 2022).

"There are many different systems in terms of physical plugs. What kind of plug is this? What power can I get out of this one? What is mots up to date? Is it the same standard on a Tesla? After a while, you start to understand."

Consumer quote in (Figenbaum, Wangsness, Amundsen, & Milch, 2022)

In an early UK trial, the lack of a standardised charging system put off some drivers from wanting to rely on it (Bunce, Harris, & Burgess, 2014). In a 2019 survey, 87% of drivers (non-EV) thought that being able to easily use any available public charge point is an important factor in deciding whether or not to buy an EV. In addition, 86% of respondents agree that all charge points on public land should be accessible to all EV drivers (Competition & Markets Authority, 2021).

Accessibility

Those with disabilities may face additional barriers to using public charging infrastructure due to the design or location of charge points. Concerns include the weight of charging cables making these very difficult to lift, and unsuitable parking arrangements / space for disability access, including trip hazards and barriers making it difficult to navigate around charge points (Competition & Markets Authority, 2021).

The (U.K. Department for Transport, 2022a) also identified the need for a minimum and maximum height for sockets (hip height for wheelchair users), no special/additional equipment required to access this, an inclusive physical environment for non-EV drivers navigating the streetscape, and that charge points should be designed with a view to reducing obstructions on the road and pavement, for those with reduced vision and mobility. In a survey, most respondents answered 'no' or 'don't know' to providing supervised stations for those who require assistance.

The UK Government has developed charge point design standards to improve accessibility at public charge points for disabled users to allow drivers to easily identify which charge points are suitable for their needs (U.K. Government, 2022). In October 2022, the British Standards Institution

(BSI) launched *PAS 1899:2022 Electric vehicles – Accessible charging – Specification*. The new standard lays out best practice on designing accessible public charge points considering the needs of all users, including disabled and older people.

Charging station etiquette

One major point of criticism arising in a Danish study is the lack of socially acceptable charging etiquette. Key points of frustration are EVs not being moved from charging spots even after charging is completed, and cases of taxis/car sharing vehicles taking up public EV charging spots. A US study found that users are unsure about how to deal with these issues and what the norm is around disconnecting the charger from a car that has been charged and connecting to their own car (Visaria, Jensen, Thorhauge, & Mabit, 2022).

The issue was also raised in a Hong Kong study, a UK survey and a US survey, which referred to ICEV drivers more generally blocking EV chargers rather than just taxis and car sharing vehicles (He, Luo, & Sun, 2022), (Electric Vehicle Association England, 2021), (Plug in America, 2022).

In an online survey of EV users and non-users, the respondents generally indicated that they were not willing to move a vehicle after charging in order to free the spot for another EV user. EV users were more neutral (2.64 out of 5) than non-users (2.03). Men were more willing to vacate their parking space (2.36) than women (1.79) (Philipsen, Schmidt, & Ziefle, 2016).

"It is a bit annoying, that someone else unplugs your car and plugs theirs in."
(Ofgem, 2021d)

A related issue identified in a UK study was that the journeys of EV drivers were delayed because their EV had been unplugged by others so they could charge their vehicle (Ofgem, 2021d).

To address this issue, Tesla has initiated an idling fee in Hong Kong of HK$7.80 per minute at Tesla Superchargers when the station is fully occupied (He, Luo, & Sun, 2022).

In the US, it is a traffic offence to park a motor vehicle within any on- or off-street parking space specifically designated by a local authority for parking and charging EVs, unless the vehicle is an EV which is in the process of charging (U.S. Department of Energy, 2023).

Facilities

A survey by (Plug in America, 2022) identified a lack of amenities near public EV chargers. There is a need for increased access to facilities, as charge points can be located in areas that can be closed or in which public services (such as toilets) can be closed (Electric Vehicle Association England, 2021).

Long-distance drivers (driving 100 km+) highly value access to the same amenities at fast charging stations as they are used to at petrol stations. Amenities mentioned include basic facilities such as toilets or benches, and also service options and the possibility to buy food and beverages (Figenbaum, Wangsness, Amundsen, & Milch, 2022).

A Germany survey identified the most preferred service options as a supermarket (76%) and a bakery shop (35%) (Institute for Future Energy Consumer Needs and Behavior (FCN), 2019), while a UK survey of taxi drivers identified that facilities such as toilets should be incorporated in larger 'hub' sites (Energy Saving Trust, 2016).

> *"I normally charge where I can use toilets, but ice-cream, coffee etc. That is much more OK than (charging stations) where there are just two chargers in the middle of nowhere. It's nice to be able to do something other than just sit in the car."*
>
> *"I'm not very fond of chargers that are in the middle of nowhere. It must be facilities that allows you to do something there while charging. Gas station, toilet, etc."*
>
> *"When it comes to amenities, the type of amenities is not so important, if it is a grocery store, kiosk or a café. The important thing is that there is something. The best option would be if the*

> *chargers were placed at petrol station because they are usually open 24/7 and have toilet facilities.”*
>
> *Consumer quotes in (Figenbaum, Wangsness, Amundsen, & Milch, 2022)*

A Danish study identified that consumers are willing to drive detours to arrive at fast-charging locations with more chargers available and facilities (Visaria, Jensen, Thorhauge, & Mabit, 2022).

Lighting and safety

An emerging concern relates to the safety of public charging stations (Competition & Markets Authority, 2021), (Plug in America, 2022). (Tooze, 2023) found that 87% of a sample of 817 of the UK’s public EV charging locations have poor lighting; and 77% don’t have security cameras.

A survey of 500 drivers found that 80.3% feel vulnerable when charging their EV, 62.9% don’t think security measures at charge points are adequate and 88.5% have chosen not to use a charge point because they felt unsafe at the location.

Keele University interviewed 16 female EV drivers and found that most were concerned about charging late at night in dark, poorly lit, unsheltered, and relatively isolated areas. Many felt “trapped” inside their vehicles while charging, especially if there were no basic amenities close by. A disabled woman could be “doubly vulnerable” if charging at an unlit location, and where accessibility to and from their vehicle to reach charging cables was more difficult.

Following a frightening public charging experience, one woman now:

— plans all her journeys in advance
— always identifies three potential charging sites
— never lets her car’s estimated remaining range go below 15% in case one charging point isn’t working
— is borrowing money to turn her front garden into a driveway to install a home charger.

The issue of safety is exacerbated as charge points are installed in an increasingly diverse range of locations, often in more isolated and exposed locations than is the case for petrol stations (U.K. Department for Transport, 2022a).

Safety issues have also arisen during a trial of on-street charging options in Oxford. Users reported a range of interactions with neighbours, friends and family relating to on-street charging. While most of these interactions were positive and supportive, others expressed feelings of vulnerability when charging their vehicles (University of Oxford, 2019).

Lighting is not only a safety issue, but enough lighting is important to be able to read the information on the charger and to be able to locate and insert the correct cable (Figenbaum, Wangsness, Amundsen, & Milch, 2022). Some drivers in a UK trial complained that the charging cable was ‘cumbersome’ and that lining up the pins in the socket was ‘fiddly’, especially at night time or if the charging location was outside and the weather was wet (Bunce, Harris, & Burgess, 2014).

In a recent UK survey, 38% of respondents believed there was not enough lighting at public charge points, 38% neither agreed nor disagreed that there was enough lighting, and the remaining 24% felt there was enough lighting at public charge points (Electric Vehicle Association England, 2021).

(Tooze, 2023) was of the view that a charging station with good safety and security features is one that is well-lit with 24/7 surveillance and has rapid chargers, accessible charging bays, contactless payment, and a number of shops and facilities, an example of which is provided in Figure 4.5.

Figure 4.5 Example of a safe fast public charging station

Source: (Tooze, 2023)

The UK Government has indicated that it will mandate that charge points should operate in a way that prioritises charge point safety (U.K. Department for Transport, 2021).

Weatherproofing

While most survey respondents in a UK survey indicated they did not feel that they experienced issues in inclement weather (78%), 69% agreed or strongly agreed that they preferred to use charge points located under some type of roofing or covering (Electric Vehicle Association England, 2021).

In Norway the absence of roofing or other means of shelter at most charging stations is a topic of great frustration for many EV owners. Being under a roof when using public chargers, especially during the winter, is appreciated when it is raining/snowing (Figenbaum, Wangsness, Amundsen, & Milch, 2022).

Signage

Respondents in a recent UK survey generally perceived a lack of signage along motorways, A-roads, at Motorway Service Areas and destinations that let them know the location of a public charge point (Electric Vehicle Association England, 2021), (U.K. Department for Transport, 2022a). Similarly, the lack of road signs along main roads indicating the location of charging points was raised in a Norwegian study (Figenbaum, Wangsness, Amundsen, & Milch, 2022).

The (U.K. Department for Transport, 2022a) has noted that consumers need improved signage, including enhanced coordination with local councils around signage. Consumers need to be able to make informed choices, including around accessibility, before they reach a charge point location.

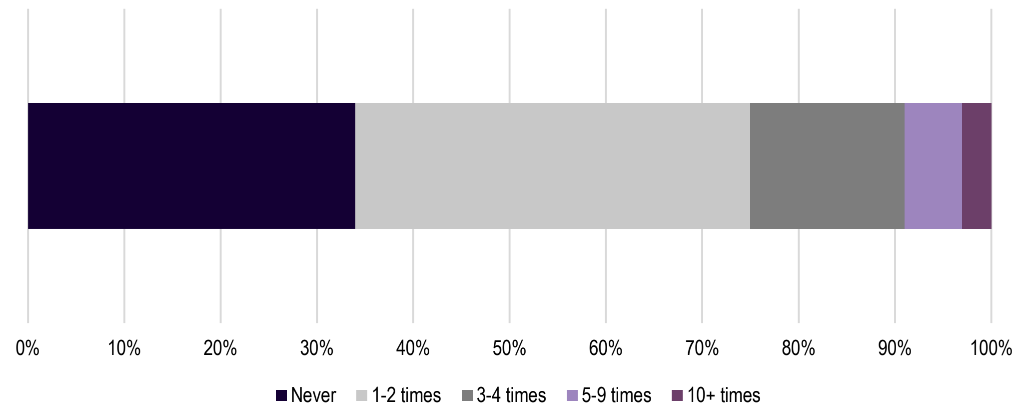
The U.K. Government has committed to improving signage to charge point locations (U.K. Government, 2022).

Ability to get help and support

The reliability issues that consumers experience with public chargers are compounded by poor customer service or long call waiting times (Competition & Markets Authority, 2021).

In a UK survey, 55% of drivers did not agree that there is clear and easy instruction on how to access assistance when issues arise. Only 15% felt that there is clear instruction on how to access assistance. As illustrated in Figure 4.6, most drivers had to call a helpline at least once in the 12 months prior to the survey. Of those drivers who had to call a helpline, 57% indicated that calling that helpline did not resolve their issues, while 43% indicated that it did resolve their issues (Electric Vehicle Association England, 2021).

Figure 4.6 Number of calls to the helpline in a 12 month period



Source: (Electric Vehicle Association England, 2021)

In the UK, the Government has indicated that it will mandate that all public EV charge points must have a free 24-7-hour helpline for consumers that experience an issue when trying to charge their EV (U.K. Department for Transport, 2022a).

4.5 Smart charging

There is substantial opportunity for smart charging of EVs, as they are currently idle about 95% of the time, and users generally need only 10% of the hours in a day for charging (Hildermeier, et al., 2019).

(NewMotion, 2020) has found that 69% of EV drivers are willing to use smart charging, while only 11% are not. The desire to use smart charging offerings is especially strong in the UK (76%) and Germany (75%) and is low in France (40%).

While a survey of German EV users has revealed that they are open to smart charging, as long as flexibility for spontaneous trips is maintained (Anderson, Bergfeld, Nguyen, & Steck, 2022), non-EV users are less willing to accept smart charging due to less control over how their vehicle is charged (Hardman, et al., 2018). (Ofgem, 2021b) similarly found that EV users were significantly more likely than the average driver to feel comfortable having an external company controlling aspects of their electricity use, including charging EVs.

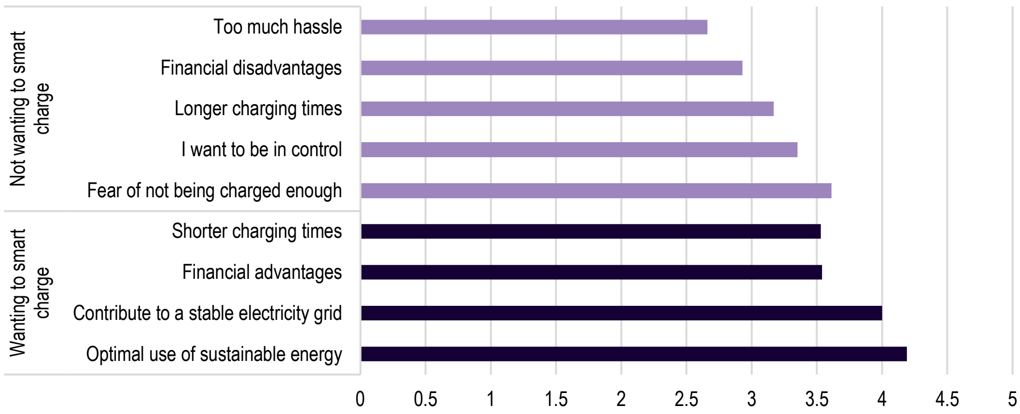
Many EV drivers in the Netherlands are familiar with smart charging. Of those that had experienced smart charging, 59% generally did not notice anything. Twenty-six per cent had a positive experience of smart charging because of:

— the financial benefits
— using their own solar panels
— giving them a good feeling
— contributing to a stable electricity network
— unburdening their installation at home.

Twelve per cent of respondents had a negative experience of smart charging because the EV was insufficiently charged in their experience, due to a problem with the vehicle or the app, the charging time was longer, or uncertainty about charging speed and charging time.

Eighty per cent of respondents indicated a willingness to smart charge. The reasons for wanting and not wanting to smart charge are illustrated in Figure 4.7. Seventy-six per cent want to keep control of their smart charging sessions, and 66% want insight into the smart charging session afterwards (de Brey, Gardien, & Hiep, 2021).

Figure 4.7 Reasons for wanting and not wanting to smart charge



Source: (de Brey, Gardien, & Hiep, 2021)

A Canadian study indicated that EV users are cautious about controlled charging (Axsen, Langman, & Goldberg, 2017). Their concerns about controlled charging relate to:

1. the uncertain impact on the EV's batteries

   "[I would] want to make sure that's not hurting my battery."

   Mr. Feng, (Axsen, Langman, & Goldberg, 2017)

2. it requires too much trust in administration

   "Like, what if I had all these plans … and I thought I was getting 80 [% guaranteed minimum charge] and then they gave me 50?"

   Christine, (Axsen, Langman, & Goldberg, 2017)

3. there is a loss of control.

   "I don't like having no control over … knowing how much the car's gonna be charged?"

   Veronica, (Axsen, Langman, & Goldberg, 2017)

4.5.1 User-managed charging or supplier managed charging?

A UK study explored users' preferences for user-managed charging based on TOU tariffs and supplier managed charging. Participants' willingness to engage with either was generally conditional on large reductions in charging costs, although some participants argued that financial savings were not important to them (or other EV users).

User-managed charging was preferred over supplier managed charging (2/3 : 1/3), because of perceived control and lower perceived risk that a vehicle might not be fully charged at the required time (Delmonte, Kinnear, Jenkins, & Skippon, 2020). After a trial of user-managed charging and supplier managed charging, (TRL Limited for Energy Technologies Institute, 2019) found that just under 90% of participants would choose one of these forms of controlled charging over unmanaged charging, with the likelihood increasing:

— with increasing experience with controlled charging
— if there was public charging nearby in case a back-up was needed
— as the cost savings increased.

Preference for supplier managed charging was based mainly on perceived advantages to society as a whole. Some participants stated they would only be willing to adopt either concept if there was an option to override it and revert to standard charging when required.[15]

Perceived issues that were common to user-managed charging and supplier managed charging were:

— a requirement to interface using a smartphone, with concerns including phone network coverage and having no experience with, other use for, or dislike of a smartphone – locating the interface in the vehicle could be preferred
— the vehicle may not be sufficiently charged in the event of unforeseen journey needs arising during the scheduled charging period
— they involved additional routine time and effort, and perceived effort involved in making the change (Delmonte, Kinnear, Jenkins, & Skippon, 2020).

Another UK trial tested three charging preferences which users could set on an app – optimise time (default), minimise cost (charge in off-peak period only), and optimise time and cost. More than 60% of trial participants changed their app preference away from the default, mostly to 'minimise cost'. Participant satisfaction with the charging arrangements increased through this trial. Eighty-eight per cent of participants who had used the app found the charging preferences and reward structure easy to understand. Eighty-one per cent of participants believed that the tariff structure and charging profiles would encourage many, or most, EV owners to charge their cars outside of peak times (Electric Nation, u.d.).

(Evergreen Smart Power, 2021) found, in a survey of current and prospective EV drivers, that there was a roughly even preference for user-managed charging and supplier managed charging. Some people want simple, convenient charging – they're happy to hand control to someone else as long as they know they'll get what they need. Others want more control – for them, the greater complexity involved in managing charging is worth it for the feeling of personal control.

4.5.2 Smart charging default settings

Both prospective EV drivers and EV drivers expect to set a default charge level (e.g., I want my vehicle charged by 80% by 6am). Those who already have and use an EV recognise the value of default charging even more than those who do not (Evergreen Smart Power, 2021). A study by

[15] The preference for an override function was also revealed by (Energy Technologies Institute, n.d.), (Evergreen Smart Power, 2021) and (TRL Limited for Energy Technologies Institute, 2019).

(Lagomarsino, van der Kam, Parra, & Hahnel, 2022) identified that the likelihood of people using smart charging increased if the default SOC level was translated to distance (in miles) or tailored information (the number of driving days covered by the SOC based on the person's personal driving profile), particularly if the driver covered short driving distances.

Most respondents to a German survey requested an option to submit a minimum range (77%). The average minimum range requested in the sample was 70 km (median 50 km). The ability to override the smart charging process and charge directly was another highly demanded feature (76%) as well as the submission of a planned time of departure (71%). Other than the minimum range, 60% of respondents opted to submit a planned range which serves as an upper threshold beyond which no additional battery charge is necessary. Gentle charging for a prolonged battery life was specifically requested by 56%. Another 37% considered a variation range around their arrival time as useful. Only 3% of the sample did not request any features at all (Will & Schuller, 2016).

4.5.3 Drivers for using smart charging

EV users participating in smart charging trials were generally motivated by an interest in technology, or practical reasons. Those with an interest in technology may be frustrated if they are restricted in their ability to mix and match different technologies. Those with practical concerns were more interested in ensuring that a problem was solved in the most practical way. They were interested in the potential economic benefits of using a charger that only charged off-peak and when electricity was cheaper due to less demand.

(Daziano, 2021) found that EV users are more likely to join a controlled charging program if they are younger, are more highly educated and are on TOU tariffs, and are less likely to join as income increases, while noting there was substantial heterogeneity in users' preferences. Data from a pilot in New York revealed that EV users would need a reduction in their annual fee of $US2.65 for each hour increase in the period during which they give up control of charging their EV.

Understanding flexibility and trust are key to the success of smart charging. Those who had a good understanding of how demand-side response (DSR) would work were significantly more likely to be positive towards it than those who could not express a good understanding. Many participants wanted to know when DSR activity had taken place, to build trust. This trust is crucial to users relinquishing control and allowing their flexibility to be utilised for the benefit of the grid (Evergreen Smart Power, 2021).

4.5.4 Implementing smart charging

While smart charging can be implemented at home, public, and work charging locations, it is not necessarily implemented at all charge points. For example, it may not always be possible to utilise smart charging at DC fast chargers as many EV drivers use these charge points to charge their vehicles quickly.

Smart charging is being implemented in the Netherlands. The system limits charging through communication between the charge point and back of office software. When charging needs to be reduced the current (amps) delivered to the vehicle is reduced. On the other hand, during periods of low demand and high supply, EVs can charge freely. Most consumers have been willing to accept this method of charge management in the Netherlands (Hardman, et al., 2018).

From June 2022, the UK Government requires all charge points installed in private off-street parking and workplaces to be smart and be set to charge only at off-peak times by default. Smart functionality is defined at the device level and includes the ability to:

— send and receive information
— modify the time of charging in response to information received
— use the functions to provide demand-response services.

It also incorporates basic cybersecurity standards, basic interoperability to ensure that charge points are not designed to block change of supplier, and data accessibility, including customer access to consumption data.

Building on these changes, as well as the release of the Smart Systems and Flexibility Plan and Energy Digitalisation Strategy, the UK Government's Electric Vehicle Smart Charging Action Plan will:

> *… improve publicly available information and evidence on smart charging, support the implementation of robust consumer service standards and ensure private charge points are secure and compatible with the latest energy innovations.*
>
> *(U.K. Government, 2023)*

The Government also announced £16 million in innovation funding for the:

— V2X (Vehicle to Everything) programme for technologies that harness the potential of smart charging, including a smart street lamppost that will enable EV owners to access smart charging on the move
— Interoperable Demand Side Response (IDSR) programme, which considers the role of smart meters, technologies, tariffs and services to allow consumers to remotely increase or decrease their use to take advantage of when energy is cheaper or more renewables are on the grid. Projects funded include the integration of EV charge points and other domestic appliances into a smarter energy system.

The Government and Ofgem will be seeking to remove barriers that currently prevent the full development of a diverse and competitive smart charging market, while making sure the electricity system is ready to respond to the increase in energy demand that EVs will bring (U.K. Government, 2023).

In August 2022, the Californian Public Utilities Commission adopted an EV Submetering Protocol. This decision allows any customer to manage the load from EV charging separately from the facility's load and to utilise submeters already embedded within their EV charger, which has the potential to enable more advanced load management (California Public Utilities Commission, 2023).

4.6 Vehicle-to-Grid (V2G)

A Dutch study showed that V2G is largely accepted by EV drivers, albeit with some reservations and caution. Many were sceptical regarding the operation of V2G, especially the incentives for end-users, the adequacy of compensation, battery degradation and its conflict with charging the vehicle for mobility providers (van Heuveln, et al., 2021). (Tarroja & Hittinger, 2021) found that drivers in Nordic countries are willing to participate in V2G programs as long as they are autonomous, do not interfere with travel patterns and drivers are compensated.

4.6.1 Factors influencing acceptance of V2G programs

The factors that were found in the Dutch study to be most important for fostering acceptance of V2G are:

— Financial compensation – both the type of compensation and amount of compensation play a role. However, the degree to which different EV drivers were triggered by compensation was found to vary.

"A monetary compensation, for instance cheaper energy, free parking etc., will stimulate and encourage me to use V2G."

"Financial compensation does not influence my willingness to participate. I do not believe that, with V2G, an amount of financial compensation could be realised which is enough to compensate for the degradation of the battery of my vehicle."

Consumer quotes in (van Heuveln, et al., 2021)

— Transparent communication – a user interface on the charging station would increase transparency and ease of use of the system and thus acceptance. The user interface could, for instance, display charging and discharging information and allow the end-user to view certain settings of the V2G system. Public relations (PR) and communication were found to be essential for fostering long-term acceptance. This included the provision of accurate information about V2G projects and communication of both the benefits of V2G and the possible risks.

"I want to be able to keep control of the system by using a smartphone application which provides notifications about when the car is going to discharge. Furthermore, I want to be able to set a limit for a minimum state-of-charge."

Consumer quote in (van Heuveln, et al., 2021)

— Reliable control of the system by the user – control over charging and discharging can contribute to acceptance. However, some did not want to have this possibility and just wanted the system to arrange everything automatically.

"Preferably, I do not want real-time control. For instance, I don't want to get notifications throughout the whole day about V2G … I believe that a weekly or monthly report (on display in the car or on my smartphone) are enough for me."

"I want to keep control … I do not want [a case where] I am going to make a trip and a third party just drained the battery of my EV."

Consumer quotes in (van Heuveln, et al., 2021)

On the other hand, the factors that were found to have a negative effect on acceptance are:

— Range anxiety – users were worried about the availability of sufficient battery capacity in the EV, particularly for unexpected trips.

"How do I know that mt car is sufficiently charged when I want to leave?"

Consumer quote in (van Heuveln, et al., 2021)

— Discomfort experienced while participating – user-friendliness was mentioned as a precondition for the use of V2G chargers. A complex system with very little information or unclear information would block their acceptance.

" I think that V2G should be made as simple as possible for the end-user. [There should be] free software and the system should work without errors."

Consumer quote in (van Heuveln, et al., 2021)

— Battery degradation – EV lessees were found to be less concerned about the effects of battery degradation than EV owners. They were more concerned about who received compensation for both the energy delivered as well as the battery degradation.

"I find the possible negative effects of V2G on battery degradation acceptable as long as the effect is not larger than for instance battery degradation caused by regular driving."

Consumer quote in (van Heuveln, et al., 2021)

Other important factors influencing acceptance were:

— EV driver profile characteristics – knowledge of batteries, EV motivations, eco-values, technology innovativeness, possession of solar panels, V2G familiarity, previous charging behaviour, EV ownership (noting that 50% of drivers in the Netherlands lease cars).

— Trust – operational reliability, trust in the aggregator, trust in system designers and trust in service providers (van Heuveln, et al., 2021).

A survey of Canadian EV drivers found that enrolment in V2G programs decreased by between 7% and 12% for every 20% decrease in reliable range due to V2G-related operation, and a US study found that EV drivers need to be compensated $US2,000-$8,000 per year to participate in V2G programs (Tarroja & Hittinger, 2021).

In a discrete choice modelling study, (Zhang, Ross, & Cain, 2021) found that potential on-street V2G users in the UK place a higher priority on 'required plug-in hours per month' than 'minimum level of battery guaranteed', but only have a willingness to pay more for an increased 'minimum level of battery guaranteed'. When the total amount of cost is limited, potential users would like to spend the limited amount for an increase in guaranteed driving range, over a decrease in required plug-in time. In other words, people would like to pay more for driving range, rather than having more flexible access to their vehicles. On the contrary, 'required plug-in hours per month' was viewed as more important when consumers were stating their preferences.

4.6.2 V2G trials in the UK

The UK has a number of V2G trials, with the first installations started in December 2018.

In one trial, customer plug-in rates peaked between 17:30 and 18:00 and unplugging between 07:30 and 08:00. On an average day, approximately 61% of the V2G portfolio was available between plug-in and plug-out times. The average battery's SOC on plugging in was 43% and most customers set their car's maximum SOC at 90%.

Based on trialist research, a minimum SOC was developed to ensure a baseline of energy was preserved at all times, in case the car was needed in an emergency (refer Box 4.1). This boosted drivers' confidence in the technology as they were reassured that they would always be able to use their vehicle (Kaluza, 2022b).

Box 4.1 Scenario requiring a change in charging schedule

Consider a scenario where a user parks their vehicle in the parking lot of a restaurant and connects the vehicle to the charging station. The user provides setting preferences, such as selecting whether to charge or discharge the battery possibly by entering a bid, the minimum threshold for the battery level the user would like to have in the vehicle, the minimum distance in miles that the user needs to travel, and the duration of time the user expects to be at the restaurant.

New requirements, such as the need to leave the restaurant sooner or to visit other destinations, result in changes to the user options. The change in charging requirements will result in a new charging schedule for the vehicle.

Source: (Saxena, Grijalva, Chukwaka, & Vasilakos, 2016)

Ninety-three per cent of participants were satisfied or very satisfied with their V2G experience. The level of concern around battery health dropped from 61% at the beginning of the trial to 24% at the end, and worries about cost savings while using V2G decreased from 43% to 28%. Customers expressed a desire for the technology to do more for them, for example, be compatible with their solar PV and be used to deliver back-up power (Kaluza, 2022b).

The concept of using the battery in an EV to power the home or sell electricity back into the grid is still unknown to most EV drivers and the wider population (Kaluza, 2022b). Key learnings from this and other trials include:

1. Clear proposition works best. There are a number of approaches along the “hands-on” to “hands-off” spectrum:
   - hands-on – direct customer reward – energy and service payments are treated separately; user has full visibility
   - mid-range – “Never pay for mile driven ever again” – energy and service payments are aggregated; limited user intervention needed
   - hands-off – easy to understand bundle; EV lease agreement requires plug-in for minimum amount of time.
2. Make rewards simple and engaging – communicating the rewards structure effectively for diverse customer segments is critical especially when it comes to a relatively complex technology.
3. V2G business case does not work for every type of user. Top customer archetypes are The Retired Professional, Council fleet – Pool cars, The Eco-Professional, The Run-around (EV as second car), Company car park, and EV Car clubs.
4. Invest in educating customers – this is key to addressing concerns and misconceptions around the technology and builds trust so that drivers can get the most out of their EV as long as possible. Enabling customers to easily set their V2X charging settings for optimum battery performance is a crucial part of making V2X adoption scalable (Innovate UK, 2019), (Kaluza, 2022b).

4.7 Cyber security

Researchers have identified a number of vulnerabilities in the EV charging system to cyber security attacks (Check Point, 2023), (Gregory, 2023).

The communications networks that connect chargers with their management system, the personal data that travels across those networks, the charge-point operators collecting payments, and the grid itself are increasingly vulnerable as the EV ecosystem grows and the attack surface expands. The risks include (but are not limited to):

- disruption of operations for public charger networks, rendering large numbers of chargers unusable and interfering with transportation
- takeover of charger networks to use the chargers as bots in massive distributed denial-of-service attacks
- theft of customers’ personal identifiable information, including payment card information
- fraudulent payments for electricity used in EV charging
- disruption to the power grid, leading to blackouts and equipment damage (Inbar, 2023).

There are a couple of examples where this has occurred (refer Box 4.2).

Box 4.2 Examples of hackers infiltrating EV charging stations

In February 2022, attackers disabled many EV charging stations along Russia's M11 motorway, which stretches from Moscow to St Petersburg, while the stations' video displays showed unkind messages about Vladimir Putin and pro-Ukrainian messages.

In April 2022, drivers on the UK's Isle of Wight discovered pornography appearing on the screen of EV charging points in the local council's car parks. The attacks took the charging stations offline, further limiting the ability of consumers to charge their cars.

Source: (Gregory, 2023), (Woollacott, 2023)

There are moves towards the introduction of security standards for EV charging stations. In the US, the National Highway Traffic Safety Administration provides recommendations on software security for manufacturers. However, there are no mandatory standards.

The UK introduced new legislation on EV charging security at the end of 2022. All home chargers must now comply with authentication standards and encrypt data. They must also allow owners to change settings to easily delete their personal data if they wish, and must be able to check regularly for security updates. They must conform to Secure Boot standards, run only signed firmware, and must not include hard-coded security credentials (Woollacott, 2023).

4.8 Data privacy

The privacy of customers' data is a big challenge associated with the charging of EVs. The main concern relates to the disclosure of a user's personal details such as name, address, phone number, e-mail address, and banking details (Savari, et al., 2023). However, detailed historical data collection could indirectly have privacy issues as it is possible to determine the home or business of a car owner or even the identity of the driver themselves, based on where cars are charging frequently (U.K. Department for Transport, 2022a).

At least 50% of customers are highly concerned about their privacy, and the other 50% are worried about their confidentiality based on the situation (Savari, et al., 2023). One of the barriers to scheduling the charging of EVs is concern around the privacy of smart charging (12% of survey respondents) (U.K. Department for Business, Energy & Industrial Strategy, 2023).

The (U.K. Department for Transport, 2022a) has stated that there should be robust security and protocols in place to prevent data breaches and fraudulent activity.

4.9 Summary of key pain points and enablers

The key pain points and enablers during the operations and maintenance phase of EV charging, as revealed by the international literature review, are summarised in Table 4.1.

Table 4.1 Key pain points and enablers – operations and maintenance phase

	Pain points	Enablers
Pricing – home charging	EV driver may not be aware of, understand and/or have switched to an EV-specific or TOU tariff.	Information and awareness raising of the benefits of EV-specific and TOU tariffs.
	A smart meter may be required to access an EV-specific or TOU tariff, and a separate meter may be required that applies only to EV charging.	Price comparison sites to include consideration of EV charging loads and EV-specific tariffs.
Pricing – public charging	Pricing structures can be complex and difficult to understand.	Pricing offer to be clearly displayed to the consumer before charging commences.

	Pain points	Enablers
	Pricing information may not be transparent, and may change during the charging process.	
Home charging	There are reported safety issues associated with charging an EV from a standard electricity socket.	Limitations on the use of standard electricity sockets rather than dedicated home charging points, and government recommendations on minimum safety standards to apply. Information and awareness raising on the safety issues, including safe storage and use of connector cables.[16]
	There is a lack of standardisation of the charging point interface.	Standardise charging point interface.
Public charging – discovery and routing	EV drivers need to plan where to charge an EV before embarking on a trip.	The need to plan will lessen with a greater proliferation of public charging points, and by addressing issues relating to reliability, queueing, and standardisation of public charging infrastructure.
	A range of apps are needed to find public charging points, and the information on these apps may be incorrect or out-of-date, and may be static in nature.	Facilitate a single app which contains the location of all public charging points, and includes dynamic data such as availability, charging speed, connector types, pricing and payment method.
Driver authentication and payment initiation	Process to pre-register to access a public charging point may be difficult and time-consuming.	Facilitate a quick and accessible process for pre-registration.
	Multiple apps or cards may be needed to access and pay for public charging points, and may not include standard credit/debit cards or contactless payment methods.	Mandate minimum standards for payment methods which are not specific to a brand and do not require a payee's mobile or internet signal. Facilitate roaming that allows people to pay for charging via a single app or card.
	An internet signal may not be available to access apps.	
	The payment method may not be known in advance of using a charge point.	
Public charging – reliability	Public charger may be out of order or cannot be easily activated or connected to the vehicle.	Mandate minimum standards for the reliability of public charging infrastructure.
Public charging – speed of charging	Charging speed may be low because of the charging speed of the charging point or the vehicle's connector type.	Provide clear information on the speed of the public charging point. Information and awareness raising of the different connector types.
Public charging – queueing	Public charging points may not be available, particularly during peak travel times.	Provide real-time data on the availability of public charging points, and the ability to book a charger.
Public charging – lack of standardisation	Public charging stations vary greatly in terms of connector types, layout, user interfaces, payment solutions, charger activation, cable lengths and locations, and charging power levels.	Increase the level of standardisation of public charging infrastructure.
Public charging - accessibility	There may be additional barriers to those with disabilities to use public charging infrastructure due to the design and/or location of the charging point.	Minimum standards or guidelines for designing accessible public charging points that consider the needs of all users, including disabled and older people.

[16] We note that current and emerging international standards for in-cable control and protection will mitigate some of the safety issues that have been identified internationally.

	Pain points	Enablers
	There may be difficulties for non-EV users with disabilities navigating the streetscape with the installation of on-street chargers.	
Public charging – charging station etiquette	EV charging bays may be blocked by EVs not charging or vehicles that are not EVs.	Prohibit the use of EV public charging bays by vehicles that are not being charged.
	EVs may be unplugged by others during the charging process.	Increase awareness of the appropriate use of public charging bays.
Public charging – facilities	There may be a lack of amenities at or near public charging points.	Provide facilities, similar to those provided at petrol stations, that are appropriate to the type and location of the charging point.
Public charging – lighting and security	EV drivers may feel vulnerable charging their EVs without adequate lighting and security.	Provide a level of lighting and security features that are appropriate to the type and location of the charging point.
	EV drivers may have difficulty charging their EVs without adequate lighting.	
Public charging - weatherproofing	Charging an EV during inclement weather is uncomfortable in the absence of a roof.	Provide roofing, similar to that provided at petrol stations, that is appropriate to the type and location of the charging point.
Public charging – signage	A lack of road signs may make it difficult to find a public charging point.	Install road signage directing users to public charging infrastructure, similar to that provided for petrol stations, that is appropriate to the type and location of the charging point.
Public charging – help and support	EV drivers experiencing difficulties with a public charging point may not be able to readily access the requisite help and support.	Provide ready access to help and support.

Smart charging and V2G	EV owners may be concerned about using smart charging or V2G due to a lack of trust and loss of control resulting in:
	– the EV:
	  – being insufficiently charged
	  – taking longer to charge
	– uncertainty about charging speed and charging time
	– degradation of the EV’s battery.
		Have a user-friendly interface which includes an override functionality.
		Provide simple and engaging rewards for using smart charging or V2G.
		Information and awareness raising of the benefits associated with smart charging and V2G.

Cybersecurity	Potential for a cybersecurity attack resulting in an inability to charge or a loss of personal data.	Minimum security standards for home and public charging points and networks.
Data privacy	Potential for the direct or indirect loss of personal data.	Robust protocols to prevent breaches and fraudulent activity.

Source: ACIL Allen

5 Retention

The retention phase occurs post-installation to ensure customers continue to be satisfied with their EV charging product or service, leading to continued engagement advocacy.

EV charging should be a seamless experience for customers. However, a number of pain points have been identified for EV users relating to the engagement and acquisition phase (chapter 2), installation phase (chapter 3), and operations and maintenance phase (chapter 4). These issues matter because current EV drivers can experience unacceptably poor service and they deter others from switching to an EV by contributing to 'range anxiety' (U.K. Department for Transport, 2022b).

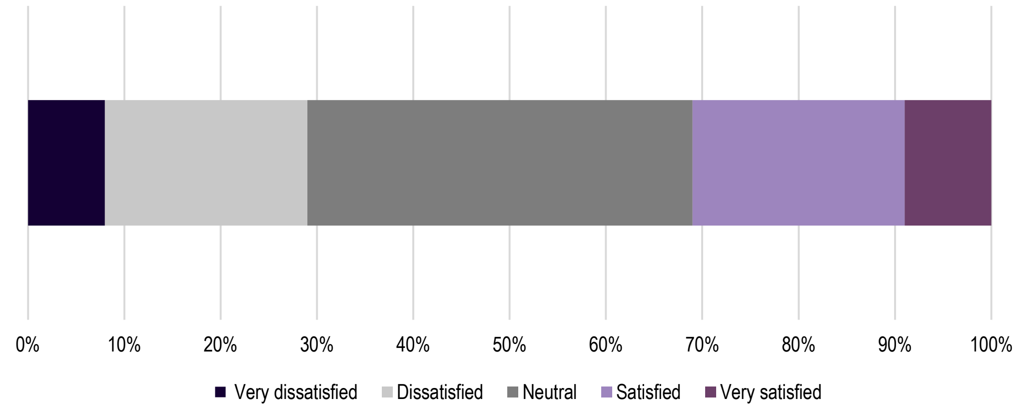
Analysis by (Chu, Im, Sun, & Park, 2019) identified that EV charging contributed to EV users being dissatisfied with their EVs, with the extent to which it contributes to dissatisfaction varying by country:

— China – range (21%), battery charging (20.3%), safety (including battery explosions) (12.6%)
— Korea – battery charging (50%), range (33.3%).

(Song, Chu, & Im, 2021) found that US EV owners were more satisfied with their EVs than Chinese EV owners. Twenty per cent of Chinese EV owners gave an overall satisfaction score of 3 or less out of 5, while only 5% of US EV owners did so. Of those that were dissatisfied in China, 70.7% was due to a lack of charging facilities and difficulties with charging, and 14.6% were worried about safety (battery explosion, etc.). Of those that were dissatisfied in the US, 30.3% was due to difficulties with charging, 30.3% was due to short driving range and none were worried about safety.

EV drivers in the UK rate their general satisfaction with public EV charging at 2.16 out of 5 (Electric Vehicle Association England, 2021) and in an early Californian survey, 83% expressed varying levels of dissatisfaction with public charging infrastructure (California Center for Sustainable Energy, 2012). As illustrated in Figure 5.1, Norwegian EV owners are only modestly satisfied with the publicly available charging infrastructure. In practice, only 4% of EV owners have experienced an empty battery and less than a quarter experienced a "close call". Almost 20% of EV owners in Norway did not use their EV on several occasions due to the lack of chargers and more than 10% due to long charging times (International Energy Agency, 2018) (Norsk elbilforening, 2017).

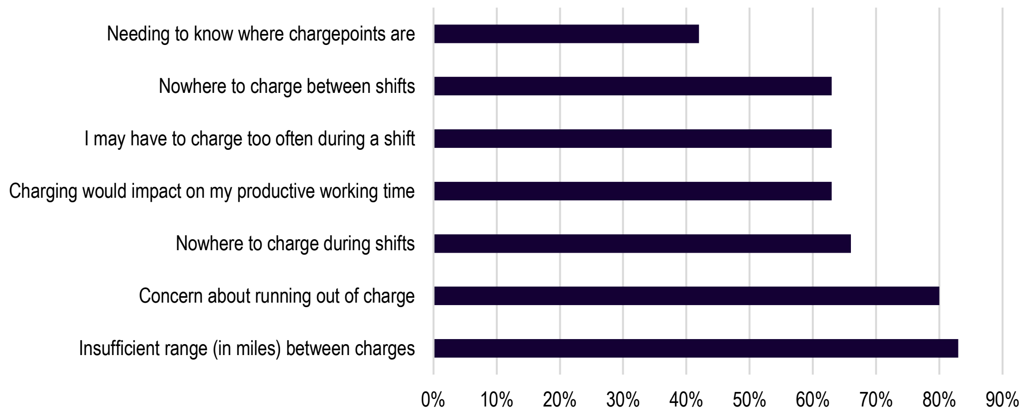
Figure 5.1 Level of satisfaction with public charging infrastructure, Norway



Source: (Norsk elbilforening, 2017)

(Energy Saving Trust, 2016) identified that 7 of the 9 barriers to UK taxi drivers operating an EV relate to charging, as illustrated in Figure 5.2.

Figure 5.2 Charging-related barriers to taxi drivers operating an EV



Source: (Energy Saving Trust, 2016)

A Californian survey by (Hardman & Tal, 2021) investigated the rates of discontinuance of EVs and factors correlated with discontinuance. The authors found that 20.1% of PHEV and 18.1% of BEV owners reverted to an ICEV. The discontinuance is correlated with the convenience of charging for both BEV and PHEV owners. BEV discontinuance is correlated with not having level 2 (240 V) charging at home.[17]

(NewMotion, 2020) identified that the most important improvements for a better charging experience are:

— faster charging (48% of respondents)

— increased availability of public charge points (46%)

— a single charge card for any public charge point (41%).

In the Netherlands, fast charging would be a more important improvement than in other countries. In Germany, UK and France the availability of charge points is considered to be more important. In

[17] The standard level 1 charger in the US uses the standard 120 V electricity socket, which is lower speed than level 2 charging.

almost all countries the switch to one single card for a seamless public charging experience is the most pressing matter to improve, except for the Netherlands. This is probably because of the high amount of roaming in the Netherlands.

Interviews by the (University of California, Davis, 2020) revealed that some early EV drivers continue to learn about their EVs and charging infrastructure, even months or years after they acquired one. Other EV owners may use their car based on habits and routines they developed early and have remained unchanged despite changes, such as increasing infrastructure.

The research did not reveal any specific activities that are currently being undertaken during the retention phase. An interview with Energy Systems Catapult identified that, for those that continue to learn about their EVs and charging infrastructure, the key activity that is missing to improve satisfaction with the EV charging experience is the provision of information to build understanding of the charging process.

5.1 Summary of key pain points and enablers

The key pain points and enablers during the retention phase, as revealed by the international literature review, are summarised in Table 5.1.

Table 5.1 Key pain points and enablers – retention phase

Pain points	Enablers
There are many sources of dissatisfaction with the EV charging process, as discussed in the preceding chapters. A US survey found that dissatisfaction with the convenience of charging and the absence of faster charging (level 2) at home were factors influencing EV owners to discontinue using an EV.	While a number of enablers have been identified above, a European study has revealed that the most important improvements required relate to: – faster charging – increased availability of public charger points – single charge card for any public charge point. Information and awareness raising of the overall charging experience.

Source: ACIL Allen

Key enablers and pain points along the customer journey 6

The EV ecosystem, including the EV charger, is complex. There are a range of pain points for customers along the EV charging journey – from the engagement and acquisition of the products and services that are required to charge an EV, installing EV charging products and services, to the ongoing charging of the EV. The key pain points along the EV charging customer journey, as revealed through the international literature review, are summarised in Table 6.1.

Table 6.1 Key pain points and enablers along the EV charging customer journey, as revealed by the international literature review

Customer journey phase	Pain points	Enablers
Engagement and acquisition	There is a chicken and egg dilemma: – the decision to purchase an EV charging product or service is secondary to the decision to purchase an EV the decision to purchase an EV is dependent on the availability of charging infrastructure.	Improved information on the availability of public charging infrastructure, and on home charging options, to increase awareness and understanding by car dealerships and end customers.
	The EV ecosystem is complex with purchasers of an EV needing to interface with multiple parties, including a number of parties relating to home charging, if the potential purchaser has the option to install home charging.	
	There is currently low awareness and understanding of the different charging point options, and car dealerships may not be well placed to advise customers.	
	A dedicated home charge point may be expensive, and all costs associated with purchasing a dedicated home charge point may not be known upfront.	Obligations on suppliers and installers of dedicated home charge points to assess the supply adequacy for a dedicated home charging point so that the full costs for the supply and installation are quoted upfront.
Installation	There are reported safety issues associated with charging EVs at home using a standard electricity socket, including burnt sockets, blown fuses, overheating of long charging cables, and rain mixed with sockets.	Government recommendations related to the use of standard electricity sockets and dedicated charging points for charging EVs at home, including separate circuit and fuse, and ground fault detection.[18] Information on charging EVs safely at home using standard electricity sockets and dedicated EV chargers.
	There may be insufficient capacity to supply a dedicated home EV charging point.	Prior to installation of a charge point, ensure there is an assessment of supply adequacy to ensure all costs are known before commencement of the installation phase.
	There may be significant additional costs to install a dedicated home charge point if the premises need re-wiring and/or the fuse upgraded to accommodate the charge point.	

[18] We note that current and emerging international standards for in-cable control and protection will mitigate some of the safety issues that have been identified internationally.

Customer journey phase		Pain points	Enablers
		Those living in rented, leased or multi-unit accommodation may find it difficult to get permission to install or decide who pays for home EV charging points.	Introduce a "right to charge" for those living in rented, leased or multi-unit accommodation.
Operations and maintenance	Pricing – home charging	EV driver may not be aware of, understand and/or have switched to an EV-specific or TOU tariff.	Information and awareness raising of the benefits of EV-specific and TOU tariffs.
		A smart meter may be required to access an EV-specific or TOU tariff, and a separate meter may be required that applies only to EV charging.	Price comparison sites to include consideration of EV charging loads and EV-specific tariffs.
	Pricing – public charging	Pricing structures can be complex and difficult to understand.	Pricing offer to be clearly displayed to the consumer before charging commences.
		Pricing information may not be transparent.	
	Home charging	There are reported safety issues associated with charging an EV from a standard electricity socket.	Limitations on the use of standard electricity sockets rather than dedicated home charging points, and government recommendations on minimum safety standards to apply. Information and awareness raising on the safety issues, including safe storage and use of connector cables.[19]
		There is a lack of standardisation of the charging point interface.	Standardise charging point interface.
	Public charging – discovery and routing	EV drivers need to plan where to charge an EV before embarking on a trip.	The need to plan will lessen with a greater proliferation of public charging points, and by addressing issues relating to reliability, queueing, and standardisation.
		A range of apps are needs to find public charging points, but the information on these apps may be incorrect or out-of-date, and may be static in nature.	Facilitate a single app which contains the location of all public charging points, and includes dynamic data such as availability, charging speed, connector types, pricing and payment method.
	Driver authentication and payment initiation	Process to pre-register to access a public charging point may be difficult and time-consuming.	Facilitate a quick and accessible process for pre-registration.
		Multiple apps or cards may be needed to access and pay for public charging points, and may not include	

[19] We note that current and emerging international standards for in-cable control and protection will mitigate some of the safety issues that have been identified internationally.

Customer journey phase	Pain points	Enablers
	standard credit/debit cards or contactless payment methods.	Mandate minimum standards for payment methods which are not specific to a brand and does not require a payee's mobile or internet signal.
	An internet signal may not be available to access apps.	Facilitate roaming that allows people to pay for charging via a single app or card.
	The payment method may not be known in advance of using a charge point.	
Public charging – reliability	Public charger may be out of order or cannot be easily activated or connected to the vehicle.	Mandate minimum standards for the reliability of public charging infrastructure.
Public charging – speed of charging	Charging speed may be low because of the charging speed of the charging point or the vehicle's connector type.	Provide clear information on the speed of the public charging point. Information and awareness raising of the different connector types.
Public charging – queueing	Public charging points may not be available, particularly during peak travel times.	Provide real-time data on the availability of public charging points, and the ability to book a charger.
Public charging – lack of standardisation	Public charging stations vary greatly in terms of connector types, layout, user interfaces, payment solutions, charger activation, cable lengths and locations, and charging power levels	Increase the level of standardisation of public charging infrastructure.
Public charging - accessibility	There may be additional barriers to those with disabilities to use public charging infrastructure due to the design and/or location of the charging point.	Minimum standards or guidelines for designing accessible public charging points that consider the needs of all users, including disabled and older people.
	There may be difficulties for non-EV users with disabilities navigating the streetscape with the installation of on-street chargers.	
Public charging – charging station etiquette	EV charging bays may be blocked by EVs not charging or vehicles that are not EVs.	Prohibit the use of EV public charging bays by vehicles that are not being charged.
	EVs may be unplugged by others during the charging process.	Increase awareness of the appropriate use of public charging bays.
Public charging – facilities	There may be a lack of amenities at or near public charging points.	Provide facilities, similar to those provided at petrol stations, that are appropriate to the type and location of the charging point.
Public charging – lighting and security	EV drivers may feel vulnerable charging their EVs without adequate lighting and security.	

Customer journey phase		Pain points	Enablers
		EV drivers may have difficulty charging their EVs without adequate lighting.	Provide a level of lighting and security features that are appropriate to the type and location of the charging point.
	Public charging - weatherproofing	Charging an EV during inclement weather is uncomfortable in the absence of a roof.	Provide roofing, similar to that provided at petrol stations, that is appropriate to the type and location of the charging point.
	Public charging – signage	A lack of road signs may make it difficult to find a public charging point.	Install road signage directing users to public charging infrastructure, similar to that provided for petrol stations, that is appropriate to the type and location of the charging point.
	Public charging – help and support	EV drivers experiencing difficulties with a public charging point may not be able to readily access the requisite help and support.	Provide ready access to help and support.

	Smart charging and V2G	EVs may be concerned about using smart charging or V2G due to a lack of trust and loss of control resulting in:
		– the EV:
		  – being insufficiently charged
		  – taking longer to charge
		– uncertainty about charging speed and charging time
		degradation of the EV's battery.
			Having a user-friendly interface which includes an override functionality.
			Provide simple and engaging rewards for using smart charging or V2G.
			Information and awareness raising of the benefits associated with smart charging and V2G.

	Cybersecurity	Potential for a cybersecurity attack resulting in an inability to charge or a loss of personal data.	Minimum security standards for home and public charging points and networks.
	Data privacy	Potential for the direct or indirect loss of personal data.	Robust protocols to prevent breaches and fraudulent activity.
Retention		There are many sources of dissatisfaction with the EV charging process, as identified above. A US survey found that dissatisfaction with the convenience of charging and the absence of faster charging (level 2) at home were factors influencing EV owners to discontinue using an EV.	While a number of enablers have been identified above, a European study has revealed that the most important improvements: – faster charging – increased availability of public charger points – single charge card for any public charge point. Information and awareness raising of the overall charging experience.

Source: ACIL Allen

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Appendices

Summary of literature reviewed

A

Table A.1 Summary of literature reviewed

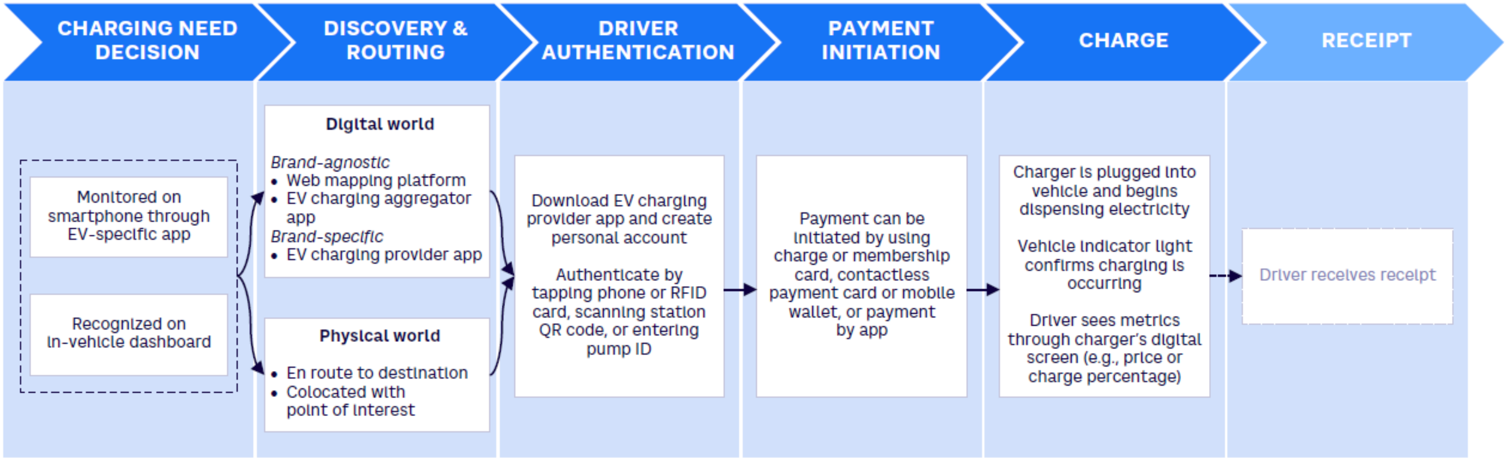
Article	Key points
(Albert, 2022)	Norway's scenic, slow-paced roads and numerous fast-charging stations make it an ideal place to go on an electric car vacation. The reason the reduced speeds are an advantage is that they typically help in getting the most range out of an electric car's battery. Another fun part of driving an electric car in Norway's fjord country is that the battery actually recharges on steep downhills. **How to start the charging session** Unless slow charging with a normal wall outlet, starting (and ending) the charging session is best done with a smartphone. Annoyingly, each charging operator has its own app, so quite a few may need to be downloaded. Charging sessions can also be started via SMS or using an RFID chip. This chip may be provided to you by the car rental agency. Different chips work for different operators, so EV drivers will most likely end up having to download a bunch of apps. **Planning an electric car road trip in Norway** When planning an itinerary, EV drivers need to see if there are convenient spots where they can combine a stop (lunch, sightseeing, hike) with a charging session, and to stay only at hotels that offer overnight charging. Since the battery generally won't get to 100% from fast charging, the only time the EV will be at full range is at the start of the day after slow/medium-charging overnight. **Finding electric charging stations in Norway** Google Maps contains information about many charging stations, but since the data often comes from the users themselves, it may not always be up to date. The electric car association of Norway has a handy guide that contains a map of charging stations. The different apps also have maps (but only of their own stations). The car's own navigation system may also be able to point towards some charging stations, but again, but this may not be entirely up to date (more stations may exist than what it knows about). **Charge when you can** EV drivers should never put themselves in a situation where they are 100% dependent on making it to a specific fast-charging station. Charging stations rely on complex technology, and don't always work. On one occasion, a whole station was knocked out of order during a thunderstorm. If travelling during a tourism rush, an EV driver may experience unreasonably long queues, so it's always good to have a plan B. This means that if an EV driver gets to a charging station when the battery is at 55% and it's available with little to no waiting, then just top up a little bit. It may save the day down the road.

Article	Key points
(Anderson, Bergfeld, Nguyen, & Steck, 2022)	Survey of around 4,000 EV users in Germany, conducted during the COVID-19 pandemic. The survey included a stated choice experiment and a willingness-to-pay analysis. The EV users were homogenous – mostly male, highly educated (e.g. university degree), 50 years or older, with a high income, and living in a two-person household in a detached house. Participants' charging behaviour was dominated by home charging; public infrastructure was perceived to be insufficient. More than two thirds of all PHEV users charge their EV (almost) daily, tending to charge every time upon arriving at home. The majority of BEV users charge 1 to 3 days per week (42%) – they more strongly perceive the wide range of charging infrastructure and wish for more flexibility when making spontaneous trips. The availability of renewable sources, charging power, and charging price play a larger role for BEV users than PHEV users. Next to charging prices, measures of comfort through the occupancy rate of charging infrastructure and additional waiting time are driving factors when making the decision whether to charge or not. Participants specified an acceptable time for walking distances when parking at charging facilities between 5 and 10 minutes. High absention rates in answering some questions indicate the need for sufficient education strategies considering existing and new charging technologies. Considering the age of the representative EV user, attention should be directed to simplifying the charging process when it comes to ease-of-use and the payment process. Drivers with high annual mileage and battery electric vehicle users are willing to pay more for additional charging power. A BEV user's willingness to pay increases with the range of their EVs. Users are open to smart charging, as long as flexibility for spontaneous trips is maintained. Most BEV users would prefer minimum ranges between 100 and 150km before smart charging starts.
(Anderson, Lehne, & Hardinghaus, 2017)	Survey of 843 EV users in Germany regarding their preferences for public charging infrastructure. Survey respondents were early adopters and thus have unique characteristics that do not mirror the larger society (i.e., high income, highly educated, open to new technologies, environmentally aware). Key preferences: 1. Preference for semi-fast (22 kW AC) charging stations (50%), compared to 22% for each of slow charging and fast charging. 2. Slow charging (3.7 kW AC) is acceptable for frequently used stations, whereas fast charging (50 kW DC) is desired for infrequently used stations. 3. Slow charging is acceptable for locations where vehicles are parked over a longer period of time. Preferences by location: work (16%), education/day care (1%), own house/apartment (3%), shopping (18%), chores 9%%), leisure (18%), other (6%), "stop-to-charge" (29%), not selected (5%). Semi-fast and fast chargers are preferred for "stop-to-charge" events. Frequency of use: (nearly) daily (18%), 1-3 days per week (24%), 1-3 days per month (33%), less frequently (20%), not selected (5%) Proximity to German freeway: 19% along the freeway (using a buffer of 250m from freeway), 81% outside the freeway
(Appunn, 2021)	In September 2021, Germany's federal parliament passed a bill that requires every EV public charging point to have a debit or credit card reader from June 2023.

<table>
<tr><th>Article</th><th>Key points</th></tr>
<tr><td>(Arthur D. Little, 2022)</td><td>

Survey of more than 750 EV drivers across the US and several in-depth interviews to understand the EV charging journey – charging need decision, discovery and routing, driver authentication, payment initiation, charge and receipt.

Figure 1. The EV charging journey



Source: Arthur D. Little

Public charging experience is inconsistent – can vary in plug type, location, type, payment availability, and membership requirements. Most charge point operators (CPOs) require drivers to download an app and create a user account before using their stations, causing additional friction in the process. A California Air and Resource Board survey found that 62% of respondents had between 2 and 5 network memberships, but membership does not equal loyalty. While ADL's survey found nearly 70% of participants use public charging relatively frequently (daily or weekly), vast majority (72%) do not have a preferred public charging provider.

In a University of California, Berkeley study, more than 25% of non-Tesla direct current fast chargers in the San Francisco Bay area were not functional, and analysis of charging data found only 85% of initiated sessions lead to a successful charge.

Pain points in the customer journey:

1. Charging needs and "range anxiety" – EVs require drivers to plan trips more thoughtfully, especially long-distance ones. Depending on the EV model, the in-vehicle display attempts to help drivers to manage charge planning by providing remaining driving capacity and how this translates to miles left in the tank. However, speed, topography, and adverse driving conditions can lead to faster-than-anticipated battery use.
2. Finding the "right" charging station – 61% of customers have a preferred public charging location, with the most important criteria being price (25%), proximity (24%), familiarity with station (16%) and reliability (14%). Public charging availability, particularly for fast charging, varies significantly depending on location. Therefore the driver must sometimes use multiple tools (e.g., in-vehicle displays, proprietary apps, Google Maps etc.) to develop a view of options in the local area. Once location decided, potential inconveniences include glitchy navigation apps leading nowhere to physical blockades like

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Article	Key points
	snowdrifts preventing access to a given charging point. Most common grievance is charging apps not updating charge-point availability in real-time. Half the drivers who arrived at a station and left without charging their vehicles cited long wait times. 15% of respondents reported an unwillingness to wait at all for a charging station to free up; 31% will wait 5-10 minutes. 3. Complicated driver authentication – the driver can authenticate via a radio frequency identification (RFID) card, a smartphone app, or by plugging in the car, which is a feature currently exclusive to Tesla. If the driver arrives at a station and is not already a member of that charging network, then the driver is frequently required to download the provider's app (often relying on cellular connectivity), create an account, and enter vehicle and payment information before being able to charge the vehicle. Excluding Tesla drivers, between 50% and 75% of survey respondents have not downloaded or very seldom use proprietary apps from major CPOs. Once the driver has joined the network, network issues can often occur and stop the authentication process from moving forward, thus making it difficult to impossible for the driver to receive a charge. 4. Payment initiation problems – more than half of respondents prefer to pay using traditional credit cards (36%) or mobile payments (18%). 27% like to pay through a charging network app. Those paying by credit card may encounter issues with the card reader, requiring the driver to call the CPO's customer contact number. Of those who call, only about half are "satisfied" with the service. 5. Charging challenges – before charging, the customers may find cumbersome plugs, lack of weather protection, or remote areas with little to no choice of activities to do during charging. Chargers may be ambiguously labelled in terms of their speed and can still be throttled due to hardware issues or CPO-imposed limits. 55% of respondents rank charging speed as "very important" and are willing to go out of their way for faster charging. The more severe charging issue regards the "handshake" between the vehicle and the charger. Handshake problems include: the charger may indicate its readiness to charge but never initiates the charge; the charge may initiate but is interrupted before completion; or the vehicle and plug may never connect at all. Reasons for leaving a charging station – wait time too long (52.4%), broken charging hardware (17.2%), faulty vehicle connection ("handshake") (16.6%), unable to process payment (7.0%), physical barriers to charger (e.g. snow) (5.6%), other (1.2%)
(Axsen, Goldberg, & Bailey, 2016)	Early PEV buyers (or ''Pioneers") can substantially differ from present conventional vehicle owners that have interest in purchasing PEVs in the future (or the ''Potential Early Mainstream buyers"). To compare the characteristics, preferences, and motivations of Pioneers and Potential Early Mainstream buyers, the authors drew data from the 2013-2014 Canadian Plug-in Electric Vehicle Study, a three-part mixed-mode survey with samples of PEV owners (n = 94) and conventional new vehicle buyers (n = 1754). They identified several significant differences in the household characteristics of Pioneers, including income (significantly higher), education (three times more likely to have a graduate degree), and recharge access (97% reported having access to a 110/120V outlet near their vehicle compared to 66% of Mainstream consumers). They are also more likely to be male and in the 46-64 age range. In terms of preferences, Pioneers express extremely high valuation of PEVs and prefer pure battery electric vehicle (BEV) designs over plug-in hybrid electric (PHEV) designs. In contrast, Potential Early Mainstream respondents prefer PHEVs. Both Pioneer and Potential Early Mainstream respondents are similarly cautious about controlled charging programs, although Pioneers are more sensitive to the guaranteed minimum charge. Pioneers place five times as much value on using electricity generated from renewable sources than the Potential Early Mainstream. Pioneers are also less likely to express interest in controlled charging programs, which could, in part, be explained by the fact that Pioneers have significant experience with PEV charging and have a better understanding of their daily need for electric range. Pioneers also tend to have different motivations, including significantly higher levels of environmental concern, and higher engagement in environment- and technology-oriented lifestyles.

Article	Key points
(Axsen, Langman, & Goldberg, 2017)	This study was part of a larger Canadian Plug-in Electric Vehicle Study conducted in 2013-2014 with Mainstream new vehicle buyers. 22 semi-structured interviews were conducted between August 2013 and February 2014 to explore Mainstream buyers' knowledge and perceptions of plug-in electric vehicles (PEVs) and utility controlled charging (UCC) programs. Participants were limited to those with an assigned home parking space for one or more of their vehicles, as early interviews indicated that access to a reliable home parking space seemed critical to conceptualising PEV charging and usage scenarios. Participants tended to be of higher income than the population, slightly older than the full Mainstream sample and significantly more educated than the population and the full Mainstream sample. Participants' perceptions of charging PEVs:

Perception	Negative or Positive	Number of households explicitly citing this	Example quotes
Finding a convenient place to charge would be difficult	Negative	15	"[With a PEV] you've got to map out the city and decide, "Okay, well, I'm going over here but if I plug in here that means I've got to walk 15 blocks …" – Al
Charging a PEV requires too much time	Negative	7	"Or road trips or something – do you literally take your family and you sit there and you charge your car and you try and entertain your kids for three hours?" – Christine
Plugging in is inconvenient	Negative	3	"And then, of course, when I get home, I have to plug it in. So it's just like for me, inconvenient." – Mr. Young
Home charging is easier than going to a gas station	Positive	3	"You come back home and you just charge it up again." – Kevin

Most of the confusion about UCC concepts stems from the fact that most consumers do not usually think or talk about the sources of their electricity, not the varying impacts of different timing of electricity generation or consumption.

Participants' perceptions of UCC:

Perception	Negative or Positive	Number of households explicitly citing this	Example quotes
Uncertain impact of UCC on PEV batteries	Negative	3	"[I would] want to make sure that's not hurting my battery." – Mr. Feng
Requires too much trust in administration	Negative	7	"Like, what if I had all these plans … and I thought I was getting 80 [% guaranteed minimum charge] and then they gave me 50?" – Christine
Loss of control	Negative	9	"I don't like having no control over … knowing how much the car's gonna be charged" – Veronica

Article	Key points
(Baumgartner, et al., 2022)	Survey conducted in Germany (n=1196) in January and February 2021 to assess users' minimum range requirements and willingness to pay for a vehicle-to-grid (V2G) charging tariff and relate them to users' experience with EVs. The respondents included 264 EV owners, 241 people with medium EV experience, and 691 respondents with no experience on a V2G charging tariff. Expectations for the minimum charging level that must always be available during the charging process were high, independently of the level of user experience. The average minimum gathering level was 199 km compared to an average driving range of 22 km in urban areas and 37 km in rural areas. Four potential explanations for these high values: 1. People expressed their objection towards V2G by stating very high values. 2. People clearly overestimated their minimum charging level or were not able to estimate realistic values. 3. People truly have high minimum charging requirements. 4. People did not understand the concept of minimum charging level. Environmental benefits are much more valued by EV owners, while financial benefits are less attractive. There was generally a low willingness to pay (WTP) for a V2G charging service: -42% over the whole sample compared to the reference price. Users assign a greater value to flexibility, leading to a significantly lower WTP or to a higher readiness to pay more to gain additional flexibility. Proficient users were WTP significantly lower electricity prices (-43%) to charge their EV using a V2G charging service than inexperienced users (-35%). That is, EV users expect the monetary benefits arising from V2G to be higher than inexperienced users. Experienced users might be better able to estimate the value of engaging in such a charging program.

(BCG, 2021)	End-customer EV charging needs:
	– Home and work charging – primarily private slow charging
	  – Practical and affordable hardware
	  – Convenient installation
	  – Ability to track and manage energy consumption
	  – Integrated into local energy infrastructure
	– En-route charging – primarily public high-power charging
	  – Broad network coverage
	  – Capacity, quality and speed
	  – Easy search and booking; prebooking functionality; automated GPS suggestions
	  – Convenient access and billing
	– Destination charging – public charging, both slow and fast
	  – Easy access, attractive offers (including free charging)
	  – Simple search and booking
	  – Available at high-demand locations
	  – Charging speed in accordance with average stay at destination

Article	Key points
(Berglund, 2022)	The Norwegian government is acting in line with the EU in forcing the operators of charging stations to accept payment via debit- or credit cards instead of having to download a huge array of apps on their mobile phones. All charging stations installed in Norway after 1 January 2023 must offer card payment, and the government will set a deadline for card payment on those already in service.
(Bleakley, 2023)	The United States has announced a new set of standards designed to solve the growing frustration over the reliability and availability for electric vehicle charging stations. the intention of the standards is to build an accessible, reliable, convenient and user-friendly EV charging network across the US. High among the new standards are a requirement that EV charging stations have a minimum 97 per cent uptime, and is also seeking to reduce the number of apps that EV drivers must download to access various chargers.
(Bunce, Harris, & Burgess, 2014)	Drivers in the UK Ultra Low Carbon Vehicle trial (n = 135, 29% female, average age of 47 years) completed questionnaires and were interviewed to assess their attitudes and experiences before they obtained their EV and after driving the EV for 3 months. The results demonstrated that drivers were positive about recharging – preferring it to 'refuelling' – and they became more relaxed over time about the frequency of recharging. Drivers managed without using a public charging infrastructure. **Issues around recharging versus refuelling** The majority of drivers did not think that adapting to charging their EV would be a difficult task (73%). After experiencing the charging process for 3 months significantly fewer drivers (88%) did not think that adapting to charging the vehicle had been difficult. It was often described in the interviews as being as simple as plugging in a household appliance. When drivers were asked after 3 months whether they preferred recharging to refuelling, the vast majority of drivers (85%) indicated a preference for 'plugging-in' at home to refuelling by visiting a petrol station. In the interviews, drivers explained several reasons for this preference which included convenience, cleanliness, independence (from oil companies), time and cost effectiveness, and not paying for the cost upfront. However, from the 3 month interviews, it was apparent that there were some differences between the times it took individual drivers to adapt to the mechanics of the charging process. Some drivers complained that the charging cable was 'cumbersome' and that lining up the pins in the socket was 'fiddly', especially at night time or if the charging location was outside and the weather was wet. Also, there was a period of learning through trial-and-error. In this period, among successful recharges, some attempts were unsuccessful. Reasons for unsuccessful charging included the charging station having tripped, incompatibility between the rate of charging for the vehicle and charging station, or the electrical connection not having been made. As indicated in the interviews, drivers would have welcomed confirmation that the electrical connection had been made, and the ability to find out remotely how the charging was progressing, for example, via a message sent to their mobile phone. Another aspect of the recharging process was the time the battery took to charge, with 66% of drivers agreeing (or were neutral) at the 3 month point that the time to charge had not limited their use of the vehicle during the trial. Experience of driving an EV may allay concerns over battery charge duration. **Recharging routines** Drivers said that they had a predominant recharging routine but sometimes recharged on the basis of different criteria depending on the circumstances. In the 3 month questionnaire, no drivers indicated that they waited until the warning light showed. Forty-nine percent of drivers agreed that they recharged at a regular interval regardless of the state of battery charge and this was usually at home overnight or at work during the day. Some drivers saw positive similarities between this recharging habit and the habit of charging their laptop or mobile phone.

Article	Key points
	Drivers also agreed that they recharged their EV when the state of charge was 'low' (54% of drivers). There was considerable variation among drivers about what constituted a low state of charge. In the 3 month questionnaire, approximately half the drivers (46%) felt that 21–40% level of remaining battery charge was 'low' and 46% felt that 10–20% was low. Drivers who recharged according to when they felt that the battery had a low state of charge usually calculated future journey requirements to decide whether or not they needed to recharge. The third charging pattern in which 55% of drivers agreed they engaged was to charge the vehicle whenever the opportunity arose. Recharging behaviour was partly affected by the way they needed to use their vehicle: drivers who charged the vehicle at every opportunity tended to use the car extensively during the day to travel to different sites as required by their employment. In contrast, drivers who tended to recharge overnight or only when necessary used their vehicle predictably to travel to and from work or for making short planned local journeys. The main change with regard to recharging routines that drivers discussed in the 3 month interviews was that they had become more relaxed about charging as they gained more knowledge and confidence about vehicle performance. **Public charging infrastructure (PCI)** Pre-trial, 89% of drivers agreed that a PCI would be essential for EV owners but after 3 months this number reduced significantly to 73%. Similarly, the number of drivers who personally thought that they would be able to complete their daily trips without a PCI rose significantly from 76% pre-trial to 85% after 3 months. In addition, over half the drivers (61%) indicated that they would buy an EV in the future, even if the only place they could charge the vehicle was at home. Drivers were asked how many times during the trial they had used a public charging site; 39% indicated never, 47% indicated between 1 and 5 times, and 14% indicated more than 5 times. Of the drivers who had used the PCI at least once, the majority (78%) had difficulty finding a charging point and of those drivers, only 46% indicated that it was easy to use. The lack of a standardised charging system also put off some drivers from wanting to rely on it.
(California Air Resources Board, 2023a)	The Electric Vehicle Supply Equipment (EVSE) Standards regulation establishes requirements for EVSE that build driver confidence in accessing public charging infrastructure. EVSE must be accessible to drivers regardless of membership in an Electric Vehicle Service Provider (EVSP) network. EVSPs must operate credit card readers and mobile payment device options on Level 2 and direct current fast charger EVSE allowing payment by members and non-members at EVSE locations that require payment. EVSE must have a sticker informing drivers of voltage and amperage capabilities of the unit. All fees associated with a charging session must be posted. The interoperable billing standard Open Charge Point Interface must be installed on each EVSE. EVSPs must report new, current and decommissioned EVSE locations and access information to the National Renewable Energy Laboratory's Alternative Fuels Data Center and California Air Resource Board to ensure accurate and up-to-date data is available to consumers.
(California Air Resources Board, 2023b)	The goal of the Electric Vehicle Charging Stations Open Access Act is to increase access to public charging stations to the greatest number of drivers. Under the bill: – Drivers shall not be required to pay a subscription fee or become a member to use a charging station; – Drivers shall have the choice to pay with credit card or mobile pay or both; – All fees associated with a charging session shall be disclosed at point of sale; – Station locations must be reported to the Alternative Fuels Data Center (U.S. Department of Energy); and – CARB may adopt an interoperable billing standard to facilitate driver roaming between networks. Adopted by the Board in June 2019, the regulation:

Article	Key points
	– Enables drivers to more readily locate public EVSE by requiring station location information reporting to the federal Alternative Fuel Data Center (a database used by providers of EVSE map and location services); – Increases transparency and consumer choice by requiring on-site pricing disclosure before a driver uses the charger; – Ensures more universal charging access by requiring public EVSE to accept payment using chip-enabled credit cards, which are the most ubiquitous form of credit card payment currently, while also requiring contactless payment for mobile payment methods; – Helps drivers understand how fast their battery may be charged by a public EVSE by requiring the display of federal standardized power information; and – Facilitates a driver's ability to access multiple electric vehicle service provider (EVSP) networks by requiring an interoperable billing standard on networked stations. In summary, the consumer benefits include familiar and ubiquitous payment methods including credit card payment using a form that nearly all credit card holders have, clear pricing information, and uniform station location information.
(California Center for Sustainable Energy, 2012)	In the first half of 2012, a survey was conducted of plug-in EV owners in California. There were 1,419 respondents, who were predominantly male (71%), highly educated (52% with a post-graduate degree and 35% with a bachelor's degree), with higher than average household incomes that own their home (96%), reside in a single-family detached home (91%) and park their vehicle in a garage (75%). Key findings: – 91% had installed a residential charger – Roughly two-thirds of charging takes place during off-peak hours (8 p.m. – 8 a.m.). Super off-peak charging (12 a.m. – 6 a.m.) is highest among owners using TOU tariffs. – 39% of plug-in EV owners had also invested in home solar energy systems, helping to "fuel" their vehicles with renewable solar energy, with an additional 17% indicating they were planning to install PV within the next year. On average 60% of respondents who did not initially size their PV system for their PEV stated that they planned to expand their system within the coming year. – Customers with PV were notably less likely to take advantage of discounted PEV charging rates if offered. The PEV rate was a better predictor of charging patterns than the underlying presence of a PV system. – 71% of plug-in EV owners reported having access to public and workplace charging infrastructure. Of these, about 90% reported having access to free charging. – 83% expressed varying levels of dissatisfaction with public charging infrastructure. – Plug-in EV owners reported they were willing to pay 40%-70% more for public charging compared to standard residential electricity rates; they are also prepared to pay 2.5 to 3 times more for "critical need" public charging than they are for daily charging, while noting that most respondents answered in the absence of well-established pricing models for public charging infrastructure.

Article	Key points
(California Clean Vehicle Rebate Project, 2023)	The cost to charge an EV depends on the vehicle's battery size and the price of electricity. Most utilities offer time–of–use (TOU) rates that greatly reduce costs associated with charging a vehicle at home by charging during off–peak hours. Home charging costs can be offset by hosting the charger on a home charging sharing network. EV drivers can earn money by sharing their home chargers or connect with other hosts to find convenient charging on the go. While charging at home is generally preferred, many people also charge their EV at public charging stations. These stations can be free, pay–as–you–go or subscription-based, and prices are set by networks or property owners. Some vehicle manufacturers, such as Hyundai, Nissan and Tesla also provide complimentary public charging.
(California Public Utilities Commission, 2023)	The California Public Utilities Commission (CPUC) approved several residential time-of-use (TOU) energy rates for customers of PG&E, SCE, SDG&E, Bear Valley, and Liberty Utilities who drive EVs to allow them to charge their vehicles at home at a more reasonable price. EV-TOU rates have a very low super off-peak price at the times that energy is at its lowest cost to encourage customers to charge their vehicles during those hours. The CPUC issued a decision in August 2022 that adopted a Plug-In Electric Vehicle (PEV) Submetering Protocol. This decision allows any customer to manage the load from EV charging separately from the facility's load, which has the potential to enable more advanced load management and VGI capabilities. Through the PEV Submetering Protocol, customers can utilize submeters already embedded within their EV charger, saving customers and ratepayers money and laying out the path for advanced load management.
(Chakraborty, Hardman, & Tal, 2020)	Using data from drivers of PHEVs the authors show that they do not necessarily plug in once per day and that some drivers rarely charge their PHEV. For the purposes of this study, if a PHEV owner reported that they plug-in more than four times a month (approximately once a week), they were considered to be 'chargers', otherwise they were considered 'non-chargers'. Based on this classification, 92% of the respondents in the sample were chargers and 8% of the PHEV drivers were non-chargers. Analyzing 30-day charging behavior of 5418 PHEV owners in California, the authors found that several factors play a role in drivers' decision to plug-in their PHEV or not, including vehicle characteristics and the availability and cost of charging at various locations. Higher home electricity prices, lower electric driving range, lower electric motor power to vehicle weight ratios, lower potential cost savings from charging, living in an apartment or condo, being female and having a lower concern for environmental issues are related to not plugging in a PHEV. Solar cell ownership and being older makes a charger more likely. Among those with access to workplace charging, the odds of being a charger is 2.05 times higher when charging is free compared to when it is paid. The interaction between electric range and commute distance has an influence on the charging decision with the odds of plugging-in being lower when the difference between the commute distance and electric range is high. Owners of older PHEVs are more likely to not plug-in their vehicles. This can be due to low battery performance and consequently lower potential cost saving from plugging in. Since households with PHEVs are still early adopters of alternative fuel technology, their demographic and socio-economic characteristics, as well as attitude towards environmental issues, may differ from more mainstream vehicle owners. The sample had higher levels of education, home ownership, income and ownership of 2 or more vehicles, and were more likely to be male and aged 40 or over.

Article	Key points
(Changing Transport, u.d.)	Key findings from study tours to Germany and the Netherlands by delegations from India and Vietnam. **Right to charge** The Dutch government instated the “right to charge” as a demand-driven approach for charging infrastructure. It requires the municipalities to set up public charging points within 250m of a home at the request of the citizens who own an electric vehicle. The charging point operators (CPO) validate the demand and choose the charging points’ location based on transparent criteria, including available capacity, accessibility, visibility and local impacts. The charging point is set up in collaboration with government bodies and distribution system operators (DSO), ensuring grid stability, and that EV charging data flows to all parties. The municipalities work closely with DSOs and CPOs who build the network on their behalf and ensure interoperability with existing payment models and compliance with standards. **Standardisation and open protocols** The Netherlands emphasised standards early on. ElaadNL, a knowledge and innovation centre in the field of smart charging infrastructure funded by the DSOs, was founded in 2009. This vendor-independent equipment certification centre ensures that standards are met, and that all equipment is interoperable. ElaadNL also supports the development of charging standards and open protocols, which are crucial to the development of open markets. **Non-public charging points** In contrast to the Netherlands, Germany focuses on non-public charging points, such as private homes, for smart, bi-directional charging. It aims to improve the legal, technical, tax and economic framework conditions to remove any obstacles to the non-discriminatory use of bidirectional charging and the integration into the national grid.
(Check Point, 2023)	When users charge their vehicles, there is also a data connection between the vehicle and the EV hub. Charging stations are connected to the internet and, like any other IoT device, are vulnerable to the actions of cybercriminals. If a threat actor can gain access to a charging hub this could have serious consequences including: – **Risk to User Safety:** Theoretically, via an EV charging point, a hacker could access a vehicle’s engine management system and either compromise safety, performance or disable the vehicle altogether. Imagine if the vehicle in question were an ambulance, where delays could pose a threat to life. – **Compromise the EV Charging Network:** Hackers could knock out an entire network of charging hubs by taking advantage of just one vulnerability in one device. This could result in loss of revenue for the operator as well as untold disruption to the road network. – **Commercial loss**: In addition to shutting down a network of EV hubs, hackers could access the operator’s management software and drop ransomware with consequent financial and reputational damage. Also, many commercial fleets are converting to electric power and a hacker could disable an entire delivery operation just from their laptop. – **Payment systems:** Threat actors could potentially compromise the payment system at an EV hub, leading to financial loss for the driver or the network operator.
(Chu, Im, Sun, & Park, 2019)	This study compares psychological and behavioral factors affecting EV (electric vehicle) adoption and satisfaction between EV users in China (early majority) and Korea (early adopters). Surveys were conducted in China in March 2018 (204 EV users) and in Korea in July 2018 (177 EV owners). There were significant differences in the battery charging behavior: – China – residence (45.6%), charging station (13.7%), both (40.7%) – Korea – residence (36.2%), charging station (36.7%), both (27.1%).

Article	Key points
	Charging frequency was significantly higher in China than in Korea (19.35 times vs 14.07 times, after controlling for total mileage). The single charge time (min) duration was also significantly longer in China compared to Korea (200 min. vs 139 min). Analysis of dissatisfaction with EVs: – China – range (21%), battery charging (20.3%), safety (including battery explosions) (12.6%) – Korea – battery charging (50%), range (33.3%). The findings were consistent with a previous study which found that the charging infrastructure in China is scarce and that payment systems are often not compatible, and some consumers are worried about the safety of the charging systems.
(Clairand, 2020)	Studies on road transport in Quito, Ecuador and working conditions find the beginning of charge times as follows: – 20% of EV users plug their EV at work between 07:00 and 10:30. – 40% of EV users plug their EV at home, after returning from work between 16:00 and 21:00. – The rest of EV users plug their EV in different periods of the day (shops, home, work etc.).
(Competition & Markets Authority, 2021)	The Competition and Markets Authority (CMA) found that while some parts of the EV charging sector in the UK are developing relatively well (such as rapid charging at destinations like shopping and charging at home or work), there are greater challenges with charging along motorways, in remote locations and on-street. – Motorways – customer satisfaction has been very low, driven by concerns about poor reliability and limited chargepoints. – Remote locations – there is a risk of 'charging deserts' emerging off the motorway in remote locations like rural areas or at tourist spots. – On-street – having convenient and affordable local public charging is crucial for the more than a quarter of drivers who do not have access to a driveway or garage and cannot install a home chargepoint. Lack of off-street parking particularly impacts city and urban areas and especially those in social housing (57% of households in social sector houses do not have off-street parking and 86% of households in social sector flats do not have off-street parking). **Public charging** EV charging can be complex, confusing, and frustrating at time – it can be difficult and frustrating to find and access working chargepoints, and to compare costs and pay for charging. A difficult charging experience will undermine trust and put people off EVs. In one survey the most common reason given by respondents (non-EV drivers) for not considering purchasing an EV as their next car, was that there are not enough chargepoints. In the same survey, two-thirds were worried about range anxiety. Other important aspects of the public charging experience are: – Reliability of public chargepoints – in 2019 and 2020 surveys, reliability has been ranked as the most important factor for a public network, particularly for en-route charging. But reliability can be poor. There can be reliability issues with the chargepoint hardware and/or software. Issues often arise due to faulty communication between the chargepoint and back office system (e.g. payment or software provider) and older technology in the chargepoint or EV. On average 1 in 25 chargepoints and 1 in 10 rapid chargepoints are out of service. The reliability issues are compounded by poor customer service or long call waiting times. – Accessible information to help find working chargepoints and to plan for longer journeys – 94% of drivers (EV and non-EV) said that access to real-time data on chargepoints (i.e. knowing in advance if they are out of service or unavailable) would make chargepoints easier to use. A 2021 survey found that 83% primarily access the information via a website or app and 17% primarily access the information via their EV sat nav. However, not all chargepoint operators make live data on availability and working status freely available, and the live data that is available can be limited, inconsistent or difficult to

Article	Key points
	access. Furthermore, submissions highlighted that consistent aggregated cross-network data would make it easier and more convenient for EV drivers to find chargepoints. – Simple and consistent payment methods - it can also be difficult to find and pay for charging easily (with multiple apps or cards needed), particularly on longer journeys. In a January 2021 survey, 49% of EV drivers thought that paying at public chargepoints is too complicated and 61% thought that too many apps are required to use the public charging network. The lack of information on chargepoints can also mean it is difficult for people to know the payment method for a chargepoint in advance. While 96% of drivers said that contactless payments at all public chargepoints would make it easier to charge, currently only 9% of public chargepoints have contactless bank account payment. 87% said that having access to all public chargepoints via a single smartphone app or membership card would make it easier. Some PAYG options can be less convenient than others as they require an additional setup to access (e.g. signing up to a RFID card or downloading an app). – Clear comparable pricing to easily find the best deals – Chargepoint operators use different pricing structures, which can make it hard to understand and compare prices. Pricing information can also be hard to find. There are currently around 160 pricing models in the UK – while most offer variable pence per kWh pricing based on the chargepoint's energy usage, some structure their prices as per hour or per minute usage of the chargepoint, or other variations. Around a third charge connection fees on top of the charging cost, and some charge additional fees such as minimum payments or overstay charges. Over 90% of drivers said that standardised pricing would make it easier to use public chargepoints. – Interoperability (i.e. public chargepoints that can be used with all brands of EV and different connectors) – in a 2019 survey, 87% of drivers (non-EV) thought that being able to easily use any available public chargepoint is an important factor in deciding whether or not to buy an EV. In addition, 86% of respondents agree that all chargepoints on public land should be accessible to all EV drivers. The public charging network is currently largely interoperable, however there are different connectors for charging which means chargepoints with only one connection type cannot be used for all EVs. The different connections can also add confusion to the charging experience. There is also one closed charging network in the UK which can only be used by Tesla cars. This can restrict the charging options available and make it more complex and difficult to charge and switch to different chargepoints. **Home charging** When people are buying an EV, they will generally put most of their time and effort into researching different EV models – which is a much larger purchase – rather than the chargepoint. Stakeholders told CMA that people currently have a low awareness and understanding of the chargepoint options and may currently rely on EV manufacturers and car dealerships for information and advice when making decisions about home chargepoints. Dealerships themselves have limited knowledge of the different chargepoints and therefore may not be in a position to support and advise customers. There is a lack of standardisation in the quoted costs for installing home chargepoints and some stakeholders highlighted there can be additional costs which may not be clear at the time of purchase (e.g. fees for fuse upgrades or rewiring). Some stakeholders noted that open standards and data can help to improve people's experience by ensuring they are not 'locked in' to the chargepoint operator's interface. Without open standards and data, people are restricted to using the interface that comes with their chargepoint, which can be costly and difficult. **Cohorts facing additional challenges** Some people have even greater problems engaging with the sector: – Those living in rented, leased or multi-unit accommodation can find it difficult to get permission to install or decide who pays for home chargepoints.

Article	Key points
	– Those with disabilities who may face additional barriers due to the design or location of chargepoints. Concerns include the weight of charging cables making these very difficult to lift, and unsuitable parking arrangements / space for disability access, including trip hazards and barriers making it difficult to navigate around chargepoints. – Those who are less 'tech-savvy' may struggle to engage with potentially complex and technical aspects of smart charging. People aged 65+ are less likely to own a mobile phone and more likely not to use the internet compared to the UK average, which may limit their ability to use PAYG options. – Those living in or travelling through remote/rural areas can experience connectivity issues when paying for charging. – Those without bank accounts and/or smartphones may struggle to pay for charging, as chargepoints largely only offer cashless payment options which can require a smartphone (e.g. QR code, app) or bank account card. **Emerging developments** Emerging developments like subscriptions and bundling could create more problems in the future – they could make it even more confusing for people, harder for them to understand and compare deals, and potentially lead to harmful subscription traps that exploit people's inertia and make it difficult to exit. Some bundles which include home charging that are starting to be offered include energy tariffs bundled with discounted public charging, and energy tariffs bundled with the home chargepoint. Emerging new payment methods are roaming, and plug and charge. Roaming is a cross-network payment method that allows people to pay for charging via a single app or card. Roaming can make it harder for people to compare charging options due to variation in pricing and mark-ups, and roaming tariffs tend to be more expensive. 'Plug and charge' technology may offer a quick and convenient option by automating payment. CMA welcomes the Government's plans to require home chargepoints to be smart. It notes that the more automated and the simpler smart charging is, the easier it will be for people to use, and the more likely that its benefits will be optimised. To use smart charging, the home chargepoint needs to be able to communicate with the EV and energy supplier to adjust the time and speed of charging. This process can be done manually (e.g. the driver sets a timer for their chargepoint) which can be complicated. Manual settings also don't fully utilise smart charging functionality as they lack the same level of flexibility e.g. it's harder and inconvenient to react to real-time charges in electricity prices. An emerging concern relates to safety due to the location of chargepoints, e.g. in poorly lit areas. **Proposed charging principles** CMA proposes the following principles: 1. It is easy to find working chargepoints e.g. people can access open data on live availability and working status and rely on minimum reliability standards. 2. It is simple and quick to pay e.g. no sign-ups needed, contactless bank account payment is widely available and charging networks keep up with payment technology. 3. The cost of charging is clear e.g. prices are presented in a simple and standardised price-per-kiloWatt hour format. 4. Charging is accessible and interoperable e.g. all chargepoints can be used by all drivers, are not limited to a single brand of car, and follow inclusive design principles.

Article	Key points
(Consumer Reports, 2020)	Nationally representative survey of 3,392 adults in the U.S. with a valid driver's licence. Charging is a concern for many. – Among drivers who are not definitely planning to purchase or lease a plug-in EV for their next vehicle, the main barriers include "not enough public charging stations" (48%), insufficient driving range (42%), nowhere to charge at home (28%), long charging times (21%). – 72% of all drivers say that if they owned an EV, they would most likely do most of their charging "in their private driveway or garage", with the percentage varying from 24% for those in a 12 to 20 unit building to 80% for those in a single-family detached house. – About half of U.S. drivers would consider purchasing an EV if it could drive at least 300 miles on a single charge.
(Daziano, 2021)	To analyse the incentives for customers to accept giving up control when charging of their vehicles takes place, data from a pilot program of coordinated EV charging – OptimizEV – in upstate New York were analysed. A negative willingness to pay of $2.65 (in the annual fee of the program) for each hour increase in the timeframe for which the customer is giving up control of charging their EV was derived. That is, there is an expected rebate in the annual fee that the customer accepts in exchange for their willingness to delay charging. Customers are less likely to enrol in a smart EV charging program with an extensive period where customers are expected to give up control. Younger individuals are much more likely to join a program of optimal scheduling of EV charging. The odds of joining the coordinated EV program are increased by 3 times on average for customers that completed graduate or professional studies, and are 4 times higher for customers with a Time-of-Use rate. Each $10,000 increase in household income increases the odds of opting out by 0.23%. There was substantial heterogeneity in preferences, probably due to early-stage attitudes towards charging. Because of unfamiliarity with delaying charging of their EVs, stated responses need to be treated with caution and only analysed as early response by a sample of relative early adopters to a newly developed program.
(de Brey, Gardien, & Hiep, 2021)	The experiences and opinions of electric drivers about the smart charging of electric cars were investigated through a survey of more than 1,800 Dutch electric drivers. The drivers were predominantly male (91%) and in their "40s" and "50s". 94% drive fully EVs, with the balance driving plug in hybrid vehicles. Most drive a new EV (86%), with the balance driving second hand cars. A high percentage were business driven EVs (73%) (business purchase or business lease). The EV drivers had higher than the annual mileage for vehicles in the Netherlands. **Charging mix** – on average 47% of the charging by respondents is completed at home (7% via a socket), 19% takes place at work, 23% at a public charging point, and 11% of all kilometres are charged via a fast charger. 58% of respondent had a charging point at home (while noting that approximately 75% of Dutch households do not have their own driveway in which to charge a vehicle). **Private charging** – about 90% of respondents were satisfied with their charging point. Apartments may have a garage or parking lot with dedicated parking spaces, or a parking lot with non-dedicated spaces, or may not have parking at all. Installing charging infrastructure for such buildings has a capital cost or gives rise to other problems. According to the research, of consumers who apply for a charging station via their Homeowners' Association or comparable collective, 31% did not experience any problems finding an available parking point, while almost 70% did. **Public charging** – 78% sometimes charge at a public charging station on the street. 72% of all respondents who use "public chargers" think there are not enough charging points in the area. More than 60% of respondents indicated that they did not know, at least once or more in the past year, what the costs are of charging at a public charging station. 55% of the respondents indicated that they have experienced the charging speed at public charging stations as "too low" in the past 6 months. It is almost never clear what the charging speed (at that time) is with public charging stations. 38% of respondents experienced one or more times in the last 6 months that the charging station could not be found; the location in the app does not always correspond to the actual location. The costs of charging are often unknown. Those who are paying for the charge most frequently want to understand pricing in advance.

Article	Key points
	Smart charging Many EV drivers are familiar with smart charging. 59% of respondents who had experience with smart charging generally did not notice anything. 26% positively experienced smart charging because of financial benefits, charging on their own solar panels, that it gives a good feeling, the contribution to a stable electricity network and the unburdening of their installation at home. 12% of respondents had a negative experience of smart charging because the car was insufficiently charged in their experience, due to a problem with the car or the app, due to a longer charging time and uncertainty about charging speed and charging time. Reasons for wanting to smart charge (on a 1 to 5 scale): 1. Making optimal use of sustainable energy (4.19) 2. Contribute to a stable electricity grid (4) 3. Financial advantages (3.54) 4. Shorter charging times (3.53). Reasons for not wanting to smart charge (on a 1 to 5 scale): 1. The fear of not being charged enough (3.61) 2. I want to be in control (3.35) 3. Longer charging times (3.17) 4. Financial disadvantages (2.93) 5. I find it too much hassle (2.66). 80% of respondents indicated a willingness to charge smart, 76% want to keep control of their smart charging sessions, and 66% want insight into the smart charging session afterwards.
(Delmonte, Kinnear, Jenkins, & Skippon, 2020)	To gain initial insight into the potential for managed charging of EVs, 60 semi-structured interviews were carried out with actual or potential UK EV users to explore user-managed charging (UMC) based on time-of-use tariffs, and supplier-managed charging (SMC). Participants' willingness to engage with either was conditional on large reductions in charging costs. UMC was preferred over SMC (2/3 : 1/3), because of perceived control and lower perceived risk that a vehicle might not be fully charged at the required time. Preference for SMC was based mainly on perceived advantages to society as a whole. Some participants stated they would only be willing to adopt either concept if there was an option to override it and revert to standard charging when required. Participants' views on UMC: – Benefits – simple to understand; offered a greater degree of control; would encourage people to avoid using electricity at peak times. – Downsides – it would only benefit those with a regular charging routine; would provide no additional advantage to those already charging overnight; the widespread use of UMC would itself increase the "strain" on the electricity grid. Participants' views on SMC: – Benefits – optimising the use of the energy supply was a more sustainable way of using energy; contributing to such societal benefits could yield attractive benefits to individual users who could see themselves as acting morally; could make charging simpler by taking way some of the decision making; brings the future of charging a step closer.

Article	Key points
	– Downsides – seen as a benefit to suppliers but not individual users; there was mistrust the supplier would pass through the cost savings; mistrust about the energy supplier knowing their schedule; reluctance over yielding personal control of the timing of charging; loss of freedom and control; loss of certainty over the state of charge of their EV; repeated stop/start charging could be damaging for their vehicle's battery. Perceived issues common to UMC and SMC – requirement to interface using a smartphone with concerns including phone network coverage and having no experience with, other use for, or dislike of a smartphone. Locating the interface in the vehicle could be preferred. The vehicle may not be sufficiently charged in the event of unforeseen journey needs arising during the scheduled charging period. Either concept perceived by some as involving additional routine time and effort, and perceived effort involved in making the change. Substantial cost savings appeared to be needed to incentivise uptake of UMC. However, some participants argued that financial savings were not important to them (or other EV users). Several considered that charging costs are so low anyway that further savings on them would not matter. For some, cost savings were outweighed by loss of flexibility around charging times. Most participants typically charged their vehicles at their homes. However, several charged at their workplaces as well as home, and one was completely reliant on public charging infrastructure and charging at work, as they stay in a flat. Charging at work and using public charging points could be unreliable. Many participants described a well-established charging habit, e.g. charging on arrival home. Some had developed habitual use of public charge points, while others had no routine basing charging on the state of charge (SOC) and opportunity. There was a desire to keep the battery topped up whenever possible. Some participants avoided topping up the battery to 100%, due to a belief that this might damage the battery. Some participants had solar panels at home and tended to charge their vehicles when their panels were generating energy. Participants who used solar panels were not always certain of the proportion of their electricity bill that was attributable to charging their vehicle. Several participants had a TOU domestic electricity tariff. Several participants discussed using timers and smartphone apps to control the timing of EV charging, even in the absence of a ToU tariff, for pro-environmental reasons. However, some participants indicated that they preferred neither to have a ToU tariff nor a timer, because they preferred the simplicity of knowing that when the car is plugged in, it is charging. Some participants were unaware of either their domestic electricity costs or the cost of recharging their EV at home. Some, however, were able to state the precise amount, and also to define the proportion of that went towards charging their car.
(Electric Nation, u.d.)	The trial recruited 673 EV owners in the UK, owning more than 40 different makes and models of plug-in vehicles, including plug-in hybrids and battery EVs, to experience smart charging. Over 2 years (January 2017 – December 2018), trial participants experienced periods of no management, and management without and then with apps to enable them to interact with the smart charging systems. The trial concluded with participants being financially incentivised to change their charging behaviour. During the trial, data from more than 130,000 charging events lasting nearly 2 million hours was collected. The percentage of EV drivers in the trial who were charging their vehicle at any one time varies from none to 6% (early in the morning) to as many as 20% or more in the late afternoon-early evening on weekdays. Most popular time was 5pm – 7pm on weekdays, as the majority of drivers got home from work. During the evening peak period, on average, about 14% of the EV population are charging their EV. There is substantial flexibility in the evening peak – 75% of EVs plugged in during this period were charging for less than 40% of the time they're plugged in. The median charge frequency for all participants is 0.5 charging sessions per day (3-4 times a week). A minority of participants (14%) charge at least once a day – this group is dominated by the 'Less than 10kWh' battery size group. Other factors which affect charging frequency include whether or not the driver makes use of other charging facilities (particularly at work) and weekly mileage. Mean energy consumed for EVs with smaller batteries (Less than 10kWh and 10-25 kWh) is 45% to 70% of their battery capacity. For vehicles with larger batteries each charge event usually refills about 30% to 45% of the EV's battery capacity.

Article	Key points
	The highest charging frequency is in the winter months between January and February – probably owing to lower battery efficiency in the cold weather, battery conditioning losses and passenger heating requirements. There was no significant variances in participants' satisfaction between the periods with and without smart charging (without the financial incentive). Those reporting low satisfaction often referred to dissatisfaction with the public charging network rather than their home charging arrangements and smart charging. In the final trial when participants were financially incentivised to change their charging behaviour, they were able to choose between three charging preferences on their app – optimise time (default), minimise cost (charge in off-peak period only), and optimise time and cost. More than 60% of trial participants changed their app preference away from the default, mostly to 'minimise cost'. Participant satisfaction with the charging arrangements increased through this trial. 88% of participants who had used the app found the charging preferences and reward structure easy to understand. 81% of participants believed that the tariff structure and charging profiles would encourage many, or most, EV owners to charge their cars outside of peak times.
(Electric Vehicle Association England, 2021)	The Electric Vehicle Association (EVA) conducted an online survey of current EV drivers in England (N=1,025) which ran from February to March 2021. **Profile of respondents** 96% indicated they were drivers of battery electric vehicles (BEV) with the remaining 4% designating they were drivers of plug-in hybrid vehicles (PHEV). 73% indicated that their EV (whether BEV or PHEV) was their primary vehicle, 22% indicated it was their only vehicle and 5% said it was their secondary vehicle. 91% identified as male, 5% classify themselves as living with a disability. The largest age demographic was the 45-54 age group, followed by the 55-64 age group. 91% indicated that they had access to off-street parking, while 9% indicated that they did not. 39% indicated that they performed most of their charging at home while sometimes using public chargepoints and 36% performed almost all of their charging at home. 10% of drivers indicated that they performed all of their charging using public chargepoints, which was closely followed by 9% of drivers who said they used an even split of home and public charging. Only 5% of drivers designated workplace charging as the primary location in which their charging events occurred. **Frequency of public charging use** 30% of drivers overall indicated that they used public charging once a month, closely followed by 27% who indicated once or twice a month. 14% of participants indicated that they used public charging once or twice a week followed by 12% who used public charging once a week. 9% of drivers used public charging more than twice a week and 8% indicated they did not use public charging. Amongst drivers who exclusively used public charging, 35% use public charging once or twice a week, 26% more than twice a week and 23% use public chargepoints once a week. Amongst drivers who indicated they did almost all of their charging at home, 35% use public chargepoints once a month and 29% use public chargepoints once or twice a month. 21% indicated that they do not use public charging. **Concern over finding public chargepoints** 94% of participants indicated that they experienced concern at some time or another – 37% of drivers indicated that they sometimes felt concern about finding a chargepoint, closely followed by 35% of drivers who often felt concern and 22% who seldom felt concern. Only 66 drivers (6%) indicated that they never felt concern about finding a public chargepoint.

Article	Key points
	Payment for a public chargepoint In order of frequency of response, drivers had accessed a public chargepoint with a smartphone app, a contactless credit or debit card, a membership card (also known as an RFID card) and charging subscription service. A contactless credit or debit card was deemed the easiest method for accessing a chargepoint with 46% of participants (472 drivers) selecting a contactless card. A contactless credit or debit card was followed by a smartphone app (145), a membership (RFID) card (137) and other contactless forms of payment such as, Apple Pay (106). 94% would prefer to use the method they selected across all chargepoints, while only 6% said they would not. 84% of English EV drivers would not welcome a call or text-based option to pay for a charge with only 16% indicating that they would welcome a call or text-based solution. **Roaming** Roaming was defined as having the ability to use an access or payment method across all chargepoints regardless of the chargepoint operator. 87% of survey participants would welcome the ability to use one smartphone app across all public chargepoint networks, while a smaller percentage (71%) would welcome the ability to use one RFID card across all public chargepoint networks. 59% of respondents said they would not prefer QR code access to chargepoints and 41% said they would welcome the option to access a chargepoint by QR code. **Opening up chargepoint data** 83% of participants primarily use a website or app to locate public chargepoints, while 17% indicated they primarily used their vehicle’s onboard map. All participants either used an app or website to locate chargepoints or their vehicle’s onboard map. information. 98% of respondents believed that having access to real-time data ahead of a charging event would save them time. Such information could include the working order of a chargepoint, the availability of a chargepoint, time until charging completes and peak usage times. The location of a chargepoint was the primary factor in choosing a chargepoint, followed by the chargepoint network and lastly the cost to charge their vehicle. **Pricing transparency** Overwhelmingly, survey participants preferred a pence/kWh format for paying for a charge. 94% indicated that a charge for electricity used (pence/kWh) was the preferred format, with 2% designating a charge for time spent charging (pence/minute), 2% for a flat rate for a charging session and 2% a membership fee. Many commented prices for public chargers were too high especially when compared to the costs to charge at home, which disproportionately impacts those without access to off-street parking and therefore without access to home charging. **Reliability** – Locating and location - 45% of drivers agreed or strongly agreed that they found it easy to locate public chargepoints with 34% neither agreeing nor disagreeing. – Number of chargepoints (at a given location) - 52% of survey participants either disagreed or strongly disagreed that there are typically enough available chargepoints to use. 29% agree that there are enough available chargepoints to use, while only 5% strongly agreed there are enough chargepoints. – Maintenance - 62% of drivers disagreed or strongly disagreed that public chargepoints are typically in good working order. Only 14% of survey participants felt that they found chargepoints in good working order.

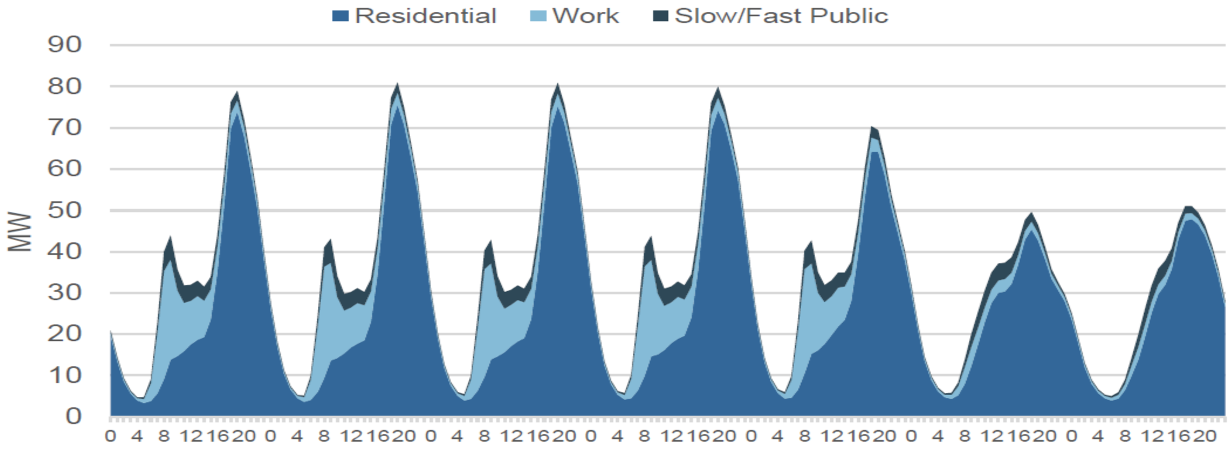
Article	Key points

	– Current reliability concerns - the most common reliability issue to drivers was that a chargepoint was out of order. This was followed by the chargepoint could not be easily activated or that the chargepoint would not connect with the vehicle. 104 drivers had not experienced a situation in which they had an issue with a chargepoint, while 96 drivers suggested that a long queue made them abandon their attempt to charge their vehicle.
	  – Lack of available chargepoints – chargepoints blocked by a petrol or diesel vehicle, or by EVs not charging or had long completed a charge.
	  – Facilities access – the need for increased access to facilities, as chargepoints can be located in areas that can be closed or in which public services (such as loos) can be closed.
	– Reliability standard - 99% of drivers believe that chargepoint operators should be required to meet a certain threshold of reliability and 93% of drivers believed that a 99% reliability standard would be fair.
	– Helplines - 55% of drivers, did not agree that there is clear and easy instruction on how to access assistance when issues arise. Only 15% felt that there is clear instruction on how to access assistance. 41% of drivers have had to call a helpline 1-2 times, while 16% drivers have had to call 3-4 times. 6% of drivers called 5-9 times and 3% have had to call a helpline 10+ times in the past 12 months. 34% of drivers indicated that they have never needed to call a helpline. Amongst drivers who have had to call a helpline, 57% indicated that calling that helpline did not resolve their issues, while 43% indicated that it did resolve their issues.
	Weatherproofing and lighting
	While most (78%) indicated that they did not feel they experienced issues in inclement weather, 69% of survey participants agreed or strongly agreed that they preferred to use chargepoints located under some type of roofing or covering.
	38% believed there was not enough lighting at public chargepoints, 38% neither agreed nor disagreed that there was enough lighting, and the remaining 24% felt there was enough lighting at public chargepoints.
	Signage
	In general, drivers perceived a lack of signage that let them know the location of a public chargepoint.
	General satisfaction with public EV charging
	The average satisfaction rating was 2.16 out of 5 amongst drivers in England with the most frequently occurring rating being a 2 out of 5.

(Element Energy for National Grid ESO, 2019)	Element Energy developed a set of annual charging demand profiles for Great Britain based on a dataset of over 8.3 million real-world charging events from 2017 and 2018. The share of charging demand across residential, work, slow/fast public and rapid public charge points is assumed to be 75%, 15%, 6% and 5%, respectively. Characteristics of charging behaviour: – Weekdays (Monday-Friday) display a large peak in the early evening, with a maximum between 7-8pm. This is driven by residential charging, which is currently the largest contributor to overall demand. This evening peak is likely the result of commuters, plugging into charge when they arrive home from work. – A secondary peak on weekdays is also observed in the morning, with a maximum between 9-10am. This is due to charging at work and slow/fast public charge points, most likely due to commuters plugging in to charge when they arrive at their workplace. This peak is short-lived which suggests that work charge points are typically not used again during the rest of the day. – On weekdays, there is also a small peak in work charging, which coincides with EV drivers plugging in during their lunch break.

Article	Key points

- Daily demand (kWh/day) gradually increases from Monday to Thursday, before decreasing back to Monday's level on Fridays. However, peak demand on Friday is noticeably lower than on other weekdays, reduced by 11% compared with Monday to Thursday. These trends are driven by residential charging.
- Daily demand (kWh/day) on weekends is approximately 25% less than during the week. There is no morning peak, and the evening peak is shifted an hour earlier than on weekdays.
- There is considerably less demand from work charging at weekends.



	Mon	Tue	Wed	Thu	Fri	Sat	Sun
GWh/day	0.90	0.93	0.94	0.96	0.91	0.71	0.70

Figure 0-2: GB-level weekly average demand profile, averaged over full year for a stock of 180,000 EVs.

Demand is higher in winter and lower in summer. EV energy consumption is known to increase as temperature falls, due to reduced battery efficiency and additional cabin and battery heating load. Winter demand may also be higher if people drive more rather than walk or take public transport. Demand was found to noticeably lower during public holidays, particularly during the Christmas period.

As EV volumes grow over the next decade there is potential for considerable changes in the EV fleet (e.g. EV ranges, BEV/PHEV ratio, higher charging rates, preferred charging location) which will influence the overall charging load.

Article	Key points
(Emobicity, 2019)	– **Slovenia** – published tariffs for the customer group of full EVs on fast charging stations on the motorway network. Petrol has three packages for those holding its payment card: – Base package – the charging rate is EUR 0,20/min (provided charging power is more than 22.01 kW). – Package 2 – needs to be contractually committed for 12 months in addition to the monthly fee of EUR 10,4, charging price EUR 0,11/min (provided that the load power is above 22.01 kW). – Package 3 – where a contractual obligation is required to reach 12 months with a monthly fee of EUR 30,90 and the equivalent of kWh per month on a charter of 225 kWh. Users having contractual obligations with Petrol's roaming providers (via their identification cards/mobile applications) may also be authorized on the infrastructure operated by it; SMATRICS GmbH & Co Co (Austria), GreenWay Infrastructure s.r.o. (Slovakia), SE (Slovakia) and The New Motion (Netherlands, Germany). – **Ireland** – no fee for charging for EV owners. All chargers are accessed using a subscriber card. – **Italy**: – Charging in private premises, i.e. the use of infrastructure at home, in which case the same tariff as for households applies and is paid by the user who has a contract with the supplier; – Private charging, i.e. the use of a system which is separate from the household, such as separate garages. In this case, the user pays a tariff for other low voltage users to the supplier with whom the supply contract for the garage has been entered into; – Public charge, for which there is a separate tariff set by the regulatory agency. This tariff is paid by the supplier of the charge service to the company with which it has concluded a supply contract. Regulated components are higher for the public charging category than those for private premises, when only the household supply fare is paid. – **Netherlands** – the network is significantly developed, and interoperability is ensured throughout the country when using charging stations. There is a significant number of different charging prices, with operators offering different prices and benefits to attract customers. There could be a charge per volume of the electricity assumed (kWh), per time attached to the charging station (which does not have to be equivalent to the charging time) and for the amount of electricity taken (kWh) plus service charge. In addition to the costs paid by the consumer to the operator, there is a cost to be paid to the service provider. This includes a one-off purchase cost (EUR 0-10), a monthly subscription (EUR 0-5), with a possibility to pay a charge by use (EUR 0-0,61) with an increase per kWh (EUR 0-0,03) or using a fixed tariff independent of the operator. – **Germany** - network operators specify requirements for the connection and operation of electrical systems, including EV charging facilities, to the low-voltage network in the form of technical connection conditions. These conditions include: – Charging facilities must be registered with the grid operator – The grid connection of charging facilities > 4.6 kVA should be three-phase – Grid-serving load management with e-mobility must be possible – Charging processes must be able to be controlled by grid operators in critical grid situations – Charging stations must be able to generate reactive power (system service: voltage and frequency maintenance at grid connection point). For a public charging station (electric charging station), a so-called charging card is almost always required. There are many different providers with very different prices. Many charging station providers nowadays join forces to form networks so that the respective charging card not only works at the company's own charging stations, but can also be used at other providers. As a rule, the cards are free of charge; at most, a one-time activation fee may

Article	Key points

	be due. Some charging stations charge per kilowatt hour for charging your electric car. In addition to payment per kilowatt hour, a flat-rate price per charging process has now also become established. Faster charging methods are always more expensive than slower ones.
	– **Greece** – free market model for the pricing method and billing conditions for EV users. The CPO provides on-site recharging services (ad hoc) to non-contracted EV users by directly invoicing them, to EV users contracted with CPO as well as EV users contracted with other e-mobility service providers (EMSP). In the latter case, the necessary interoperability is achieved through processors of e-mobility transactions (PEMT) or through bilateral contracts between operators in the electricity market. The applicable pricing for the case charge is selected by CPO and must be notified to the EV user before the start of the recharging process, with a clear mark on the recharging point or in an adjacent area of the recharging point or at the entrance of its installation site, in the case of controlled access areas. The final charge of the EV user includes all the parameters of the charge that form the final price, such as energy consumed or duration of the session and power or type of charge, as well as other charges. Charging data and additional charges used to calculate the final charge must be made available to inform the EV user while he / she is still at the point in one or more ways, such as display on the charging station screen, indication on a receipt or invoice issued at the same place and sent through a suitable electronic application and sent directly to the contracted EMSP, if they are contract users.
	  – EV charges:
	    – Private charges – price per kWh
	    – Public chargers of fast or semi-fast charging, such as those that can be found today in the Motorists Service Stations along motorways. Access is free for all owners / users of electric cars (and of course plug-in hybrid vehicles), without the use of a card or any other subscription and at a cost that currently depends on the charger usage time and may also include an additional cost per charging session.
	    – Shared semi-fast (AC) and fast charging (DC) network chargers owned by a provider. It is necessary to identify the user - a process that can be done using an RFID card or with a special application (app) via mobile. In this case, just like mobile phone providers, the user chooses to subscribe to the Mobility Service Provider through a contract in one of the existing programs (usually there is a fixed monthly charge and an additional charging price per minute) or alternatively through a prepaid charge card, which can be renewed online.
	    – Common low power chargers, such as in large parking lots, shopping malls, supermarkets etc., for which there is absolutely no charge for charging an electric or PHEV vehicle.
	– **Portugal** – charging network operates in an interoperable manner. Users can access any charging point in the country through a single access mean – a card. Retail prices for charging EVs are market-based. The network tariffs are set in euros per kWh, broken down by time period.
	– **Azores** – public chargers charged based on consumed electricity (€/kWh), charging time (€/minute) and usage number (€/charging). Tariff for private charging the same as for the premises.
	– **Czech Republic** – the Law on motor fuels provides that an operator shall disclose information on the compatibility of charging stations and electric vehicles to the charging station itself, clearly indicate charging prices for vehicles, and provide for charging to consumers who do not have contracts with a recharging service provider. Examples of charging models by charging service providers:
	  – CEZ group – flat rate for a six month period
	  – E.ON – payment is based on the power of the used port (3.7 kW, 22 kW, 43/44.50 kW) and the duration of charge (€/minute).
	  – Pre group – quarterly fee, plus an amount for energy supplied (€/kWh) plus time (if more than 2 hours) (€/minute).
	– **Hungary** – a high number of public charging services are still free of charge. There are no EV-specific tariffs for private EV chargers.
	– **Croatia** – no specific tariffs for charging EVs; the electricity price is the same as for the entire household.

Article	Key points

(Energy Saving Trust, 2016)	A survey of 672 licensed taxi drivers in London, of which 500 respondents completed the full survey.
	– Drivers should have the flexibility to charge for as little or as much time as required, and pay per minute or per kW.
	– Majority of drivers (58%) expressed a preference for a pay-as-you-go model – either an RFID card, SMS, a smartphone application, or contactless and chip and pin card payment.
	– Charging is likely to take place either side of drivers' peak working time.
	– Drivers will expect to access charging when and where it is convenient and not experience problems in finding a chargepoint.
	– Balance needs to be struck between providing sufficient spatial coverage and installing few chargepoints at a large number of sites. Installing more chargepoints at hubs reduces anxiety that chargepoints may be in use or out of service.
	– Chargepoints should be incorporated with other facilities such as toilets, particularly at larger 'hub' sites.
	– 7 of the 9 top barriers to operating a plug-in vehicle relate to charging:
	  – Insufficient range (in miles) between charges (83%)
	  – Concern about running out of charge (80%)
	  – Nowhere to charge during shifts (66%)
	  – Charging would impact on my productive working time (63%)
	  – I may have to charge too often during a shift (63%)
	  – Nowhere to charge between shifts (63%)
	  – Needing to know where chargepoints are (42%).

(Energy Technologies Institute, n.d.)	The ETI Consumers, Vehicles and Energy Integration (CVEI) project, included trials with mass-market consumers in the UK to test charging management and uncover range requirements. The CVEI project collected very detailed journey and charging data from 127 BEV and 121 PHEV drivers whose journeys, age and gender distribution, and geographic locations are a very good match to the core two-thirds of drivers (rather than early adopters); each driver had the car for 8 weeks. **Background** The scale of charging at or near homes is likely to be far larger than elsewhere. For the more than 60% of homes with off-street parking, charging at home will represent the most convenient and affordable option. Even for those without offstreet parking, a good proportion may well seek to charge near home over the same period. Providing mechanisms for managing charging at or near home is a critical issue. It seems that drivers can be engaged through managed charging, provided it is designed around their needs, and aligns the capabilities of the supply-side to cater to those needs in an effective way. **Findings from the charging trials** Both a Time-of-Use form of managed charging and a more sophisticated variant, where the consumers provided information about their needs and delegated control of the charging to a third-party, were tested; alongside a Control group who did not have managed charging. The trials provided evidence that mass-market consumers do in fact predominantly charge at peak times of electricity demand, when not using managed charging. By contrast both forms of managed charging, were shown to be effective at shifting charging away from typical peak times of electricity demand.

Article	Key points
	Across the experimental groups, between 76% and 96% chose one of the two variants of managed charging. This revealed broad characteristics of managed charging offerings that would enhance their appeal. For example, consumers highly valued the presence of an override function, to charge straight away, even though they only used that feature in the trial infrequently. The Time-of-Use form of managed charging resulted in charging coalescing at the start of the cheapest period of the tariff. A more intelligent form of managed charging, such as the delegated control variant that was tested in the trial, may be needed. The consumers in the trial who had experienced this more sophisticated variant of managed charging – where they merely indicated when they next needed the car and how full they wanted the battery – were more likely to choose that than the Time-of-Use variant. **Technical standards and governance** If vehicle charging is to be managed effectively, a whole range of standards and codes will need to be developed or modified, and adopted within the system governance, including any primary or secondary legislation. Examples include: – Communication between charge points and vehicles. – Communication between charge points and Smart Meters. – The basis on which Smart Meters can be used by multiple suppliers. – Standards for monitoring network loading. – Standards for preventing network overload by communicating with charge points. – Market structures to implement incentives and rewards for suppliers to manage charging to allocate network capacity, minimise additional systems costs and minimise additional systems carbon emissions. There will also need to be agreement amongst the energy and automotive industry as to the form that managed charging should take and how it should evolve over time.
(European Council, Council of the European Union, 2023)	In June 2022, EU member states, meeting within the Council, agreed a common position on the Commission's proposal for the alternative fuels infrastructure regulation – part of the Fit for 55 package. The proposal includes: – Recharging stations at least every 60 km on main roads by the end of 2025 for passenger cars and trucks below 3.5 tonnes, and by the end of 2030 for trucks above 3.5 tonnes – Every year, the total power output provided through recharging stations for passenger cars and trucks below 3.5 tonnes should grow with the number of registered cars – New infrastructure will have to allow ad-hoc charging, accept electronic payments, and clearly inform users about pricing options.
(European Parliament and Council, 2014)	Each Member State is required to adopt a national policy framework for the development of the market as regards alternative fuels in the transport sector (including electricity) and the deployment of relevant infrastructure. The framework must contain, for example, national targets and objectives, measures necessary to ensure that the national targets and the objectives contained in the national policy framework are reached, measures that can promote the deployment of alternative fuels infrastructure in public transport services. The Commission must publish and regularly update information on the national targets and objectives submitted by each Member State, including the number of recharging points accessible to the public.

Article	Key points
	Member States were required to ensure that an appropriate number of recharging points accessible to the public were put in place by 31 December 2020, to ensure that EVs can circulate at least in urban/suburban agglomerations and other densely populated areas, and to encourage and facilitate the deployment of recharging points not accessible to the public. Member States were to ensure that normal and high power recharging points for EVs, excluding wireless or inductive units, deployed or renewed from 18 November 2017, complied with technical standards, for interoperability purposes. The recharging of EVs at recharging points accessible to the public were required to make use of intelligent metering systems where possible. All recharging points accessible to the public shall provide for the possibility of EV users to recharge on an ad hoc basis without entering into a contract with the electricity supplier or operator concerned. Prices charged by the operators of recharging points accessible to the public were required to be reasonable, easily and clearly comparable, transparent and non-discriminatory.
(Evergreen Smart Power, 2021)	The Flexibly-Responsive Energy Delivery (FRED) trial was run by Evergreen Smart Power together with Myenergi, GenGame, Energy Systems Catapult, and Swansea, with over 250 participants (early adopters) across the UK in 2019-2021 to understand how to encourage and reward smart charging of EVs. The vast majority of participants had solar panels at home, and had bought first-generation myenergi products to make the most of their domestic generation. Many also had batteries, and some were attempting to participate in multiple industry trials at the same time. **Charging habits** – trial participants spent far longer plugged in than any previous studies have found, with a mean plug-in rate of 44%. Trial participants were routinely plugging their cars in when they didn't *need* to charge, in the hope that they could charge for free. Participants responded very well to incentives—those with off-peak rates almost always charging in off-peak times. On the flip side, without any incentive, those with flat tariffs hardly ever availed themselves of greener overnight energy. In many cases this was not due to lack of education, but a deliberate decision not to switch to a two-rate tariff. **Everybody is different** – over 160 EV drivers participated in FRED, and most of them charged their car in a distinctive fashion. Trial participants made different use of the modes and resources at their disposal. **Choice of tariff** – most of the 50 trial participants that were interviewed were fully aware they could save money on their charging by employing an off-peak tariff. But plenty chose not to, feeling they would have to pay more during peak periods, and (for example) as young families with limited flexibility beyond EV charging, this would be a negative overall. **How much charging?** – everyone wants to make sure they get enough charge in their car, but people differ in how they balance other factors to do this. People also hold differing opinions on what "enough" is—and for some there is even a worry about too much charging (for instance, if they want to leave space for solar in next week's heat wave). Finally, people also need confidence that they will be able to complete planned journeys, but that confidence can be built up in different ways (at least one participant made sure they reached 90% battery capacity the day *before* a long journey so the minimise the scope for things to go wrong). **Consumer attitudes and conflicting motivations** – there is no one-size-fits-all answer to the question of how best to charge a car, with several "likes" in direct conflict with each other. **Control vs. simplicity** – an online survey of 1500 people (including prospective and current EV drivers) found that some people want simple, convenient charging – they're happy to hand control to someone else as long as they know they'll get what they need. Others want more control – for them, the greater complexity involved in managing charging is worth it for the feeling of personal control. There was a roughly even split between the number of people that preferred the idea of supplier-managed charging to user-managed, and both options were popular amongst the quantitative study participants. There was also a roughly even split between those that preferred one consolidated bill and those that were interested in more complex propositions involving separate tariffs and bills. Those showing a preference for user-managed charging were also interested

Article	Key points
	in more complex propositions like bill-splitting. Those participants more interested in supplier-managed charging were more interested in a single consolidated bill. Ultimately, customers need to feel in control and confident they will get the charge they need, whether their charge is being managed by them or their supplier. Households are more likely to opt in to supplier managed charging if they feel in control and so there needs to be a mechanism to communicate preferences. **Personal control** – both prospective EV drivers and EV drivers expect to set a default charge level (e.g., I want my vehicle charged by 80% by 6am). Those who already have and use an EV recognise the value of default charging even more than those who do not. 90% of respondents in the survey said they'd be quite or very interested in having an override function to allow them to override supplier-managed charging and charge as normal. Understanding flexibility is key – those who had a good understanding of how demand-side response would work were significantly more likely to be positive towards it than those who could not express a good understanding. **Trust** - many people wanted to know when DSR activity had taken place. This would help build trust (and excitement – for example one person was impressed at how 'seamless' DSR had been, though a little disappointed he hadn't noticed any activity as he wanted to know DSR was working!) This trust is crucial to users relinquishing control and allowing their flexibility to be utilised for the benefit of the grid. **Smart charging app** A consistent theme of trial participant feedback over the course of FRED was the lack of consistent user interface for smart charging. Participants wanted to know when demand response was occurring, to be able to *prevent* it from occurring if needs must, and to consistently leave room in their batteries for tomorrow's free solar. It was evident that a dedicated user interface was needed. An app was developed for the trial. Most trial participants found the app an easy way to automatically shift charging into the most optimal periods of the evening, but more can be done to increase the amount of flexibility made available. However, some users used the app in a way that made insufficient flexibility available, and therefore a significant amount of charging occurred during the early evening. Participants said the main benefit of using the app was convenience: achieving low cost and low CO_2 charging without manual intervention—"set and forget". Although all participants were pleased with the general level of information in the app, there was still appetite for more detail about energy consumption history and carbon savings to be displayed. Additional data and information from home chargepoints would simplify the user experience further. In particular, data pertaining to the car—its state of charge, its battery size, its on-board charger power. Relying on users for this information adds friction to the smart charging experience. Trust in a smart charging app must be earned; participants felt comfortable trusting the app based on positive experiences with other apps, with the myenergi cloud, and with the FRED trial. A key barrier is the state-of-charge and interoperability. The state-of-charge of an EV is a vital piece of information currently not made available to smart EV chargepoints as it is not a part of the communication protocol between EV and EVSE. This information would be a big help in designing compelling, interoperable user experiences.
(EY, 2022)	Annual survey conducted in March 2022 with ~13k respondents in 18 countries. A lack of charging stations replaced high upfront cost as the top inhibitor to purchase EVs: – Lack of charging stations in your city/route (34%) – Range anxiety (33%) – Upfront cost (27%)

Article	Key points
	– Absence of adequate home/work charging infrastructure (26%) – Charging/running cost (26%). ~80% of EV owners use home charging. Shopping centers and retail locations emerge as the most preferred nonresidential charging location.
(Figenbaum, Wangsness, Amundsen, & Milch, 2022)	The focus of the study is on the user-friendliness issues related to the access to and use of charging infrastructure. It draws on the literature, an online survey of 1,237 members of the Norwegian Automobile Federation conducted in June 2021, and 15 BEV owner interviews. A total of 76% of the survey respondents were BEV owners, 18% were ICEV owners, 5% were PHEV owners, and 1% used car sharing services. The mean age of the respondents was 54 years, and the majority were men. **BEV owners' preferred charging** BEV owners' preferred charging locations are still primarily at home, then at work and in other public locations. Over 90% of Norwegian BEV owners charge at home. Most households can install a wall box charging solution as they have access to a private parking spot. Flat owners must rely on installation of shared charging systems in the buildings' common parking facilities. About 75% of BEV owners in three Norwegian counties reported having used fast chargers when driving long distances. Users want easy access to public chargers, but user surveys show that charging queues can be an issue on peak travel days/times, chargers can be out of order, payment could be easier, and users do not want to use a myriad of apps to access chargers. fast charging in Norway is characterized by different charging systems, power levels, user interfaces, plugs, access and payment solutions, and (up to 2022) also a variety of pricing schemes. Very few public fast chargers have bank terminals, so users must pay via apps, operator-specific payment cards, SMS messaging, or other means. To avoid extra costs associated with SMS messaging, customers must register their credit card information in each charging operator's system. When registered, the customer identification can operate the charger via an app or an RFID (radio-frequency identification) card. Few actors have opened for roaming. The networks of slow chargers have similar payment systems, access, roaming, and user interface issues. **User-friendliness** The charging stations vary greatly in terms of layout, user interfaces, payment solutions, and charger activation, which comes on top of the different types of plugs, the cables with different lengths and locations, and different charging power levels associated with the BEV technology and chargers in general. Consequently, several of the respondents were dissatisfied with public fast charging services and emphasized the need for standardization of all public charging stations. To avoid having to learn the operation and payment system of other operators, 55% of the survey respondents stated that they deliberately used the same charger operator each time they use public chargers. Almost half of the respondent stated that they had bought a BEV with large batteries to avoid having to use public chargers. **Pricing and payment method** The operators of the fast-charging stations in Norway had different prices and pricing models up to 2022. During 2022, all major actors changed to pricing per kWh. The survey and interviews were carried out in 2021, and pricing was then a major user concern. Up to the end of 2021, some CPOs and EMSPs charged for kWh, some per minute to avoid users charging slowly past 80% battery state-of-charge, and some used a combination of these solutions. Many found paying by the minute unfair because the important part is how much kWh you receive. Most of the respondents found it difficult to understand in advance how much the charging would cost. Price information was often lacking or difficult to understand. BEV users were often not provided with price information until the charging had finished.

Article	Key points
	More than 50% of the BEV owners found the payment method at public fast charging stations inconvenient. Many state that they wished paying with a credit/bank card was an option. Even among BEV owners who use the chargers more than 20 times a year, the level of dissatisfaction was relatively high. The average BEV driver in the user survey had downloaded three different charger operator apps. About 75% agree to the statement "*It is inconvenient when charging operators operate with different apps*". **Information and on-site services** BEV owners desire better information about the availability and operational status of chargers, i.e., information about out-of-order charging points and available charging points at the different charging stations. Moreover, several informants wished for road signs indicating the location of charging stations along main roads. For long-distance drivers (driving 100 km+), access to the same amenities at fast charging stations as they are used to from petrol stations are highly valued when using public chargers. Amenities mentioned include basic facilities such as toilets or benches, but also service options and the possibility to buy food and beverages. Lighting conditions on site were also frequently mentioned. Enough lighting is important to be able to read the information on the charger and to be able to locate and insert the correct cable. The fact that most charging stations are built without roofing or other means of shelter is a topic of great frustration for many BEV owners. Being under a roof when using public chargers, especially during the winter, is appreciated when it is raining/snowing. Many BEV owners pointed out the need for a system for handling charging queues, which has become an increasing problem, especially during the seasonal vacation times, public holidays, and on weekends. Location and payment methods were considered the most important factors when choosing a charging station, but price and amenities were also important. **Standardisation** As BEV market shares increase and BEV buyers are becoming the majority car buyers, the need for a more user-friendly experience will become pressing. Standardisation can increase the overall user-friendliness by: 1. Standardising the payment method. The same type(s) of payment methods should be available at all stations. Preferably, it is one common app for all charging stations, as well as easy options for drop-in clients (debit/credit card option). 2. Standardising the pricing system. The price should be clearly marked, and the pricing system should be easily comparable between different charging stations (without having to download an app). 3. Standardising the charging operation (user-friendliness). Available user information, placing of charging cables to fit all vehicle models, method for starting the charging, etc. Universal design at fast charging stations (easy use independent of nationality, technological skills, or disabilities). 4. Standardising the level of amenities at fast charging stations along the major highway network, such as, for instance, toilets, light, garbage bins, road signs, roof, etc.
(Franke, Gunther, Trantow, & Krems, 2017)	User satisfaction is a vital design criterion for sustainable systems. The research aimed to understand factors relating to individually perceived range satisfaction of battery electric vehicle (BEV) users. Data from a large-scale BEV field trial in Leipzig, Germany (N=72) were analyzed. There were four main time points of data collection: before vehicle handover, after the first week of BEV usage, after six weeks, and at vehicle return after 12 weeks. Users had charging opportunities at home and/or at work depending on their mobility patterns. The sociodemographic profile of the sample paralleled the profile of early BEV customers in Germany relatively well in terms of variables such as age, gender, education, and income. There was an initial drop in range satisfaction from vehicle handover to the first week, then increased range satisfaction with increasing practical experience from week 1 to the end of the trial period. Classical indicators of users' mobility profiles (daily travel distances) were only weakly related to lower range satisfaction (not significant), after controlling for practical experience and preferred coverage of mobility needs. The regularity/predictability of users' mobility

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	patterns, the percentage of journeys not coverable because of range issues, and users' individual comfortable range accounted for variance in range satisfaction. The effect of comfortable range in particular shows how relevant the individual representation of available range (i.e., psychological range) is for range satisfaction. This points to the fact that it is not just the objectively available (i.e., displayed) range, but it is the subjectively available range that is the actual satisfaction-relevant range variable.
(Ge & MacKenzie, 2022)	The authors analysed battery electric vehicle (BEV) users' fast-charging choices on long-distance trips using the data from an interactive stated choice experiment. An online survey was conducted in the US in September to October 2018. There were 309 respondents, of which 267 completed the survey in full. 80% of the respondents were male, the reported income was higher than average and more than 69% had at least a bachelor's degree. The results show that battery state of charge (SOC) and the ability to reach the next station without deviating from the original plan are the primary factors influencing charging decisions. Charging cost, time, the detour time to reach a station, and the amenities are statistically significant predictors, but less important than SOC and the ability to complete the trip as planned. Having a restroom alone does not significantly influence the charging choices of the BEV drivers, but having a restroom, dining, and Wi-Fi does significantly increase the probability of charging. Time since the last charge, as in how long the driver has been driving since the last charging activity, is not significantly associated with the charging decisions, at least when already controlling for state of charge and the ability to reach the next charging station. The authors speculate that for home-based tours, the respondents are confident about finding public chargers outside of the planned destinations if necessary, and the cost of having to make a mid-trip stop to charge is not very high. Whereas on a long-distance trip, it might be rather difficult or costly to find a charger off the route. It is also likely that BEV owners tend to be more cautious and conservative when they are on long-distance trips.
(Gregory, 2023)	Hackers can infiltrate EV charging stations. In Russia, attacks disabled many EV charging stations while the stations' video displays showed unkind messages about Vladimir Putin. Last spring, electric car owners wanting to charge their batteries at one of three publicly owned charging station son the Isle of Wight in the UK were presented with a porn video at the station. The attacks took the charging stations offline, further limiti9ng the ability of consumers to charge their cars. The Carlos Alvarez College of Business's Department of Information Systems and Cyber Security also found vulnerabilities during a study of charging stations. Evaluating 16 charging systems, researchers discovered 13 areas of significant security concerns and vulnerabilities. Concerns included missing authentication and cross-site scripting, which puts malicious code into scripts and can launch cybersecurity attacks. Researchers noted that they were concerned about cybersecurity criminals being able to steal credentials and access user data. Other vulnerabilities included the ability to manipulate the firmware, which then allows criminals to launch more sophisticated attacks.
(Guidehouse Inc., 2021)	The Netherlands has one of the lowest number of EVs per public EV charge point in the world, while also having the highest number of public chargers installed per capita and per square kilometer. This can be partly attributed to the specific country characteristics of the Netherlands: densely populated, small travel distances, highly reliant on public parking, as well as the Dutch charging strategy. Dutch households rely significantly more on public parking. Across the UK 25% of vehicle owners rely on public parking, while in the Netherlands the comparative figure is 70%. The Dutch charging strategy is based on a demand-driven approach and the Dutch 'right to charge'. Charge points are installed considering user requests; historically, these constituted the bulk of placed charge points. This practically guarantees access to available charge points nearby, improving electric mobility attractiveness for consumers and ensuring equitable access for those without off-street parking. End-users were required to use a minimum of 2,000 kWh per year for charging, noting that the actual average consumption per charge point is growing and was over 7,000 kWh in Rotterdam in 2020.

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	The majority of the UK's charging demand is fulfilled by home charging, with 85% of EVs in the UK having home charging available.
(Hardman, et al., 2018)	This paper presents a literature review of studies that investigate infrastructure needs to support the market introduction of plug-in electric vehicles (PEVs). It focuses on literature relating to consumer preferences for charging infrastructure, and how consumers interact with and use this infrastructure. This includes studies that use questionnaire surveys, interviews, modelling, GPS data from vehicles, and data from electric vehicle charging equipment. This review considers charging for light duty BEVs and PHEVs. **Charge point activity and locations** Around 50–80% of all events for BEVs and PHEVs occur at home. Home location charging can include private charge points and public charging infrastructure in residential areas. After home charging work or commute location charging is the most frequently used infrastructure according to data from questionnaire surveys with consumers who own PEVs or who have driven them in trials. When BEV owners commute in their vehicle on average 15–25% of charging events occur at work. PHEVs tend to charge at work less. Public and corridor charging stations are the least used infrastructure type. Single digit percentages (around 5%) of charging events occur at these locations. However, these charging events can still be important for longer journeys and can be perceived as a safety net for other charging options. These locations are used more frequently by BEVs compared to PHEVs. Short range BEVs are unlikely to undertake long distance travel, but longer ranges BEVs are. For short range BEVs DC fast charge points are used mostly at intra urban locations. For longer range BEVs charge points may be used mostly at inter urban locations. The study shows that desired locations from survey data are the furthest from home, optimal locations based on GPS data are slightly closer to home, and actual use data from DC fast chargers indicates charging occurs far closer to home than is optimal or desired. This suggests that consumers anticipate that they will charge further away from home than they do in reality. **Pricing and interoperability** Consumers typically need to use a membership card to access public charging stations. Currently there are several different charging infrastructure providers, sometimes more than 20 different providers in a region. If consumers wish to access all stations, they may be required to hold a membership card for each company. This situation can cause difficulties for consumers and can be a barrier to them purchasing a PEV. To reduce complexity policymakers and charging infrastructure companies are finding ways to ensure PEV owners can access any charging station, regardless of membership status. This has been done in the Netherlands and Portugal, is a requisite for public charging in Germany, and has been proposed as a legislation in the UK. Empirical data investigating consumers and interoperability is limited. Results from an early study indicated that consumer respond positively to interoperability. The most important consideration for respondents was the possibility to access fast charging at public locations. In Norway, the Norwegian EV Association issued RFID cards to their members that can be registered with the main charging infrastructure providers and used at any location. It was found that 61% of PEV owners preferred this method of payment. Consumers believed this was easier than other solutions. Another potential barrier for consumers is the lack of clear information on how payments work. Payments for charging usually include one or more components: a onetime connection fee, charge time based payments, kWh based payments, or charging cost based on parking cost. This is significantly different from refuelling a conventional vehicle where consumers are aware of exactly what they are paying, and how much each unit of fuel costs. **Cost to charge** BEV owners who would need to charge to complete their daily travel may not risk driving their PEV if they perceive charge point congestion to be an issue or if they think charge points could be inoperable. Studies indicate that most cases of low dependability are due to congestion at the chargers, rather than from missing infrastructure or low technical reliability.

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	Free DC fast charging may encourage consumers to charge when they do not need to. Consumers may substitute overnight home charging for free DC fast charging at peak power demand times. This can also be problematic for PEV driers who need to use the fast chargers as they cannot access charging when they need it most. **Number of public charging stations** Few studies have worked towards understanding how many charging locations are needed to support PEV roll out. The optimal number of public charging locations may depend upon factors such as the number of workplace chargers, access to home charging (often dictated by housing type), travel patterns, and the market share of PHEVs and BEVs. In some regions, most households have their own dedicated off-street parking space on a driveway or in a garage. This is the case in Norway where 75% of households have their own dedicated parking and in California where over 80% of new car buyers can park their car in their garage or driveway. Another study found that more than half of new vehicle-buyers in the US park their vehicle within 25 feet of a level 1 charging opportunity. However, in many other regions (e.g. China or Netherlands), a higher proportion of drivers are unable to do this: they park their vehicles on the street, in off street public parking lots, or in private parking lots. Consumers in these regions may not have easy access to home charging, this can be a barrier to them purchasing the vehicles. According to several studies consumers perceive a lack of charging at home as a one of the greatest barriers to them purchasing a PEV. **Temporal distribution of charging and charge management** With uncontrolled charging, consumers are likely to charge their PEVs when they arrive at work, in public locations in the evening, and when they arrive home in the evening or night-time. Charging could be managed to prevent this, especially as vehicles have significant flexibility in when they charge as they parked for long periods of time (particularly overnight). A method of controlling home charging, and something that is being used at present in California, USA, is TOU domestic electricity tariffs. At off-peak hours (often at night), consumers pay a lower electricity rate. During peak times (often in the day), they pay a higher electricity rate. Households are incentivised to charge their vehicles at night. In some cases, additional metering equipment is required for consumers to have TOU tariffs. A California study found that consumers who had TOU rates chose to charge their vehicles in the lower priced off peak time. Smart charging is a more advanced system of managing charging. Smart charging can be implemented at home, public, and work charging locations. At DC fast chargers it may not always be possible to utilise smart charging, due to some PEV drivers wanting to charge their vehicles quickly. Smart charging is being implemented in the Netherlands. The system limits charging through communication between the charge point and back of office software. When charging needs to be reduced the current (amps) delivered to the vehicle is reduced. On the other hand, during periods of low demand and high supply, PEVs can charge freely. Most consumers have been willing to accept this method of charge management in the Netherlands A study using surveys and interviews with mainstream car buyers found that they are less willing to accept smart charging. Interviewees expressed concern over having less control over the how their vehicle is charged though. **Information, education, and outreach** According to questionnaire surveys and interviews mainstream car buyers' knowledge and awareness of PEV recharging infrastructures is currently low. The only consumers who have a high awareness of charging infrastructure are consumers who have purchased a PEV or ones interested in purchasing one. In other studies, increasing knowledge of infrastructure amongst PEV adopters led to increased use of charge points, which increases the overall electric miles driven by the vehicles.
(Hardman & Tal, 2021)	The authors conducted five questionnaire surveys in California between 2015 and 2019 (n=1,672) to investigate the rates of discontinuance of EVs and factors correlated with discontinuance. The authors found that 20.1% of PHEV and 18.1% of BEV owners reverted to an ICEV. The discontinuance is correlated with

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	having fewer vehicles in the household and dissatisfaction with the convenience of charging for both BEV and PHEV owners. BEV discontinuance is correlated with owning other vehicles in the household that are less efficient and not having higher speed level 2 (240 V) charging at home rather than lower speed level 1 (120 V) charging, which uses a standard electricity outlet. PHEV discontinuance is also correlated with not being male, not living in a detached house, being dissatisfied with the purchase price of the PHEV but being satisfied with running costs, shorter commute distances and undertaking more long-distance trips.
(Hasan, 2021)	The study of 278 Norwegian EV owners assesses their satisfaction with relevant aspects such as range-recharge, environmental attributes, cost, availability, symbolic attributes, and use-based policy measures. Only EV users were included in the study, because actual EV users could plausibly have different attitudes towards EVs than consumers who do not have any real-life experience with EV use. Respondents voice relatively low satisfaction with items related to range-recharge constructs (battery range, battery range during winter, and recharging duration). The limited battery range at low temperatures is relevant for cold regions as well as for many countries during the winter period. Countries need to install publicly accessible charging infrastructures and support installing charging facilities at home or workplaces where possible to mitigate consumers' range anxiety and overcome the low battery range issues. In addition to installing fast charging stations, recharging options at home or workplaces also offset challenges related to longer recharging duration as they facilitate recharging the car at night and/or during work hours when the cars usually stay idle.
(Haugneland & Kvisle, 2015)	The authors present and analyse the results from the 2012 and 2013 Norwegian electric car user survey. In the 2013 survey, 1,858 EV users (early adopters) contributed with their experiences and opinions. The typical Norwegian EV user is a middle-aged family father with higher education and income, and he owns a Nissan LEAF as one of two cars. He drives his electric car on a daily basis instead of a traditional petrol or diesel car. **Use of electric cars in daily life** 67% agree to the statement 'The charging time is fast enough'. 51% agreed to the statement 'The range satisfies my needs', while 60% also agreed that they need more charging stations. 53% agreed to need fast charging. The survey asked if the next car would also be electric. For the 31% who did not know and the 5% who answered no in the 2013 survey, they were asked to specify why they were uncertain or did not want to buy an EV the next time. The main relevant reason seems to be related to the limited range, either battery capacity or lack of charging network (29%). **Charging the electric car** In the 2013 survey, 1,579 (85%) of the respondents can charge in their own garage or parking lot. In addition, 178 (10%) have access to charging in the shared apartment building where they live. This means that 95% of the respondents can charge their electric car at home during the night. In addition 1,102 (59%) have access to charging where they work and 898 (48%) at public charging stations in the area they normally use the electric car. Charging at work or at public charging stations can be important for users with longer commutes or for those who do not have possibilities to charge at home. Public charging is also a supplement for longer trips and during winter when the range is shorter than normal. For a big majority of the charging points at home, ordinary household outlets (Schuko-points) are used (85%), not dedicated charging point equipment (9%). The remaining do not have charging possibilities at home. Respondents were asked about their use of public charging stations during the last month (May 2013). 11% of the respondents used public charging and parking on a daily basis the last month, 28% on a weekly basis and 35% less frequent. 26% of the respondents did not use public charging and parking at all the last month. When it comes to fast charging, only 1% of the respondents used a fast charging station on a daily basis last month. 8% fast charged their electric car on a weekly basis and 29% less frequent. 62% did not fast charge at all the last month.

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	It seems that the fast chargers are important to prevent range anxiety and extend the range of the electric car for extraordinary trips. Even if fast chargers are not frequently used, they still have an important function. **Payment for fast charging** Until the time of the survey, nearly all of the fast chargers in Norway were open and free of charge in a test period. The operators were starting to phase in payment solutions to their charging stations. 994 of the respondents stated they will use fast charging for having the possibility to drive the EV for longer trips in weekends, holidays, etc. Convenient locations where they can spend the time do shopping, restaurant visits, etc. is important for 551 of the respondents. As a safety net when it by accident is need for a quick refill of electricity, is important for 555 of the respondents. Real time status information, easy payment solutions, universal charging card and acceptable cost is important for around 500 respondents each. Slower fast charging for cold batteries (around half the effect) in four to five months in Norway complicates for the users the normal procedure by taking payment per minute using the fast charger, not the amount electricity (kWh) charged.
(Hawkins, 2022)	A common complaint from EV owners in the US is the sorry state of public EV charging: broken chargers, janky software, and busted screens. JD Power surveyed 11,554 EV and PHEV owners from January to June 2022 to measure customer satisfaction with EV charging on a 1,000 point scale. According to respondents, satisfaction with charging at a public Level 2 charger had worsened from the previous year, dropping from 643 to 633, while satisfaction with the speedier DC fast charger segment remained flat at 674. Finding a public charger has never been easier, but finding one that works remains a serious problem. According to the survey, one out of five respondents ended up not charging their vehicle after locating a public charger. Of those that didn't charge, 72% indicated that it was due to the station malfunctioning or being out of service. Tesla ranked near the top for customer satisfaction, with its Destination wall-mounted Level 2 chargers (most often found in parking garages or at hotels) ranking highest with a score of 680 out of 1,000, and is Supercharger network ranking highest among DC fast chargers with a score of 739. However, its network is designed to work only for its own EVs. It uses a proprietary connector in North America, so non-Tesla vehicles need an adapter to access the company's Superchargers. Tesla was expected to begin opening up its chargers to non-Tesla EVs at the end of 2023. The Biden administration released new standards aimed to accelerate the installation of new charging stations. Companies will be directed to build chargers that are convenient, affordable and accessible to the broadest number of people, and there will be a requirement that chargers be functional nearly 100% of the time and adhere to technical standards for communicating with vehicles.
(He, Luo, & Sun, 2022)	This study measures the objective, perceived and prospective accessibility of public EV charging facilities in the context of a high-density Asian city, investigating how and to what extent this set of accessibility measures affects the EV adoption intention of individuals. The data are primarily derived from a questionnaire survey of driver license holders in Hong Kong (noting that licensed drivers constitute 30.8% of the total population) administered to both EV owners (N=238) and non-EV owners (ICE vehicle owners N=327, do not own a car N=417) from February to May 2019. Objective accessibility is measured by the number of (population-weighted) Tesla and standard chargers publicly available within five minutes walking distance of an individual's residential district, and subjective (i.e., perceived and prospective) accessibility is measured by four Likert-scale questions. The results show that objective accessibility significantly and substantially influences an individual's intention to purchase an EV. Meanwhile, both perceived and prospective accessibility are highly significant for the adoption intention of non-EV owners.

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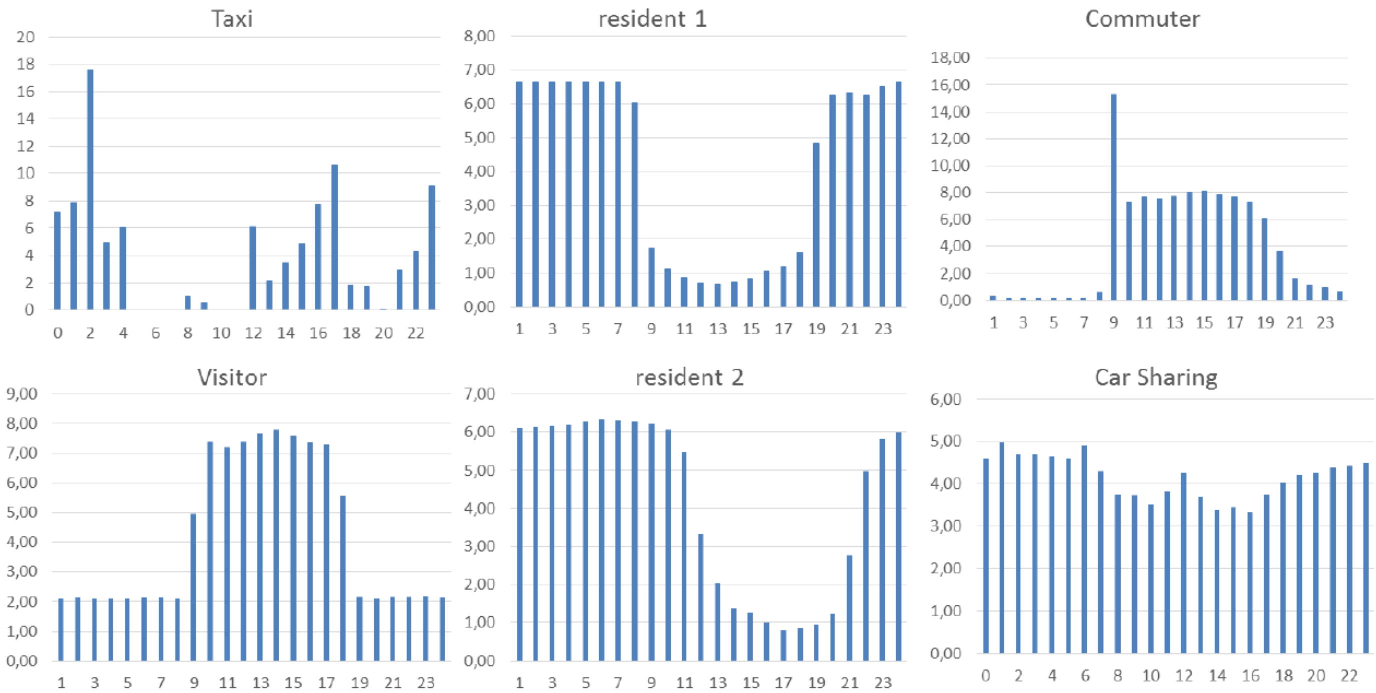
	In Hong Kong, public charging stations are typically located in public car parks. EV owners are exposed to more highly accessible quick and medium chargers, but had considerably less access to standard chargers and Tesla chargers. Improved charger accessibility was a commonly articulated issue, with 399 of the 720 valid comments indicating that improved charger availability would increase their adoption desire. Among those who mentioned charger availability, ten percent specified convenient access to chargers, which corresponds to the model result concerning the significant contribution of short-distance access (within 5 minutes) to charging facilities. There was a significant preference for charger accessibility in home rather than work districts. Currently, installing EV chargers in residential buildings or estates in Hong Kong is costly and cumbersome. Application proposals require consent from the owners' corporation or property management company. Meanwhile, power providers require applications for electricity supply that specify the estimated loading, wiring diagram and charger position. Given the potential disputes with incorporated owners pertaining to the limited power reserved for alternative electricity uses and the insufficient space available at standard parking lots, installing a private charger in one's parking bay is not a common practice. These physical constraints and administrative obstacles hinder perceived accessibility. The reliable service of accessible chargers represents another primary concern of EV pioneers. EV owners criticized the behavior of EV drivers leaving cars parked after charging is complete and ICE vehicles parking in such a way there is no access to EV charging points. To address this, Tesla has initiated an idling fee of HK$7.80 per minute at Tesla Superchargers when the station is fully occupied.
(Helmus & van de Hoed, 2015)	In 2014, in Amsterdam, more than 380,000 charge sessions logged of more than 10,000 charge cards were analysed to unravel the particular charging patterns of different user types (residents, commuters, city visitors or users of electric car sharing schemes) in terms of timing, charging amount and location preferences. Charging behaviour is the result of three influencing factors: – Driver related – EV experience, degree of trip and charging planning, social interaction – Infrastructure related – charging point area, charging point density, parking pressure, ratio of types of charging points, infrastructure policy – Vehicle-related – vehicle type, battery size, range, consumption. Charging behaviour develops from an unsteady state of charging behaviour to a more steady, consistent behaviour as users gain more experience with EV charging. Key findings: – Residents – start charging on weekdays between 5pm and 7pm, and end next morning between 7am and 9am; long duration (8 hours); valley pattern – Commuters – start charging on weekdays between 7.30am and 9am, and end same day around 6pm; long duration (8 hours); hill pattern – Taxis – start and end times for charging vary; short duration (4 hours); multiple saw teeth – Visitors – mostly start charging between 10am and 2pm, and mostly end between 6pm and 10pm; long duration (8 hours); flat with possible peaks – Car sharing – charging all day; very short duration (around 4 hours) except for charging sessions starting at night; valley at daytimes when driving, flat at night – RC chargers – resident and commuter times and aspects; flat pattern with two small valleys for travel time

Article	Key points
	 Figure 2: Six illustrations of typical connection patterns found in the dataset
(Helmus, Lees, & van den Hoed, 2020)	This study analyses the charging behaviour and EV user types based on a dataset of 4.3 million charging sessions of 28,668 users in Amsterdam from January 2017 until March 2019. The research is based on level 2 public charging, noting that around 75% of households in the Netherlands are dependent on public charging facilities. The users in this dataset comprised regular (private) users (96.5%), shared fleet cars (1.5%) and taxis (2.0%). As 80-90% of EVs in the Netherlands are company cars, either company owned or leased, it is expected that the users are biased towards higher income, larger mileage and higher educated persons. Pricing of public charging in the Netherlands consists of a flat fee per use (kWh) with a price cap of €0.28 per kWh. The clustering revealed 13 distinct charging session types and 9 user types. Charging session types: – 3 types of daytime charging sessions with medium duration (14% of sessions) – these mostly likely correspond with workplace charging.

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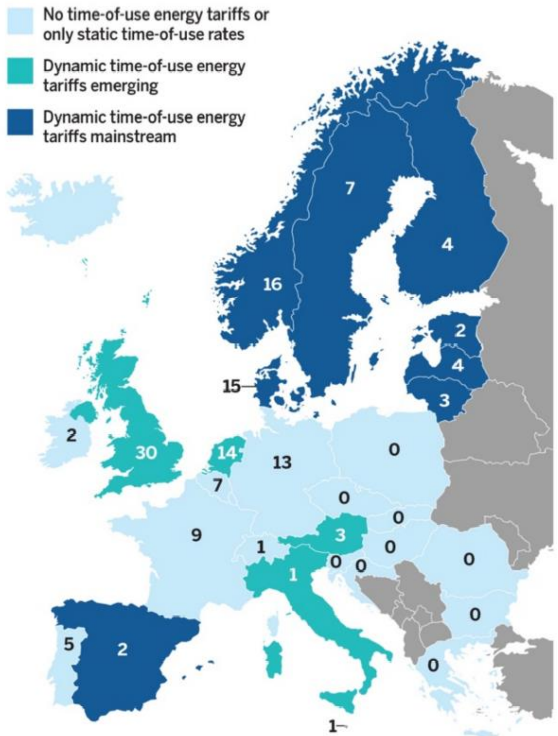
	– 4 types of daytime charging sessions with short durations (35% of sessions) – referred to as opportunity charging. Charging is driven by the opportunity to charging, related to parking, rather than a necessity to charge (e.g. range anxiety).
	– 6 types of overnight charging sessions (50% of sessions) – these most likely correspond with home (or near home) charging.
	User types:
	– Daytime user types:
	  – User type 5 (8.3% of population) – 1.7 charging sessions per week, 65% during office hours, around 35% typically opportunity charging and 4% overnight charging.
	  – User type 1 (8.9% of population) – 1,42 sessions per week, 40% during office hours, about 40% outside office hours during the daytime, and 20% during the weekend of which 0.1% overnight.
	  – User type 8 (5.7% of population) – 60% of sessions during office hours, 23% on same day outside office hours. Charging session is short. User likely to have a job requiring traveling.
	– Overnight charging user types
	  – User type 6 (21.0% of population) – a residential user with 4.6 charging sessions per week, 75% overnight and 25% short sessions during the daytime of which 30% is on the weekend. Battery size is significantly larger than for user type 2 (26 vs 15 kWh).
	  – User type 2 (13.2% of population) – an infrequent residential charger with 1.8 sessions per week, 72% overnight charging and 28% short duration charging.
	  – User type 7 (14.8% of population) – similar to user type 2 but has a large proportion of sessions occur at a different location, typically within walking distance (1,000 m). Typically in areas with high EV uptake and charging infrastructure maturity.
	– Non-typical users
	  – User type 3 (14.1% of population) – 2 sessions per week with a mixture of office and residential charging, with 23% of sessions during office hours, 47% nighttime charging and 30% opportunity charging.
	  – User type 4 (8.4% of population) – around 1 charging session per week of around 4 hours. Multiple destinations (e.g. shopping, sports, health).
	  – User type 9 (5.6% of population) – random user with little to no locations at the same location as the previous session. Includes car sharing EVs.
	Results show that none of the user types display solely stereotypical behaviour as the range of behaviours is more varied and more subtle. Analysis of population composition over time revealed that large battery users increase over time. From this, it is expected that shifts in charging portfolios will be observed in the future, while the types of charging remain stable.

(Henriksen, Thorsden, Ryghaug, & Skjolsvold, 2021)	Qualitative study based on 14 semi-structured interviews and email correspondence with 1 participant following their participation in a pilot project to test smart charging of EVs in Norway. However, due to technical issues, the smart part of the charging trial was not up and running before the interviews were conducted in January and February 2019. Accordingly, the focus of the study is on the users' motivation for opting to use smart charging and direct load control of the EV charging. **Background** In the early days of EVs in Norway, car owners would just simply plug their vehicle into a regular socket wherever one was found available and charge outside their home or in their own garage. Safety concerns have now led many EV users to install dedicated EV charging stations, with the added bonus of higher charging speeds.

Article	Key points
	The charger can be connected to the home energy management system (HEMS), or the home area network (HAN) of a smart electricity meter (as in the case study), which opens up the possibility of managing charging though demand response, either from the level of grid operators or by using automatic power management (APM). This is especially important given the prospect of Norway replacing the existing system of energy bills (whereby users pay by the kWh) with power tariffs (settled according to kW peaks). In Norway, 97% of fuse boxes have a smart meter and many EV owners have their own parking space at home. **Findings from the study** The analysis revealed four different, albeit somewhat overlapping, motivations for participation in the pilot and adoption of the use of a smart charger: ***Fast and fire-safe charging*** One important reason for participants wanting to procure a charger for their household was their concern for the lack of fire safety inherent in the practice of charging from a regular outlet. Even though the fuse on the circuit that could be used to couple and charge an EV would be sufficient in many cases (max 10 A), the impedance added to a long cable could risk adding to the amperage requirements without any immediate indication, resulting in cables overheating and eventually catching fire. The Norwegian Government issued stark recommendations on how to charge EVs safely. This included advice to install a dedicated charger, but there were still several concerns. In cases where it is necessary to use a regular outlet, an EV owner needs to make sure that it is earthed, and that is on a separate circuit with at minimum a 10 A fuse. Furthermore, a connector (usually one that comes with the car as standard equipment) can be damaged due to its weight, and therefore it is recommended that it should be hung on a hook or stored in a basket. Otherwise, the optimal solution is a home charging station. Such a device is usually fitted with a 16 A or 32 A fuse, but up to 63 A fuses are used in some cases. ***Technological interest and enjoyment*** Other EV users had signed up to join the pilot purely out of a keen interest in technology and the prospect of enjoyment from the use of smart technology. The users ascribed the motivation to their interest in mixing, matching, and playing with smart home technologies. However, the EV owners with an interest in technology and enjoyment encountered problems with lock-ins, bundling, and any kind of proprietary gadget or app that restricted their DIY aspirations, as they were unable to mix and match gadgets to achieve creative solutions and optimal conditions. This motivation meshes poorly in the absence of a personality that identifies strongly as technologically avant-garde or technologically competent, or if the person lacks sufficient income to spend on technology. ***Practical and economic concerns*** Some users were motivated by the prospect of installing smart home technology in the form of smart chargers because first and foremost it was *practical* to do so. Those with practical concerns were more interested in ensuring that a problem was solved in the most practical way. They were interested in the potential economic benefits of using a charger that only charged off-peak and when electricity was cheaper due to less demand. ***Flexibility as a means to enhance physical comfort*** To preheat the battery in wintertime in Norway was important for some of the EV owners, due to their expectations about battery health and battery-life expectancy. They expected that preheating would save the power in the battery, and would slightly increase the driving range. Night-time charging and preheating afforded some degree of physical comfort too, as the EV would be warm before setting out in the morning.

Article	Key points
(Hildermeier, Burger, Jahn, & Rosenow, 2023)	This article analyses 139 tariffs and services for smart EV charging available in Europe, collected between February and April 2022. It is focused on those tariffs specifically marketed as 'EV tariffs', meaning those labelled as such and/or which require (proof of) the use of specific vehicle or charging equipment. It does not include generic time-of-use tariffs. Number and distribution of smart charging tariffs and services across Europe:  It finds that while the market for smart EV charging services is growing, there is a lack of consumer information on the savings and broader environmental benefits it offers, such as integration of renewables. Offers are also unevenly distributed across the continent, resulting in unequal access to smart EV charging. The number of EV tariffs and services ranges between 0, mostly in Central ad European countries and Greece, 16 in EV market leader Norway, and up to 30 in the UK, where consumers have access to a tool to compare prices. Most (77) smart charging services are based on dynamic prices, which follow the day-ahead wholesale prices and therefore have hourly changing prices that are known a day in advance. Most of these services offer automation for adjusting EV charging to the hours with the cheapest energy prices within the user's preferences. Forty-four of the services analysed are based on other dynamic inputs, such as the share of renewables in the grid. The third-largest category of services (38) are based on static time-of-use signals. This means predefined times, typically set on an annual basis, in which a certain price is valid.

Article	Key points
	The fourth-largest category of services (29) are based on signals from the national grid operators and other energy system actors, based on the balance of supply and demand. These inputs are processed by services that adjust EV charging. Only 13 services in the sample use signals from local distribution grids to adjust their use in order to reduce stress on those grids, by avoiding adding to peak demand and/or by consuming at times of higher renewables feed-in.
(Hildermeier, et al., 2019)	In the current phase of the mobility transition, which still focuses on private ownership of cars, vehicles are idle about 95 percent of the time, and users generally need only 10 percent of the hours in a day for charging. **Smart pricing** At present, the most common type of pricing across Europe is the standard tariff, which is a rate that does not vary with time. Standard pricing is based on a flat, per kilowatt-hour charge for consumers' electricity demand. Because customers cannot lower their electricity bills by shifting their power use, they charge their vehicles at a desired time, regardless of grid conditions and regardless of the cost to generate and deliver electricity. Utilities across most of Europe offer their customers forms of time-varying price structures, but the uptake by consumers has been low on the whole. Pilot programs, featuring smart pricing, show that those consumers who do participate are responsive to price signals and willing to change their charging behaviors. Electricity tariffs that support managed EV charging require consumers to learn how to best use them to save money. Customer education is key, in particular to attract new user groups, who are not already convinced of the specific advantages of electric vehicles. Experience from the United States confirms that many energy suppliers reported positive experiences when testing the introduction of time-varying tariffs in smaller pilot projects. **Smart technology** At present, it is difficult to foresee which business models and technologies for managing electric vehicle charging will survive the current rapid-growth phase. Some manufacturers install the metering equipment in the vehicle, others place it in the charging equipment, and yet others in the charging cable. The electric vehicle users of the future may have the option of choosing from different levels of technological capability, different price categories and a variety of solutions to their mobility challenges. **Smart infrastructure** While most charging can be expected to happen at home or at work, research and industry broadly agree that a small but significant share of (fast) charging will occur at publicly accessible sites, depending on the uptake of electric fleets, fleet use and mobility-as-a-service schemes.
(Inbar, 2023)	The communications networks that connect chargers with their management system, the personal data that travels across those networks, the charge-point operators collecting payments, and the grid itself are increasingly vulnerable as the EV ecosystem grows and the attack surface expands. The risks include (but are not limited to): – Disruption of operations for public charger networks, rendering large numbers of chargers unusable and interfering with transportation – Takeover of charger networks to use the chargers as bots in massive distributed denial-of-service (DDoS) attacks – Theft of customers' personal identifiable information (PII), including payment card information – Fraudulent payments for electricity used in EV charging – Disruption to the power grid, leading to blackouts and equipment damage.

<table>
<tr><th>Article</th><th>Key points</th></tr>
<tr><td>(Initiative Deutsche Zahlungssysteme e.V., u.d.)
(Initiative Deutsche Zahlungssyteme e.V., u.d.)</td><td>Survey conducted among motor vehicle owners (not EV owners) in September 2021 in Germany (1,058 people) and November 2021 in France (538 people), Greece (535 people), the Netherlands (514 people), Poland (529 people), Slovenia (538 people) and Sweden (535 people).
Many users want to use public charging stations. Card payment is the most popular payment method at charging stations across the surveyed countries.
<table>
<tr><th></th><th>Want to use public charging station</th><th>Bank card (credit / debit card), smartphone</th><th>RFID card or charging app with prior registration and billing via invoice from an electricity provider</th><th>Scanning a QR code with smartphone and entering payment data via mobile website</th></tr>
<tr><td>Germany</td><td>71%</td><td>78%</td><td>5%</td><td>7%</td></tr>
<tr><td>France</td><td>55%</td><td>89%</td><td>4%</td><td>3%</td></tr>
<tr><td>Greece</td><td>24%</td><td>91%</td><td>2%</td><td>4%</td></tr>
<tr><td>Netherlands</td><td>76%</td><td>79%</td><td>8%</td><td>5%</td></tr>
<tr><td>Poland</td><td>70%</td><td>89%</td><td>2%</td><td>5%</td></tr>
<tr><td>Sweden</td><td>67%</td><td>67%</td><td>15%</td><td>10%</td></tr>
<tr><td>Slovenia</td><td>76%</td><td>83%</td><td>4%</td><td>5%</td></tr>
</table></td></tr>
<tr><td>(Innovate UK, 2019)</td><td>The UK has a number of V2G trials, with the first installations started in December 2018. Key learnings include finding the right customers:
1. Clear proposition works best. There are a number of approaches along the “hands-on” to “hands-off” spectrum:
– Hands-on – direct customer reward – energy and service payments are treated separately; user has full visibility
– Mid-range – “Never pay for mile driven ever again” – energy and service payments are aggregated; limited user intervention needed
– Hands-off – easy to understand bundle; EV lease agreement requires plug-in for minimum amount of time.
2. V2G business case does not work for every type of user. Top customer archetypes are The Retired Professional, Council fleet – Pool cars, The Eco-Professional, The Run-around (EV as second car), Company car park, EV Car clubs.</td></tr>
<tr><td>(Institute for Future Energy Consumer Needs and Behavior (FCN), 2019)</td><td>A Discrete Choice Experiment (DCE) conducted in Germany with 4,101 respondents, of which 84 were EV owners, to assess current and future EV drivers’ valuation of six attributes of the charging process of privately-used passenger EVs in Germany: charging location, charging speed, charging technology, waiting time for a charging spot to become available, share of renewables, and monthly charging cost.
The most preferred locations for EV charging are home (80%) and work (12%). The preferred payment schemes for EV charging are pay-per-kWh (47%) followed by a flatrate for a fixed monthly fee (42%). The two other payment schemes, pay-per-minute and monthly subscription (fixed costs & pay-per-minute), are preferred equally (5% each). The most preferred services at EV charging stations are a supermarket (76%) and a bakery shop (35%).
The six attributes were rated in importance as follows:
1. Cost – lower costs are preferred.
2. Charging duration – there was hardly difference in preferences between 10 minutes and 30 minutes, with lower preferences for 4 hours and 8 hours.
3. Place of charging - participants prefer charging at home to at work to roadside charging as a side activity to roadside charging as the main goal.
4. Waiting time – only two values were statistically significant – no waiting time and a 30 minute waiting time.
5. Share of renewable energy – higher shares are preferred.</td></tr>
</table>

Article	Key points
	6. Technology – weak preferences for inductive charging (without cabling) rather than tethered charging (with cabling). Other important attributes were range of the EV (0.68), compatibility of charging points of different providers (0.39), dynamic pricing (e.g. discount for night charging) (0.38), payment scheme (0.30), possibility to reserve a charging spot (0.21) and possibility to use the EV as power storage (0.15). EV owners' choices diverged from the entire samples. They selected an 8 hour charging time more than the sample indicating an advanced usage experience where long charging times are tolerable. They selected higher shares of renewable energy and were less cost-sensitive. **Willingness to pay**

Variable	WTP (€/month)
Charging duration (reduction by 1 minute)	0.16
Waiting time (reduction by 1 minute)	0.82
Renewable share (increase by 1%)	0.42
Technology (inductive instead of cabling)	8.38
Charging location:	
At home	(base)
On the road (main goal)	-46.26
On the road (side goal)	-35.64
At work	-22.31

Article	Key points
(Institute of Transport Economics, Norwegian Centre for Transport Research, 2019a)	The report presents the results from an online survey of Battery Electric Vehicle (BEVs) and Internal Combustion Engine Vehicle (ICEVs) owners, which was conducted in May/June 2018. The report compares the results to the results from a 2016 survey. While BEV owners in the 2016 survey were typically "early adopters", participants in the 2018 survey were typically the "early majority" of adopters. **Daily driving and home charging** The frequency of home charging was the same in 2018 as in 2016, with 80% of users charging 3 times or more per week in the garage or their own parking lot at home. Only about 3% reported that they charged in the street at home weekly or more often, and most respondents reported that they never do this (88%). 18% reported that they charged three times or more per week at the workplace, and 27% reported that they did this on a weekly basis. Few respondents reported using available public chargers. Only 13% used them on a weekly basis (1 times or more per week). On average, users said they charged about 4.4 times/week at home and about 1.1 times/week at work. The type of electricity connection is relevant for the safety of the charging process. New installations are required to have a dedicated socket and line with a specific fuse and ground fault detection unit installed in the fuse box or in the form of a home charger. The home charger units (also called "wallbox") have built in ground fault detection and circuit breakers and are connected to the fuse box with a dedicated power line and fused separately. Using an ordinary domestic socket over time can pose a fire risk and should be avoided, and it is no longer allowed for new installations. The home charging process had become safer with 43% using home chargers ("wallbox") in 2018, up from 24% in 2016. There was no great difference in type of electricity connection being used between the type of housing/degree of detachment. There was however a smaller share among those living in apartments that reported that they used an ordinary socket than those living in detached houses or row houses/town houses. The reason is likely that the boards of the apartment buildings have to approve the charging solution used in the common parking facility, and that they therefore require that safe solutions are used.

Article	Key points
	Only 7% of users said they never charged their vehicles at home, whereas another 2% said they did it rarer than monthly. For these two groups of BEV owners, 53% said they charged at work, 29% at public chargers and the rest on-street close to home. BEV owners living in apartments charged less often at home (65% weekly or more often) than owners living in detached houses (96% weekly or more often). **Long distance driving** A large challenge for full diffusion of BEVs in Norway is efficient charging solutions for long distance driving. The challenge will be particularly important during peak long distance travel times, such as vacations. An analysis of the market by sub segments and vehicle prices, and the availability of long range BEVs, indicate that such vehicles will become available in most vehicle segments. Users will thus be able to select a more expensive vehicle or battery option that allow them to avoid charge queues on peak travel days. The range anxiety went down somewhat with increasing battery size. The effect was however rather small up to battery sizes of 40 kWh. When looking at the owners that strongly or somewhat agreed, the difference between the long range and the short range vehicles seems fairly small. The reason could be that these vehicle types are used differently, i.e. that the vehicles with small batteries rarely are used for trips where the range is too short. When vehicles get longer range, people likely use them for longer distance trips and the range anxiety is reduced less with increased battery capacity than expected. **Fast charging** Fast charging supports long distance trips in addition to extraordinary local and regional travels, as well as those that forgot to charge their vehicle overnight. The surveyed BEV users said they did about 19 fast charges per year on average. 12-18 percent experienced queues often or always depending on location. Another 41%-54% experienced queues sometimes. Owners seemed to accept between 1-3 stops and 5-20 minutes of charge queues on days when many people are travelling. About half of users were willing to change travel time on peak travel days to avoid charge queues, but mainly within the same day. BEV owners reported a variety of activities while charging, such as checking/sending e-mails, looking at social media, taking a stroll or using the facilities at the charge station (kiosks, cafés, toilets etc.). Users in general rated the availability, location, payment solutions, reliability and quality of fast chargers on long distance trips to be good, with only about 1 out of 10 users (non-Tesla) not satisfied. The ease of payment was also rated satisfactorily, likely because all operators offer a pay per minute solution through the use of an App, an RFID card or with an SMS message via the cellular phone networks. A large share of Tesla owners answered not relevant on the ease of payment which is understand-able, as most of them did not need to pay in the Tesla Supercharger network at that point in time. Tesla has an easier job than other car manufacturers when it comes to making the fast charge experience seamless, as they have control of the hardware and the software both in the vehicle and in the charger. Availability and position of the fast chargers were, by the users that have an opinion, on average for Norway rated as good by 65% of users and poor by 11%. Capacity of the charger locations were on average for Norway rated as good by 65% of users and poor by 11%. Quality of the charger locations were on average for Norway rated as good by 69% of users and poor by 10%. Payment was the overall most positively rated parameter of fast chargers, and on average for Norway rated as good by 81% of users and poor by only 6%. “Plug’n charge” solutions are currently being developed. In these solutions users plug in and the system automatically detects the vehicle, authorises the charge and sends the bill, much like Tesla owners already experience. User assessment of payment solutions is thus likely to become even more positively rated in the coming years.

Article	Key points

(Institute of Transport Economics, Norwegian Centre for Transport Research, 2019b)	Home charging (based on unpublished results from a 2018 survey)
	– Detached / small houses
	  – EVSE wallbox cost about US$1,200-1,800 to install
	  – Ordinary socket (35%), dedicated socket (with proper fuse) for the car cable (20%), home charger station 16A (23%), home charger station 32A (20%), other connection (1%), don't know (2%)
	– Flats with common parking
	  – Parking facility jointly owned, annual meeting decides, high cost, insufficient grid power
	  – Typical solution – basic infrastructure jointly owned, load shedding equipment, common cost $US1,000 per flat, wallbox chargers are bought by flat owners which is billed for the electricity, charger cost US$1,500 per flat
	Public charging – 2019 and beyond
	– Cities – fast charging – challenge is land to put chargers on
	– Cities – normal charging – main challenge is on-street parkers, due to cost, permit, practicality, time. Makes road use less flexible. But more important as adoption increase among users without parking
	– Fast charging between cities – expanding to super fast
	– Destinations – resorts, private cabins and holiday homes.
	Fast charger user types:
	– Occasional user (30%) – used for rare range problems
	– Frequent user (10%) – without home charging or professional users
	– Long distance trip user (rare) – to get to far-away destinations
	– Local user (common) – to solve everyday needs.

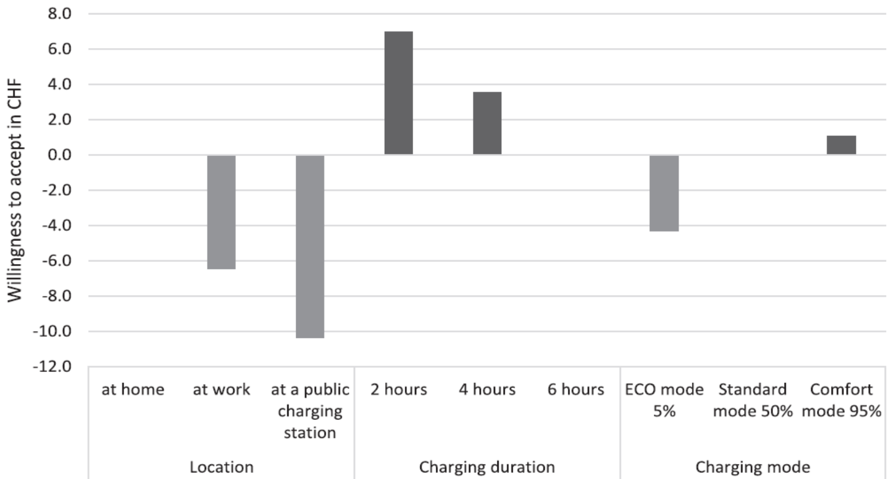
(International Energy Agency, 2018)	The IEA paper provides insights on charging behaviour, building primarily from surveys which analyse consumer behaviour for electric car charging practices. It focuses primarily on Norway and Sweden; similar research suggests that electric car charging practices are largely similar in Denmark. **Norway** Surveys of Norwegian BEV and PHEV owners suggest that electric car drivers most frequently charge their vehicles at home or at work, relying on slow chargers. In Norway, 63% of private home chargers are ordinary plugs without additional functionalities, while 19% are chargers with a 3.7 kilowatt (kW) wall box, 12% with a 7-22 kW wall box, 3% with a Tesla charger and 3% did not specify. The preference for using private home chargers matches the fairly limited number of long distance trips of electric cars, which are mostly used for commuting (92%) to work and common day trips (57%). Home charging has also proven to be reliable for most households: almost 90% of Norwegian electric car owners have never experienced issues with it. The third most frequent charging choice (after home and workplace) is publicly available slow chargers, followed by chargers located at commercial and leisure facilities (charging at a destination) such as supermarkets, hotels or restaurants. The predominant use of slow chargers is consistent with the preference of Norwegian electric car owners to typically drive 20-40 km/day, as this leads to fairly limited amount of energy and time needed for daily recharges (less than 1.5 hours with a 6 kW charger, with 40 km and 0.2 kWh/km).

Article	Key points
	Fast charging is not used frequently, and it primarily takes the form of planned stops for long distance trips. Consumers that use fast charging stations have had limited problems with queues. Norwegian electric car owners are only modestly satisfied with the publicly available charging infrastructure. In practice, only 4% of electric car owners have experienced an empty battery and less than a quarter experienced a “close call”. Almost 20% of electric car owners in Norway did not use their electric car on several occasions due to the lack of chargers and more than 10% due to long charging times. **Sweden** In Sweden, up to 80% of electric car users live in individual houses, compared to around 50% for the general population. Home charging dominates other forms of charging and more than two-thirds of respondents use the regular Type C socket and plug. Most home charging takes place at the residence. Very few electric car owners charge their car at a publicly available street parking place near the house. Charging at work is also relatively common: 35-40% of people surveyed claim to do so daily or weekly. Charging when parked at shopping centres and other commercial or leisure destinations is not very common: 65-70% of electric car owners never or seldom use that option. Other public charging, including fast charging on highways, is used more frequently: nearly half of BEV owners claim to charge on highway fast chargers at least on a monthly basis (and very few on a daily basis). There are two distinct user groups of public charging. The first group used normal charging only when they knew that they would be parked for several hours. Typically, during a workday at a parking place near the workplace or at public transport node. The second group almost only used fast charging. Users in both these groups resist changing their charging behaviour, since any other option was perceived as not worth the effort. The study shows that different types of public charging infrastructure serve various user needs.
(International Energy Agency, 2022b)	As EV markets swell, access to public charging will need to expand as well. Today most EV charging takes place at residences and workplaces. Consumers will increasingly expect the same services, simplicity and autonomy for EVs as they do for conventional vehicles. Both the markets in Norway and United States are characterised by widespread reliance on home charging, due to the high share of single family dwellings (with garages) by international standards. It appears that in countries that rely more heavily on public charging, the charging network is expanding accordingly, while for countries with high shares of residential charging, fewer public chargers can serve a higher number of EVs. As the market evolves and more consumers replace conventional vehicles with EVs, even in countries with high shares of single family dwellings, the reliance on public charging solutions will increase. The Alternative Fuels Data Centre lists almost 50 000 EV charging stations currently in operation in the United States. Of these, 93% are publicly accessible, and 17% are on non-urban roads (including highways and other arterials). A disproportionate share of direct current (DC) fast chargers are public (99%) and located on highways (25%), reflecting the faster charging needs at these locations. About 6% of charging stations are located along the interstate highway system, the backbone of the national road network. Stations along the interstate highways account for 16% of the total number of DC fast charging points. About 8% of the US population lives more than 10 km from a public charging station. As part of its goal to ban new ICE cars by 2030, effectively shifting to EVs and PHEVs, the United Kingdom took action to mandate smart EV chargers. The Automated and Electric Vehicles (AEV) Act 2018, mandates that all EV charge points sold and installed in the country have smart functionality and meet minimum device level requirements. The United Kingdom was an early adopter of a policy to mandate smart charger functionality; others such as France have followed suit. Germany and Greece mandate smart charging for private chargers to qualify for subsidies. Greece mandates smart chargers for all publicly accessible charging points. Portugal mandates smart chargers at publicly accessible charging points.

Article	Key points
	In July 2021, the UK government released its smart charging strategy that is based on a two-phased approach. Phase 1 requires that new charge points, public or private, be smart chargers and be set by default to charge only at off-peak times of the electricity system. Smart functionality is defined at the device level and includes: the ability to send and receive information; to modify the time of charging in response to information received; and to use the functions to provide demand-response services. It also incorporates basic cybersecurity standards (existing cybersecurity standard ETSI EN 303 645), basic interoperability to ensure that charge points are not designed to block change of supplier, and data accessibility, including customer access to consumption data. The specifications are outlined in regulations for EV smart charge points that come into force in June 2022. Phase 2 topics include full charge point operator interoperability (the ability of consumers to switch operators) and more in-depth analysis of elements such as cybersecurity and grid stability.
(Johnson, Berg, Anderson, & Wright, 2022)	Calculating cybersecurity risk is challenging because this depends on equipment, customer interaction mechanisms, interconnectivity to other systems, and, in the case of power system impacts, the location and power levels of impacted installations. The primary consequence of concern involves Electric Vehicle Supply Equipment (EVSE) and EV functionality and safety, personal and corporate privacy, financial operations, and electric grid operations. Negative outcomes include theft of energy, creation of hazards to people and equipment proximate to EVSE, disablement and damage to vehicles, and interference with grid functions.
(Kalthaus & Sun, 2021)	This paper analyses the effect of four determinants of electric vehicle diffusion in China for a panel of 31 regions for the period 2010‑2016, using data from various sources provided by the Chinese government. The paper analyses diffusion of four different electric vehicle types, namely battery electric cars and buses as well as plug-in hybrid electric cars and buses. Availability of public charging infrastructure increases diffusion of all vehicle types. Charging points are relevant for cars, while charging stations are especially decisive for the diffusion of electric buses.
(Kaluza, 2022a)	The first in a three-part blog that explores what it's like for customers to buy and charge an EV. The first blog considers the research and EV purchase phase of the EV journey. When buying an EV, there is also the option to buy a dedicated EV home charger (electrical vehicle supply equipment or EVSE). Charging tends not to be a consideration until the purchasing phase is well underway, or even completed, and tends not to be a barrier to the purchase of an EV. Since vehicle providers – both dealers or the automakers themselves – tend to be different from the charger providers, there are multiple touchpoints to deal with in this phase of the journey, compared to just one with a traditional ICE vehicle. The customer has multiple opportunities to 'drop off' the charger purchase pathway, due to the volume of additional actions required to complete. Along this pathway, there needs to be consideration of things such as: – Is a home charger needed or will public charge points suffice? – What is the budget? – What features are important? – Technical evaluations such as: is the home currently capable of supporting a charge point? – Which company should be chosen to complete the installation?
(Kaluza, 2022b)	This paper summarises the findings of the world's first and largest domestic V2G program. The program onboarded > 330 customers in the UK, and analysed half-hourly data from the charger fleet over 12 months.

Article	Key points
	Customer plug-in rates peaked between 17:30 and 18:00 and unplugging between 07:30 and 08:00. On an average day ~61% of the V2G portfolio was available between plug-in and plug-out times. The average battery's state of charge on plugging in was 43% and most customers set their car's maximum state of charge at 90%. Based on trialist research, a minimum state of charge was developed to ensure a baseline of energy was preserved at all times, in case the car was needed in an emergency. This boosted drivers' confidence in the technology as they were reassured that they would always be able to use their vehicle. 93% of participants were satisfied or very satisfied with their V2G experience. The level of concern around battery health dropped from 61% at the beginning of the trial to 24% at the end, and worries about cost savings while using V2G decreased from 43% to 28%. With regards to how V2G could be improved, customers expressed a desire for the technology to do more for them, for example, be compatible with their solar PV and be used to deliver back-up power. The concept of using the battery in an EV to power the home or sell electricity back into the grid is still unknown to most EV drivers and the wider population. Two key focuses came out of the feedback from the program: 1. Make rewards simple and engaging – communicating the rewards structure effectively for diverse customer segments is critical especially when it comes to a relatively complex technology. 2. Invest in educating customers – this is key to addressing concerns and misconceptions around the technology and builds trust so that drivers can get the most out of their EV as long as possible. Enabling customers to easily set their V2X charging settings for optimum battery performance is a crucial part of making V2X adoption scalable. The complexity of the EV ecosystem makes EV acquisition and ownership overwhelming for many customers. Today, an average customer needs to interface with at least 6 different parties to receive the full EV experience. Potential parties include: auto OEM, dealership, digital marketplace, finance provider, insurance provider, EVSE OEM, smart charging, retailer, distributor, installer, CPO.
(Kaluza, 2023)	The second in a three-part blog that explores what it's like for customers to buy and charge an EV. The second blog considers the set-up and onboarding phase of the EV journey. **Set-up: App overload** In the current EV climate, at least eight apps are likely to be needed on a phone to set up and manage the EV day-to-day. Each app gives some information on a specific aspect of EV use – such as where it can be charged, when best to charge, how much it's costing and battery health – but there is no single app that can give this holistic view so the EV driver has to download and flit between several. **Deciding on an energy tariff** Whilst over two thirds of drivers are aware of the advantages of switching to an EV tariff and have considered doing so, most have not yet taken the leap, the reason being that they may be unaware of tariffs that offer the right incentives to switch. Switching also requires more work from EV drivers at the set-up stage so it's unsurprising that not many move tariff even when customers are aware of their options. **Setting up for public charging** Among the collection of EV-related apps, will likely be at least one for locating, accessing and paying for public charging. There are over 80 charging networks across the UK, all with their own apps and subscriptions. Many automakers, roaming platforms and even car parks are now also offering their own apps. EV drivers are therefore faced with a bewildering array of apps and cards for public charging offered by a number of vendors – electric utilities, eMobility specialists, fuel retailers and automakers, amongst others.

Article	Key points
	The majority of European drivers today own more than one public charging card and app, with over a third of UK drivers using more than 4 public charging apps. The US has a similar problem, with almost all of the charging networks (of which there are at least 35) requiring their own app or card to access in many states. 90% of chargers are not equipped with a credit card reader in the EU, meaning each charging network will often require registration and its own app or card to use. Other areas of dissatisfaction include: – patchy charger information on availability and pricing – different pricing conventions between networks, and – finding chargers that actually work.
(Kim & Heo, 2019)	This study analysed the revealed preference data for EVs in Korea from 2013 to 2017. The more chargers are available, the easier it is to use the EVs so a number of studies have hypothesised that the number of charging stations would have a positive impact on EV adoption. However this study found that the public fast chargers had a negative impact on the annual sales of EVs, although it is statistically insignificant. The authors suggest that Level 2 chargers have been mainly used while fast chargers have played an auxiliary role – for charging in an emergency or a psychological role in reducing range anxiety. The breakdown of EV charging in Korea is fast charging (31.0%), home (27.9%), public level 2 chargers (24.0%) and workplace (15.3%). At the time when one has to move his or her car out of the parking lot after 30 minutes of fast charging, the Level 2 chargers can provide a great many advantages over the fast chargers to the EV owners who want to charge during the time when the car is parked at home, the workplace, or at their convenience.
(Kim, Yang, Rasouli, & Timmermans, 2017)	This study analysed four years of charging transactions of 9,027 Dutch EV users from August 2010 to August 2014. In the Dutch context, more than 85% of the PEV market share is dominated by PHEV. Thus, these users dominate the use of public charging stations. BEV users mainly charge at home in private parking places or at work. Given that PEV users exhibit heterogeneous charging behavior in terms of charging frequency and charging regularity, this study examined how often PEV users charge their car, and to distinguish the distinct characteristics of random (erratic) users and regular (routine) users. The results show that 90% of PEV users charge their car randomly at public charging stations, while 10% charge regularly. It was found that significant differences exist between the two groups in terms of charging characteristics, such as charging interval, charging duration, loyalty to charging station and total number of charging episodes. Most PEV users tend to charge randomly at public charging stations, and they are likely to be light users given the short charging durations and long charging intervals. Regular users, however, those who exhibit habitual process in terms of charging interval, have a high loyalty to a specific charging station. On average, regular users charge at public charging station almost every 2.75 days, while random users charge every 5.65 days. PEV users who have regular charging patterns tend to charge more and longer compared to random users. Weekend charging is more significant in the random user group. That is to say, regular users tend to charge more at weekdays. Weather conditions appear to have a direct impact on charging decisions at public charging stations. Harsh weather conditions postpone one's decision to charge a PEV at a public charging station. When the mean temperature is lower than 0 deg C, a PEV users' charging rate increases by 5%. This result may indicate this variable reflects not only PEV users' charging behavior but also factors affecting battery consumption such as parasitic load (e.g., heating) and battery performance at low temperatures. In contrast, *Temperature > 20 deg C* leads to a 14% decrease in the charging rate on the corresponding day suggesting good performance of the battery at this temperature. *Heavy wind speed* and *Heavy precipitation* have high negative effects on inter-charging times of PEV users at public charging stations, and lower the charging rate by 5% and 4%, respectively.

Article	Key points
(Klein, Lupke, & Gunther, 2020)	This study uses empirical data primarily derived from a choice-based conjoint study of young German consumers' preferences to analyse the buying behaviour regarding BEVs and PHEVs. The study comprised 552 Germans with an average age of 25. The aggregated relative importance values and their standard deviations indicate a high level of heterogeneity regarding customers' evaluations of attributes, other than a very homogenous view on charging time. Range and charging time were, on average, found to be less important than consumption costs and initial purchase price. They found that home charging has an important influence on the diffusion of both, electric and plug-in hybrid electric vehicles. However, its importance decreases with faster charging times at public charging stations. Furthermore, the findings reveal that in the longer term, technological progress in charging time, range, and charging station density of electric vehicles is presumably cannibalizing PHEVs' market shares more than that of conventional vehicles (CVs). Contrary to the other technological improvements, an increase in home charging has a strong additional effect on consumers switching from CVs to PHEVs.
(Kubli, 2022)	Customer adoption is a crucial success factor for implementing smart charging solutions. This paper employs a choice experiment, based on a sample of 202 current and potential EV drivers in Switzerland, to measure the extent to which and under which conditions EV drivers are willing to adjust the charging location, duration, and charging mode to enable smart charging. The charging mode is the guaranteed range after 50% of the charging duration, and considers three levels – 5% (ECO mode), 50% (standard mode) and 95% (comfort mode). EV drivers put the highest weight on the charging costs when deciding on the charging options. Charging location follows charging costs as the second most important attribute. The two lowest importance factors are charging duration and charging mode. While costs outweigh all other attributes, the impact of providing flexibility (as captured in the attribute 'guaranteed range after 50 % of the charging duration', which was abbreviated as 'charging mode') is of considerably lower importance for potential adopters. This implies a low sensitivity of EV drivers toward a moderated charging process, as long as the EV is fully charged at the end of the charging duration. In addition, the location of charging station is relatively more important than the potential impact of smart charging. **Willingness to accept:**  Fig. 5. Willingness-to-accept values for changes in the levels of the charging offer.

Article	Key points
(Kuby, 2019)	This paper reviews the limited literature on revealed preferences of where actual early adopters of single-fuel fast-filling and fast-charging alternative-fuel vehicles (AFVs) choose to refuel or recharge when faced with the reality of a sparse network of stations, that is, it does not consider slow charging. The studies suggest that drivers adapt by focusing more on convenience of locations than price. Drivers refuel: – more frequently at the same stations – at higher tank or battery levels – fast-charging commenced 14-19 km earlier than necessary, which was attributed to range anxiety among drivers. This inefficiency was not improved with higher capacity batteries or experience with the EVs. – more on work-anchored trips – more in the middle of trips – less often near home – more often on their way – take larger detours compared with drivers of gasoline and diesel vehicles – 18% of EV drivers fast-charged at a station where either the origin-station distance or the station-destination distance exceeds the origin-destination distance, that is, the recharge clearly took them away from or past their destination. Plug-in hybrid EV charging is different than for pure BEVs. PHEV drivers charged them on only 19% of trips and were mostly plugged in at home in the evening. Small-battery PHEV drivers charge at public stations less frequently than large-battery PHEV drivers possibly because there is less incentive to charge a smaller battery when the car can run on gasoline when the battery is depleted. Note, the paper draws extensively on (Sun, Yakamoto, & Morikawa, 2016).
(Kwon, Son, & Jang, 2020)	The paper is based on a face-to-face survey of actual BEV owners in South Korea (N=152) who had driven BEVs for at least 6 months as of March 2016. 64.5% of respondents were male (noting that 71% of driver licence holders in South Korea are male) and were 50 years old on average. 98.7% of respondents had a BEV charger (residential 79.6%, workplace 15.8%, mobile charger 3.3%). The survey included 18 questions. The lowest scores related to range satisfaction (The range of BEV is sufficient for accomplishing my trips) and charging satisfaction (I am satisfied with the charging of my BEV). Although most BEV users were not satisfied with the current status of driving range and charging, the authors hypothesise that satisfaction regarding these factors will gradually improve with technological advances. For example, fast chargers and high-capacity batteries are becoming available at affordable cost and the charging infrastructure continues to expand. Cost-saving intention behaviour is more pronounced for BEV users; sensitivity and intention to reduce operation costs of BEVs were the most influential factors on BEV user satisfaction. The electricity rate in South Korea accounts for a large portion of the operating cost and this varies with the time of day and type of charger (i.e. slow or fast charger). As a result, charging cost can differ depending on the charging strategy adopted. This may not hold true if the electricity rate for charging BEVs is flat or substantially low (e.g. in Norway).
(Lagomarsino, van der Kam, Parra, & Hahnel, 2022)	An online randomised-controlled experiment was conducted in 2020 with two waves (baseline and experimental phase, *N* = 222), to examine drivers' preferences for smart charging and tested a behavioral intervention to increase the number of smart charging choices. In the first wave, on average, participants decided to use smart charging 67.28% of the time. The time of the day, price concerns and the initial state-of-charge (SoC) were the most important attributes. Compared to the reference level (i.e., the least preferred attribute level) of 25% SoC, participants preferred smart charging to immediate charging significantly more at 75% SoC, and 50% SoC, and more at 75% SoC compared to 50% SoC. Variation in *time of the day* significantly impacted charging choices: compared to the reference level of 8AM, participants preferred smart charging to immediate charging significantly

Article	Key points
	more at 6PM, and at 12AM, and significantly more at 6PM than at 12PM. Compared to the reference level of 0p/kWh savings for smart charging, participants preferred smart charging over immediate charging significantly more when they could save 6p/kWh and 12 p/ kWh. However, there was no statistical difference in charging choices between 6 and 12 p/kWh savings. In the second wave. the SoC information was translated from percentage of battery level (*Control*) into: – *miles* corresponding to the battery level – *tailored* information, i.e., the number of driving days covered by the actual SoC based on participants' personal driving profiles. The likelihood that a participant chose smart charging over immediate charging was 1.34 times more likely in the *Miles* condition than the *Control* condition and 1.49 times more likely in the *Tailored* condition. The more participants aimed to increase the amount of renewable energy used for driving, the more they chose smart charging compared to immediate charging. Individuals in the *Tailored* condition overall allocated significantly less importance to the battery SoC information than respondents in the *Control* condition when making the charging choice. However, tailored information only decreased the importance of battery SoC information for drivers covering short driving distances. When drivers covered long distances, the weight they assigned to battery SoC information in the decision process was relatively high, independent of the experimental condition. Under this condition, assigning high relevance to battery SoC information is in line with individuals' intensive driving behaviour and the associated need to assure high battery SoC. The *Miles* condition had no effect on choices.
(LaMonaca & Ryan, 2022)	**Home charging** Charging at home tends to be the most common approach for EV recharging and comprises level 1 or level 2 chargers. Drivers' ability to install home charging is dependent upon whether they have access to a dedicated, off-street parking spot, typically a driveway or garage. For example, approximately 80% of Swedish electric car users live in individual houses, compared with only 50% of the general population. **Public charging** Frequency of charging events (rather than volume) can show that even those drivers who charge mainly at home do access public charging networks for some journeys. Public charging stations consist of level 2 and DC fast chargers. While Level 2 charging stations can be located where vehicle owners are parked for long periods of time, such as shopping centres, airports, hotels, government offices, and other businesses, fast chargers are found more frequently along highway corridors. In Europe, the Alternative Fuels Infrastructure Directive (AFID) (EU/ 2014/94) required EU members to set deployment targets for publicly accessible chargers for 2020, 2025 and 2030, with an indicative ratio of 1 charger per 10 electric cars. Drivers prefer to charge at home, where charging is convenient and low-cost. Yet, while their actual charging requirements may be largely satisfied with home charging, drivers still look to public charging networks to provide reassurance that charging will be available to them should they need to access it. The high rate of home charging could shift as public charging infrastructure becomes more widely available, and as driver needs and characteristics change with growing EV utilisation. **Workplace charging** Charging at work can provide a critical opportunity for EV drivers who may not have easy access to home charging. Level 2 stations are the most common type of chargers installed in the workplace. Where primary or sole reliance on workplace charging is possible, employer-located charging availability could be particularly useful for promoting adoption among drivers without access to off-street parking for home charging.

Article	Key points
	Role of fast charging Level 2 public charging stations play an important role in the overall network of charging options for EV drivers, but particularly so when drivers are able to charge over an hour or more without interruption to their travel needs. This could include charging while at work or while spending time shopping, for example. However, fast charging is more practical for drivers concerned with taking longer journeys, upwards of 100 miles or more, during which they may need to refuel their car. It can also be usefully aligned with existing behavioural profiles to meet day-to-day driving needs, for instance when siting fast-charging stations at locations where drivers would typically run a quick errand. Fast charging can also more closely replicate the refuelling experience of conventional vehicles, potentially providing a more accessible transition for drivers switching to EVs. Availability of fast charging has therefore given rise to concerns that quicker charging times may accelerate the rate at which batteries lose driving range. Behavioural literature shows that EV owners do not utilise fast charging in a manner that inhibits battery performance. A 2015 NREL study found that drivers typically received 7.6% of energy from fast charging, up to a maximum of 41.5%. Because fast chargers are used infrequently, the impact on battery capacity loss was negligible
(Lanz, Noll, Schmidt, & Steffen, 2022)	Fuel costs play an important role in the cost of using EVs. While gasoline and diesel costs to consumers are quite transparent (i.e. the pump price at gas stations), EV charging costs to consumers are not as straightforward, as they depend on a variety of factors including charging location, charging speed, time of charging, or even other pricing mechanisms such as charging subscription packages. It is therefore not always immediately clear what charging cost an EV owner should expect when pulling up to a charging station. This paper compares the levelized cost of electric vehicle charging (LCOC) options in Europe. It found that the LCOC of different charging options varies significantly not only between but also within countries. For EV users capable of installing home-charging infrastructure, residential charging options are enticing. In certain countries, residential charging without PV power is in fact cheaper than commercial charging. For users with access to PV power generation on-site, charging costs can be further reduced, particularly in countries with high capacity factors of solar rooftop PV or high grid electricity costs. Note that this study neglects on-site storage options, which could further reduce charging costs in some cases However, these residential charging options are typically available only to house owners—EV users in city apartments mostly rely on public charging infrastructure, which often comes at higher LCOC. For countries with low population shares living in owner-occupied dwellings such as Switzerland (42.5%), Germany (51.7%), Austria (55%), Denmark (61.7%) and the UK (63.4%), EV users, in particular those in lower-income groups, may rely exclusively on commercial charging and thus face much higher charging costs.
(Latinopoulos, Sivakumar, & Polak, 2017)	The authors seek to understand how electric vehicle drivers respond to uncertain future prices when they charge their vehicle away from home. They do this by designing a survey for a sample of London drivers (N=118) to interpret the booking behaviour of EV drivers when parking and-charging prices vary dynamically or, in other words, to measure their willingness to wait for future reductions in price. The results suggest that (a) the majority of the electric vehicle drivers are risk averse by choosing a certain price (the safe option) (67.9%) to an uncertain one (the risky option) and (b) there is a non-linearity in their choices, with a disproportional influence by the upper end of the price distribution. The myopic behaviour of EV drivers who stated that they charge their vehicle more than once per day could be justified by the planning burden associated with comparing dynamic prices every time they charge. Moreover, EV drivers that have been charging their vehicle for free are strongly inclined towards the safe option, possibly because they are less willing to risk an increased charging price. Experienced EV drivers, i.e., individuals that have been driving an EV for more than a year, have a higher likelihood of being strategic. On the other hand, EV loyal enthusiasts exhibit a more myopic behaviour. Finally, individuals

Article	Key points
	that have been regularly driving long distances with their EV prefer the ‘‘book later” choice. This behaviour is possibly an outcome of their higher familiarity with risky situations, due to the fact that they repeatedly strain the limits of their battery range. It is observed that specific demographic groups, like for example young and educated individuals, are more likely to exhibit forward-looking (riskier) behaviour.
(Lee, Chakaborty, Hardman, & Tal, 2020)	This paper examines the charging behavior of 7,979 plug-in electric vehicle (PEV) owners in California (4,230 BEVs and 3,749 PHEVs) using information on the choice of charging locations (Home, Work, and Public) over a period of 7- days. The following seven groups were identified: – Home-only: those that only charge at home. – Work-only: those that only charge at work. – Public-only: those that only charge at non-home and non-work locations (e.g. public chargers at charging stations, highway corridor chargers, Tesla superchargers). – Home-work: those that charge at home and at work. – Home-public: those that charge at home and at non-home/non-work locations. – Work-public: those that charge at work and at non-home/non-work locations. – All: those that charge at home, work, and public. Although there is negligible daily variation in the charging during weekdays, different charging patterns for weekdays and weekends among BEV and PHEV owners were identified. Using the charging data, the authors classified survey takers into seven different groups of PEV owners based on their charging patterns. 37.8% of the BEVs and 30.5% of the PHEVs use more than one location and, in many cases, different charging powers over the week. However, both BEV and PHEV owners relied heavily on home charging, with more than half of them only using home chargers. In terms of choice of the charging infrastructure, PHEV owners were found to be dependent on L1 chargers at home about three times more than BEV owners. This may be due to the current vehicles having smaller capacity batteries that can charge fully overnight on level 1. Sociodemographic characteristics like household income, home ownership, and gender of the driver, PEV characteristics like electric range and age of the vehicle, travel behavior, electricity cost at home, workplace charging availability and accessibility to L2 charger at home were found to be the key factors influencing the infrastructure use patterns. Commute distance is a crucial factor for mixed usage of charging infrastructure among PHEV owners, indicating that PHEV drivers who reside far from their workplace are more likely to use workplace charging along with other options, allowing them to maximize the use of the electric range of the vehicle. PEV adopters living in apartments are at present mostly dependent on workplace and public infrastructure. Workplace charging is used more frequently by multi-unit dwelling residents than any other non-home charging location, including DC Fast public charging. Level 2 work charging is also important for BEV owners who only have level 1 charging at home. More owners of 200-mile plus range BEVs like Tesla BEVs and the Chevrolet Bolt charge only at home. Also, 8.9% of PHEV owners in this study do not charge their vehicles at all.
(Libertson, 2022)	Supplier-managed charging was tested at public charging stations in Sweden and followed by three surveys (N = 1428, N = 24, N = 31) and semi-structured interviews (N = 27). The results show that while the participants were positive toward smart charging as a concept, the technology was also associated with uncertainty and anxiety. Furthermore, while the participants were willing to relinquish some control, their capacity for flexible energy use was dependent on factors beyond their direct control, including working patterns, financial resources, and access to charging stations.

Article	Key points
(Lorentzen, Haugneland, Bu, & Hauge, 2017)	This paper presents the experiences with public and private charging infrastructure investments and the user experiences from the 2017 Norwegian EV owners survey (N~12,000). **Pricing and payment systems** It has not been easy to get access to and pay for fast charging. The BEV owner must relate to different charging standards, find charging stations with different map services and pay for charging with different payment systems such as charging tags, SMS or mobile apps. Conventional payment methods like credit card or cash have not been an option in Norway in most cases. The Norwegian EV Association has from 2015 provided a universal charging tag to all their members. This tag can be registered with many of the charging operators for easier access and payment for charging services, noting that the BEV user still gets one invoice from each operator. 57% of the Norwegian EV Association members use the charging tag. For those who not use it, 60% do not use public charging because they cover their need with charging at home or work. Users prefer RFID-tags over other payment methods like SMS or phone apps, even though all major operators offer quite decent app solutions. This is due to ease of use, and that it is not necessarily very desirable to use your phone outside in adverse weather conditions. Tesla, with their plug and play system, is by far the easiest system to use for Tesla owners, and is preferred by them. A few years previously, there had been a heated debate regarding payment systems, and many users called for payment through normal credit cards and cash. As the payment systems have improved, and BEV users have gotten used to new payment solutions, this debate has cooled considerably. The use of RFID tags is the preferred way to start fast charging sessions, and many users finds this to be an easier solution than credit cards/cash. However, the process for registering the RFID tags has to be straight forward, and it is important to have backup solutions like SMS and apps. **National database for charging stations** Cooperation between the governmental entity Enova and the Norwegian EV Association resulted in the development of an open, publicly owned database that allows everyone to build services using standardised data free of charge. This has been instrumental in providing BEV users with up to date information about the charging infrastructure, and the data is being used by several in-car navigations systems in addition to charging maps and apps. **User experiences** BEV owners who live in detached housing to a very large degree charge at home, while those living in apartment buildings to a larger degree also charge at public charging stations and use fast charging more frequently. Most BEV users don't fast charge on a weekly basis. Normal charging while the car is parked is in other words the dominating charging method. However, fast charging is crucial when needed, for instance on longer trips. Fast chargers also function as an important "safety net" for everyday use. When it comes to home charging, most BEV owners use the normal household socket (Schuko) (63%). For those that charge at home using the regular household socket 2% have experienced issues with a burnt socket, which constitutes a possible fire hazard. This gives a clear indication that the regular house hold socket is not well suited to long term EV charging, and that dedicated charging equipment (Type 2 outlets) should be the norm.
(Lu, Zhang, Yuan, & Tong, 2020)	This paper simulates the optimal driving range of battery electric vehicles (BEVs) by modeling the driving and charging behavior. The driving and charging patterns of BEV users are characterized by reconstructing the daily travel chain based on the practical data collected from 50 BEVs in Shanghai, China over a period of 4-12 months, spanning from June 2015 to July 2016. In terms of travel demand, the indicator that best reflects daily travel demand is the daily travel distance. Its average is 51.6 km, which is only 30% of the battery's driving range. In addition, the average number of daily trips is 2.97, and the highest value is 9, which can be roughly understood as a daily commute

<table>
<tr><th>Article</th><th>Key points</th></tr>
<tr><td></td><td>user. For charging habits, the average SOC before charging is 45.6%. This means that the user prefers to start connecting the charging plug when there is still about half of SOC remaining.

The findings include the following. (1) Users with different daily travel demand have a different optimal driving range. When choosing a BEV, users are recommended to consider that the daily vehicle kilometers traveled are less than 34% of the battery driving range. (2) Increasing the charging opportunity and charging power is more beneficial to drivers who are characterized by high daily travel demand. (3) On the premise of meeting travel demand, the beneficial effects of increased fast-charging power will gradually decline.</td></tr>
<tr><td>(Marinescu, 2023)</td><td>EV customers from some large (from the perspective of an EV volume criteria) countries consider that charging station availability is important when using an electric car.

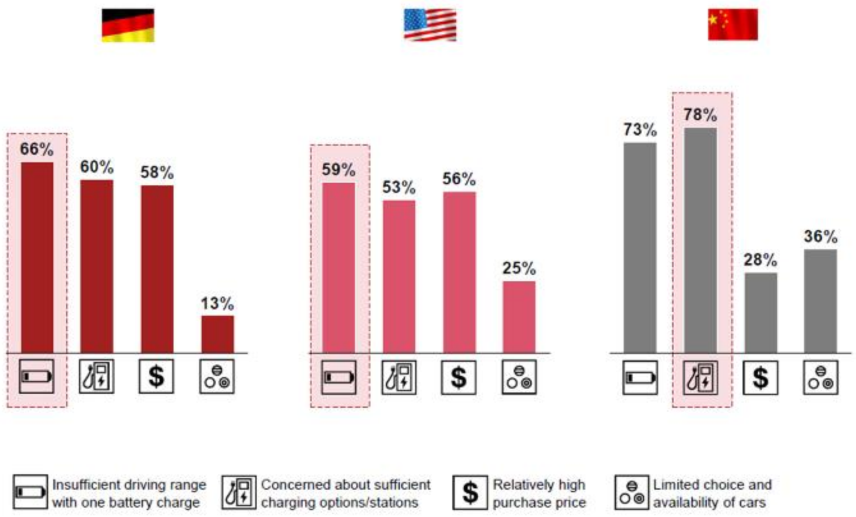


Figure 3. Deterring factors of using an electric car in Germany, US, and China [2].

90% of chargers will be at home, accounting for about 65% of the energy demand required.

German case study

in 2016, an EU directive related to the environment was implemented as a law, establishing uniform charging and payment standards. It imposes binding rules in order to harmonise socket standards for publicly accessible charging stations. In 2017, the minimum payments standards unified authentication and payment methods at charging stations. The users of EVs are now able to pay for charging using an app web-based payment system, a credit card, or cash.

Fewer than 40% of all EV chargers use solar-optimised charging apps.

Note: paper is more focused on technology and the economics of charging rather than customer preferences.</td></tr>
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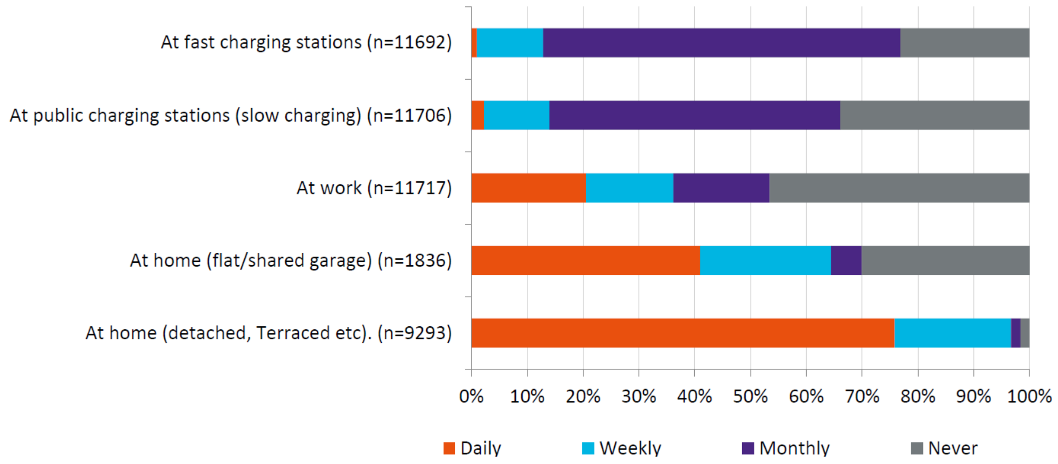
Article	Key points
(McKinsey & Company, 2022)	The Bipartisan Infrastructure Law (BIL) provides $7.5 billion to develop the US's EV-charging infrastructure. The goal is to install 500,000 public chargers—publicly accessible charging stations compatible with all vehicles and technologies—nationwide by 2030. Of the $7.5 billion, $5 billion is available through the National Electric Vehicle Infrastructure Formula program, which focuses on adding public charging stations in underserved communities and on highways. For EVs to catch on with all drivers, America's charging infrastructure must serve a diverse population. This includes sizable groups of drivers who will make extensive, if not exclusive, use of public chargers because they may lack home charging equipment. It also includes the many drivers who need public chargers to keep commercial or ride-sharing vehicles powered throughout long days (and nights) on the road. Finally, it includes rural drivers, who see plenty of filling stations but few fast EV chargers in their areas and don't want to risk running out of power. In the United States, most EV charging (in terms of electricity consumption) now takes place at home. By 2030, in the scenario McKinsey analyzed, they estimated that considerably less charging would be done at home, and the amount of charging in fleet depots would nearly double. EV drivers who cannot charge at home or must recharge on the road will want chargers to be placed where they need them. In the scenario McKinsey analyzed, their estimates suggest that public charging would deliver more than 20 percent of the electricity EVs would use in 2030. Drivers of private passenger cars with access to home or overnight charging will mostly charge at home, given the significantly lower cost of energy, and seven in ten drivers are likely to install a home-charging system, according to a McKinsey survey. These drivers will need fast chargers only when they are on long-distance trips and can't take the extra time to refuel at a slower public alternating-current Level 2 (AC L2) charger or when they forgot to charge at home and can't make the round trip in the time available. Drivers of private passenger cars who don't have access to home or overnight charging, by contrast, will choose either fast or slow public charging, depending on their daily trip plans. Drivers of electric commercial-fleet vehicles will charge publicly only as required by the length and location of their trips. Overall, six in ten charging sessions globally will take place at home or work, according to the McKinsey survey, and US drivers say they expect to rely more on home charging than drivers elsewhere do. At parking lots and other public destinations, for example, DC charging can be available as a premium service, but when a driver is parked for an hour or more, slower AC L2 charging usually works well enough. The McKinsey survey suggests that customers' experiences with public charging are often unsatisfying. Respondents mentioned the speed, cost, availability (including both free and working chargers), and safety of charging locations as the main shortcomings of public charging. Drivers struggle to find chargers because information is limited; mobile apps for locating them tend to exclude competitors' chargers, and that reduces both availability and pricing options. Pricing systems can vary considerably—from pricing by the minute or kilowatt-hour to different rates for memberships or pay per use. It isn't always easy to tell which option offers better value, and payment is often a hassle. Finally, the design and operation of chargers differ greatly, and customer service isn't always prompt or helpful. Electricity purchased at a public charger can cost five to ten times more than electricity at a private one.
(Miele, Axsen, Wolinetz, Maine, & Long, 2020)	The paper is based on 2017 survey data from 1,884 Canadian households planning to buy a new vehicle within the next 12 months. The survey found that zero emissions vehicle (ZEV) infrastructure access does not seem to be a strong factor in the decision of whether or not a mainstream, new vehicle-buyer will purchase a ZEV. Respondents were more sensitive to financial attributes in vehicle purchasing decisions.
(Moon, Park, Jeong, & Lee, 2018)	To identify consumers' preferences for EVs and public EVSEs, as well as preferred EV charging time of day and location, the authors conducted a survey with discrete choice experiments. The data were collected using an online survey that was conducted in Korea from December 26 to 27, 2016 (N=418).

Article	Key points
	The results show that consumers mainly preferred charging during the evening. However, when we considered different types of EVSEs (public and private) in the analysis, people preferred to charge at public EVSEs during the day. During peak load time, people tended to prefer charging using fast public EVSEs, which shows that consumers considered the tradeoffs between the full charge time and the price for charging. Peak electricity consumption of fast public EVSEs occurs during the early evening period (6–9 PM) and peak electricity consumption of private EVSEs occurs during the midnight period (12–3 AM). In addition, electricity consumption on fast public EVSEs exceeds consumption on normal public EVSEs during the morning (6–12 PM) and early evening periods (6–9 PM). Furthermore, consumers prefer public EVSEs with lower charging cost, shorter full charge time, and greater accessibility.
(Motoaki & Shirk, 2017)	This paper analyzes real-world field data to examine direct current fast chargers (DCFC) usage in the United States. In particular, it examines changes in recharging behavior between periods when the charging service was free and when it was not. The data were analyzed from April to June 2013 when DCFC charging was free (pre-fee period) and from September to December 2013 after a flat fee of $US5 was introduced (post-fee period). The pre-fee period contains data from 888 Nissan Leaf drivers who used DCFCs and a total of 4,910 fast charging events. The post-fee period contains 685 Nissan Leaf drivers using DCFCs (i.e., a 23% decrease from the pre-fee period) and a total of 2,805 fast charging events (i.e., a 43% decrease from the pre-fee period). The unweighted mean of the SOC increase per minute of park duration is 1.48% during the pre-fee period and 1.42% during the post-fee period, which shows a decrease in the average rate of charge for every minute of park duration. Among 31% of the charge events during the pre-fee period, the vehicles were parked for more than 30 minutes and the proportion increased to 40% during the post-fee period. Because recharging an EV from nearly empty with DCFC for much more than 30 minutes is an inefficient use of DCFC in terms of the rate of charge, these statistics show some evidence that consumers engaged in less efficient recharging behavior after the flat-rate fee was introduced. People plugged their vehicles for a longer time at a diminishing rate of charge after the fee was introduced and there were more extremely long charge events during the post-fee period than during the pre-fee period. Higher proportions of charge events took place at low SOC during the post-fee period compared to the pre-fee period. This means the fee made some people wait to recharge their cars until SOC became low relative to when charging was free. There are two conceivable reasons for this. First, people may have wanted to get the most out of a single DCFC charge session and the cost of charge was fixed per session; therefore, people may have been incentivized to recharge their vehicles when emptier so they could get more charge for the same price. Another reason is that because the number of charge events decreased once the fee was introduced, it is reasonable to think people wanted to avoid using DCFC because they had significantly less expensive home charging and they only used DCFC when needed to complete a trip or maintain a comfortable SOC. With a flat-rate fee, users are not incentivized to move their vehicles after the rate of charge significantly deteriorates. The benefit of DCFC is its fast rate of charge. Occupying the station after the rate of charge diminishes considerably may defeat the purpose of DCFC charging and is time costly to other users who may need to recharge their vehicles.
(Mulach, 2022)	Electric-car owners in California were told to avoid charging their vehicles as the state prepared for a heatwave. The Labor Day holiday coincided with predicted temperatures between 35 to 38 degrees Celsius in south-west California, placing excess demand on the state's electricity grid.
(NewMotion, 2020)	NewMotion conducted an online survey (N=4,492) in December 2019, with EV drivers across Europe. 50% of the participants were from the Netherlands, 32% from Germany, 6% from Belgium, 5% from the UK, the remaining 7% was from other European countries. Most drivers (80 percent) park their EVs on a private driveway or garage. 11 percent park their car publicly on the street and 8 percent will use a dedicated parking spot in a garage or in a car park. Only 1 percent use a shared parking spot in a garage. More than two thirds of the respondents (66 percent) drive a BEV and a quarter (24 percent) have a PHEV.

Article	Key points
	On average, EV drivers do lots of research into driving electric before purchasing an EV. 92 percent of EV drivers say they do at least some specific research before their purchase. The third most important research topic, after car models and battery range is around the charging options (35 percent). Almost half of the respondents say they worry about a future lack of charge points as demand for them increases, while a third (32 percent) don't think this will become a big problem. 77 percent of drivers have a charge point at home while more than half of the respondents (55 percent) have a charge point available at work. From the respondents who do not have a charge point at home, 53 percent say they also do not have one available at work. 61 percent of the people without a charge point at home would use a standard socket to charge an EV at home, while 30 percent simply prefer to charge at work or at public locations. Standard sockets have a lower charging speed and are accompanied with safety issues such as rain mixed with sockets, or an overused electricity network in the street. In the Netherlands, a charge point at work is quite common: 72 percent of the respondents say they have a charge point at work. Only 29 percent of British respondents and 41 percent of German respondents have a charging solution for their EV at work. The use of a charge point at home is slightly higher in the UK compared with other countries. People in urban areas are less likely to have a charge point at home, while people in rural areas are less likely to have a charge point at work. For those who own a charge point, they clarify ease of use as being most important when choosing their solution, with more than half (52 percent) citing this as their main purchasing driver. A third (33 percent) say the price of the charge point is important, while a quarter (26 percent) says that a recommendation from a third party such as a lease company, a car dealer or employer, as most influential to their decision. When it comes to charge point providers, convenience is key. The ease of use is mentioned most often (35 percent) as the main decision driver for respondents' preferred charge point provider, while a quarter of the respondents (24 percent) say that technical specifications of the hardware is an important factor towards their choice. When considering what they value most in their charge point provider, 46 percent of respondents mention reliability of the product, while 19 percent of EV drivers indicate smart functionalities (such as automatic reimbursement of the energy usage by the employer or remote start-and-stop functionality) as most important. 11 percent feel that customer service quality is key. Although many EV drivers (37 percent) own just one charging card, a lot of EV drivers admit to needing multiple charge cards. A striking 45 percent say they own 2-4 charge cards while 15 percent requires 5 or more charge cards. The average amount of charge cards that EV drivers own is 2,5. The average number of charge cards per EV driver is highest is in Austria (3,81), followed by France (3,48) and Czech Republic (3,42). Also in Germany (3,37) and the United Kingdom (3,19) drivers feel the need for multiple charge cards, while the situation in Belgium (2,44) and the Netherlands (1,82) is slightly better. The relatively low amount of charge cards per EV driver in the Netherlands is most likely because most charge points are interoperable and because of the high volume of charge points, which is the highest in Europe. Charging prices (41 percent) and network coverage (38 percent) are mentioned most often as the reason to use one charge card more than another. 43 percent of EV drivers say they know what they will pay for a charging session before starting the session. 37 percent say they will specifically look up the price of a session before they start charging. Two out of five respondents say they've had at least one instance where the actual price of a charging session turned out to be different than a price shown beforehand at the charge point. EV drivers in the Netherlands are significantly less likely to know what they will pay for a charging session than in all other countries. Dutch EV drivers are also less likely to look up the price before starting a charging session. British EV drivers were the most likely to know what to pay for a charging session (3,8 on a 5-point scale), while EV drivers in Austria will carry out the most price research in advance.

Article	Key points
	A large share of electric vehicles are bought or leased via companies. Half (50 percent) of the EV drivers acquired their current electric car via their business; either leased via their employer, bought via their own company (generally SMEs) or driven as company vehicle. The other 49 percent bought or leased their car privately. Almost half (46 percent) of EV drivers charge their car at home daily. Another 20 percent will charge their vehicle at home on a weekly basis, while 5 percent say they will barely ever charge their car at home (yearly or never). Work is frequently used as a charging location too. One in five (19 percent) respondents use a charge point at work daily, while 12 percent charge at work three or four times a week. However, 2 out of 5 respondents (40 percent) never charge their vehicle at work. When charging in the evening or overnight, most EV drivers use a private charging option at home (84 percent). 9 percent use a shared or public charge point close to home, while only 5 percent have no option (or need) to charge their car overnight. 3 percent of respondents leave their car to charge at work. One in ten respondents will use public charging destinations such as retail stores or restaurants on a daily basis. A charge card or token is the main payment method at public charging sessions: 80 percent. 8 percent pay via ad-hoc charging (via a credit card or payment link), while 36 percent of the respondents say their public charging sessions are free. Faster charging (48 percent), increased availability of public charge points (46 percent) and a single charge card for any public charge point (41 percent) are the most important improvements for a better charging experience. In the Netherlands, fast charging would be a more important improvement than in other countries. In Germany, UK and France the availability of charge points is considered to be more important. In almost all countries the switch to one single card for a seamless public charging experience is the most pressing matter to improve, except for the Netherlands. This is probably because of the high amount of roaming in the Netherlands. Not all EV drivers require a fully charged battery within their vehicle when they leave work. EV drivers trust their battery range: a third of drivers believe their battery should be 30 – 50 percent full when they leave work. 21 percent say their battery should be 60 – 80 percent full and another 21 percent do want their battery to be (almost) full when they leave work. Confidence in the battery of electric vehicles can be explained by the fact that an average daily community costs about 20 percent of the battery. As many people have charge points at work and/or at home, they don't have to be afraid of a limited battery range. 69 percent of the EV drivers are willing to use smart charging, while only 11 percent are not. The desire to use smart charging offerings is especially strong in the United Kingdom (76 percent) and Germany (75 percent) and is low in France (40 percent).
(Narassimhan & Johnson, 2018)	The authors analysed EV purchase data in the US from 2008-2016 and found that the presence of public charging infrastructure has a strong influence on vehicle purchases decisions. The correlation of infrastructure with vehicle purchases strengthens with the battery-only driving range of a PHEV, while weakening with increasing driving range of BEVs. Neither the sales of Tesla Model S nor the Prius (the two poles of battery range) are affected by the availability of charging infrastructure. This may be due to the following factors. First, unlike long-range BEV owners, short-range BEV owners may be more range anxious and consider public charging availability seriously when making purchase decisions. Second, PHEV drivers with a significant electric driving range may base their purchase decision more on total cost of ownership, which would include utilizing low-cost/free electric power from public EVSEs whenever possible.
(Nordic Road and Transport Research, 2022)	The market for electric car charging – apart from home charging – is characterized by low profitability due to large start-up investments, a complicated picture of players and far too many bad user experiences.

Article	Key points
	The overall charging market becomes dysfunctional for users when 20-30 apps are needed to access all available charging options, and when 13 different payment solutions are in use, but not credit card payment. This comes on top of an already complex charging system with different plug types, power levels and user interfaces on the chargers themselves. Refers to four categories of electric car charging: – Home charging – Charging at workplaces – Charging at the travel destination (shopping centers, hotels, etc.) – Publicly available charging (which includes fast charging and super-fast charging en-route).

Article	Key points
(Norsk elbilforening, 2017)	Results from 2017 Norwegian EV survey, which was conducted from 23 April to 2 May 2017. 1. How satisfied are you with the public charging where you live? 1- Very unsatisfied (8%), 2(21%), 3 (40%), 4 (22%), 5 – Very satisfied (9%) 2. Have you run out of battery power the last year? Yes (4%), No (73%), Close call (23%) 3. How often do you charge …  4. How do you normally start fast charging? Norwegian EV Associations RFID tag (38%), RFID tag from the fast charging companies (23%), test message (8%), mobile app (9%), plug and play on Tesla superchargers (17%), don't know / no opinion (4%), other (2%) 5. Do you often experience queues at the fast charging stations? Always (2%), Often (10%), Sometimes (39%), Rarely (37%), Never (12%) 6. How do you charge your EV at home? Regular household socket (63%), Home charging unit 16A (19%), Home charging unit 32A (12%), Tesla (3%), Other (3%) 7. From where would you prefer to buy a home charging point? Car dealership (20%), Electrical contractor (31%), Energy supplier (4%), Online (18%), Don't know (24%), Other (3%) 8. Have you ever experienced any issues charging your EV at home with a regular household socket? No (86%), Yes, burnt socket (2%), Yes, the fuse went (10%), yes, other (4%) 9. Why haven't you installed a home charging point? Too expensive (48%), Too little information (11%), Don't have the need (35%), The ordering process is difficult (3%), don't know / no opinion (7%), Other (15%)
(Ofgem, 2021a)	The connection process for households with a domestic chargepoint is generally simple and often does not trigger upstream network reinforcement. In the vast majority of cases they won't need to pay for a network upgrade when they install their EV chargepoint. However, developers requiring larger scale chargepoint connections can experience two significant barriers: the costs of connecting to the network (47%); and the pace and difficulty of the process of connection time to connect 11%, lack of capacity 9%, uncertainty in regulatory regime 5%, lack of capacity and time to connect 3%, inconsistency between DNOs 3%, lack of response from DNOs 2%).

Article	Key points
	Current arrangements mean non-domestic consumers seeking to connect must pay for any reinforcement required to the existing network at the same voltage level or the one above. But for larger scale charging infrastructure, eg, vehicle depots, car parks, blocks of flats, this can result in prohibitively high costs, meaning connecting customers delay or decide against installing EV charging infrastructure. Ofgem has recently set out its minded-to proposals to connection charging. Ofgem's proposals would reduce barriers to network connection by removing those costs associated with reinforcement of shared networks. The costs of this reinforcement would be spread more fairly over a wider customer base and over time, through ongoing use of system charges. Most EVs in the UK are not currently smart charging due to a combination of factors: not every EV chargepoint is smart, the current incentives for smart charging are not sufficiently strong and, partly as a result of this, there are limited smart EV tariffs on offer from suppliers. And there are additional barriers facing V2X: few EVs are currently V2X enabled, the required equipment is relatively expensive, and there are regulatory barriers. Most EVs are not currently capable of exporting power due to the protocol and cables they use, but this is expected to change by the mid-2020s. Additionally, as with smart charging, there are relatively weak incentives. Ofgem committed to work with Government and industry to progress smart charging defaults (pre-set charging at off-peak times); to remove barriers for V2X; and to develop enablers such as data and communications for dynamic smart charging. Although growing, there is limited choice of EV-related products and services, and limited awareness and confidence around current offerings. There are an increasing number of electricity supply tariffs on the market that are designed for EV users (often referred to as "EV tariffs"). Most of these offer a cheaper tariff rate overnight, to encourage EV users to charge their car at off-peak periods. Some of these EV tariffs offer bundles or incentives, such as access to a public EV charging network, vouchers, or free miles. It is not yet clear whether potential future EV users will adopt smart charging: Ofgem's research shows that a third of consumers (34%) (predominantly non EV owners) aren't currently open to using products and services that would help them use energy flexibly, such as smart appliances, and a further third (34%) are undecided or don't know, with reasons including fears that their appliances wouldn't operate when required, and data privacy concerns (refer (Ofgem, 2021b), (Ofgem, 2021d)). With these changes, including bundled products, EV tariffs may be more complex for consumers to understand and compare than traditional electricity supply tariffs. Ofgem is working with Government to consider the role of third-party intermediaries (such as price comparison websites) and to improve the use of data, to give consumers the right tools to help them make the right choices for their circumstances. EV charging at home will change the nature of domestic consumers' electricity usage, which may lead to the creation of new situations in which consumers find themselves vulnerable.
(Ofgem, 2021b)	Ofgem's 2021 Consumer Survey interviewed 4,037 energy consumers in Great Britain who were solely or jointly responsible for their household's energy bills, including 202 consumers who have a plug-in electric vehicle (fully electric or plug-in hybrid). Fieldwork was conducted in August and September 2021. The main barriers to adoption of an EV were similar to the 2020 survey – costs (60%), nowhere to charge at home (33%), short battery life (32%), and takes too long to recharge (25%). EV owners are more likely to have other low carbon technologies such as solar panels, smart appliances/smart heating controls or heat pumps. Most EV users (83%) use their EV for local trips, with just under half (44%) using them for longer-distance trips. Only a fifth (19%) use their EVs for long distance trips on unfamiliar routes. When it comes to charging behaviours most (59%) plug-in EV users said they usually charged their vehicle at home. 1 in 4 (25%) tend to charge after every journey they make and a further 23% only charge their EV when the battery gets low. In total around a quarter (25%) of plug-in vehicle users say they usually charge their vehicle at peak times.

Article	Key points
	Of the 120 EV users who say they usually charge at home, 59% use conventional chargers, with 22% reporting they have a smart charger and 26% have a charger with programmed apps or timers. While plug-in vehicle users are more likely than average to say they are on a time of use tariff which would enable them to access lower prices for off-peak energy, only 13% are at the moment. Some plug-in EV users intend to charge their vehicle in a flexible manner. For example, 36% try and plan when they are going to charge their EV to get the best price. However, not all these consumers are currently benefitting from the smart products and services designed to enable flexibility, as a minority of this group currently report being on a time of use tariff or having a smart charger. The use of conventional chargers over smart or programmable chargers is driven by lack of availability and awareness of the availability of smart chargers, as well as their perceived cost. 67% of plug-in EV users said they would be likely to use smart charging systems in the future to reduce the cost of their household's energy bills. 58% of plug-in EV users said they would feel comfortable having an external company controlling smart charging, smart appliances or heating. EV users were significantly more likely than average (20%) to feel comfortable having an external company controlling aspects of their electricity use (e.g. smart heating, appliances or EV charging).
(Ofgem, 2021c)	Ofgem's 2020 Consumer Survey interviewed 4,608 energy consumers in Great Britain who were solely or jointly responsible for their household's energy bills, with 3% having a fully EV and 2% having a plug-in hybrid. Fieldwork was conducted in June to September 2020. While reported ownership of EVs is low, those who have adopted them are very highly engaged in the energy market. Most EV owners have switched or compared tariffs in the past 12 months, many report being on time of use tariffs (44% compared with 12% of the sample) and many have signed up to energy-deal switching services (52% compared to 20% for the sample). Most vehicle charging takes place at home (70%), with 50% using their electric charging point and 20% charging from the mains. 16% use a public chargepoint near on their street or nearby, 5% use a public chargepoint at a car park, 4% use a public chargepoint on the motorway and 3% use a public chargepoint at the supermarket. Many EV users (66%) indicated they are open to the idea of smart charging, but the survey did not explore comprehension. This is higher than the appetite for smart appliances or smart heating among the population (34%). Of the population, 63% were uncomfortable with the idea of an external company controlling when appliances run. Of these, 61% had safety concerns (e.g. risk of fire, flooding), 56% had concerns that the company might not switch things on, 54% had concerns about data sharing, and 53% would not trust the company with the information. The key barriers to adoption of EVs were costs (59%), the range on a full charge is too short / short battery life (38%), nowhere to charge at home (36%), and takes too long to recharge (26%).

Article	Key points
(Ofgem, 2021d)	Ofgem conducted 29 qualitative interviews with EV drivers in late September and early October 2020 to understand the current situation for EV drivers, what they need, and what they are trying to achieve. The 29 EV drivers covered a wide range of EV drivers in terms of location, careers, demographics and choice of car, while noting EV drivers are still largely early adopters.

EV user journey and pain points

	User journey	Pain points
Motivations and research	Main motivation for getting an EV was financial. Information largely has to be researched with the YouTube show *Fully Charged* often cited.	– Range anxiety and lack of public charge point infrastructure is a worry for most participants when deciding to move to an EV or not. – People had to carry out their own research on EVs, had to know where to look and what to search for. – Not all costs are clear upfront, e.g. rewiring in the home to be able to install a home charge point.
Buying an EV	Participants typically gave a lot of thought before buying. Range and price were the most common factors in what car they got. For those looking to charge their vehicle at home, dealers typically put them in contact with a charge point seller.	– Not made clear what essential items need to be purchased separately. – Lack of full transparency around the full costs of running an EV. – Mixed perceptions of dealerships being knowledgeable / interested in EVs.
Journeys	All participants said they don't use their EV for long journeys, due to worries about range.	– Actual miles able to drive on a charge much lower than expected / quoted. – Lack of sufficient technician availability for some makes/models in some areas. – Battery range affects what journeys drivers use their EV for, reverting to petrol cars for longer journeys.
Charging publicly	Participants reported a very different experience depending on their location. There is a greater variety of charge point operators and processes in GB outside of Scotland, with participants reporting a number of barriers due to this.	– Infrastructure of public charge points still being developed. – Not all public charge points can be accessed at point of need – e.g. some require pre-registering to be issued a physical card to use. – Charge points can be reliant on an internet connection to be able to use – e.g. website or app on your mobile phone. – Participants reported it can be a challenge to find a working public charge point. – They are not universally compatible. They don't work with all makes and models. – And the behaviour of other EV drivers sometimes delayed their journey (others unplugging your car to charge theirs). – It is difficult to understand the difference in price between the various charge point operators.

Article	Key points

		– Paying for your charge works differently to paying for petrol. In many instances it requires setting something up beforehand. – With more EVs on the road, public charge points are busier.
Charging at home	Not all participants were able to charge from home. Participants that home charge tended to leave their car plugged in overnight, but start their charge in the evening when they get in. This differs for those working nights.	– Some participants experienced unplanned and rising costs for charge point installation. – Interoperability. Not all charge points work with all models of cars. – Some participants perceived a lack of awareness of installers for more bespoke charge point set-ups.
Energy use at home	Some participants reported being on a time-of-use tariff. But for others, getting an EV hadn't made them think or do anything differently with how and when they use electricity in their home.	– Benefitting from time-of-use tariffs require behavioural change from all household members.

Energy use in the home – insights

– Most said they charge their car as soon as they get in. There is a reassurance need to be able to see that the car has started charging.

– Participants often hadn't heard of and were unfamiliar with the concept of smart charging.

– Some participants had moved to a time-of-use tariff.

– For those that have changed when they charge their car, this isn't a behaviour change their whole household has adopted for all their energy use.

– The majority said that getting an EV hadn't changed what they look for in an energy deal, or how they use their energy.

– All compare the cost of charging their car to the cost of filling up a tank of petrol.

User needs

	User needs
Before I get my EV	As someone who is thinking of getting an EV … – I need a trusted source of information, so that I can make an informed decision. – I need to know what the actual driving range for a charge is, so that I can make an informed decision about which EV/battery size is right for me. – I need to know what financial support is available to me and how to access sit, so that I know what I can get for my budget. – I need to know all the costs involved, so that I can make an informed decision about what set-up is right for me. – I need to know what charge points are available and how I can access them, so that I know what additional things I need to get to use them. – I need to know who the right people are to talk to for my circumstances, so that I can get the right products for me, e.g. charge my car through my solar panels.

Article	Key points	

	When driving my EV	As an EV driver …
		– I need to complete my journey with minimum hassle so that I can get to where I'm going.
		– Going on a long journey, I need to know there'll be charge points available for me, so I'm not stranded.
		– Charging publicly, I need:
		  – to be able to charge my car when I need to, so that I'm not stranded
		  – the way different charge points work to be similar, so that I use them
		  – the charge point to be in a suitable place, so that I feel safe
		  – to know that I'm paying a fair price for charging my car, so that I know that I'm not being ripped off.
		– Who is unable to charge at home, I need public charge points to be located in a convenient place for me, so that I can charge my car when I need to.
		– Who needs to charge publicly, I need clear information on how to use the charge point, so that I can charge my car.
		– Who uses my car to schedule when I charge, I need to easily change from my scheduled times when I charge publicly, so that I can charge my car without hassle.
		– I need to be confident that using my EV won't make my journey too long, otherwise I'll use my petrol car.
		– I need to know who to go to when things go wrong, so they can resolve my issue quickly.
		– Who is having a problem with a public charge point (e.g. cable is stuck), I need the charge point operator to resolve my problem quickly, so that I can continue my journey.
		– I need good technician availability in my area, so they can fix my car quickly at a fair price.

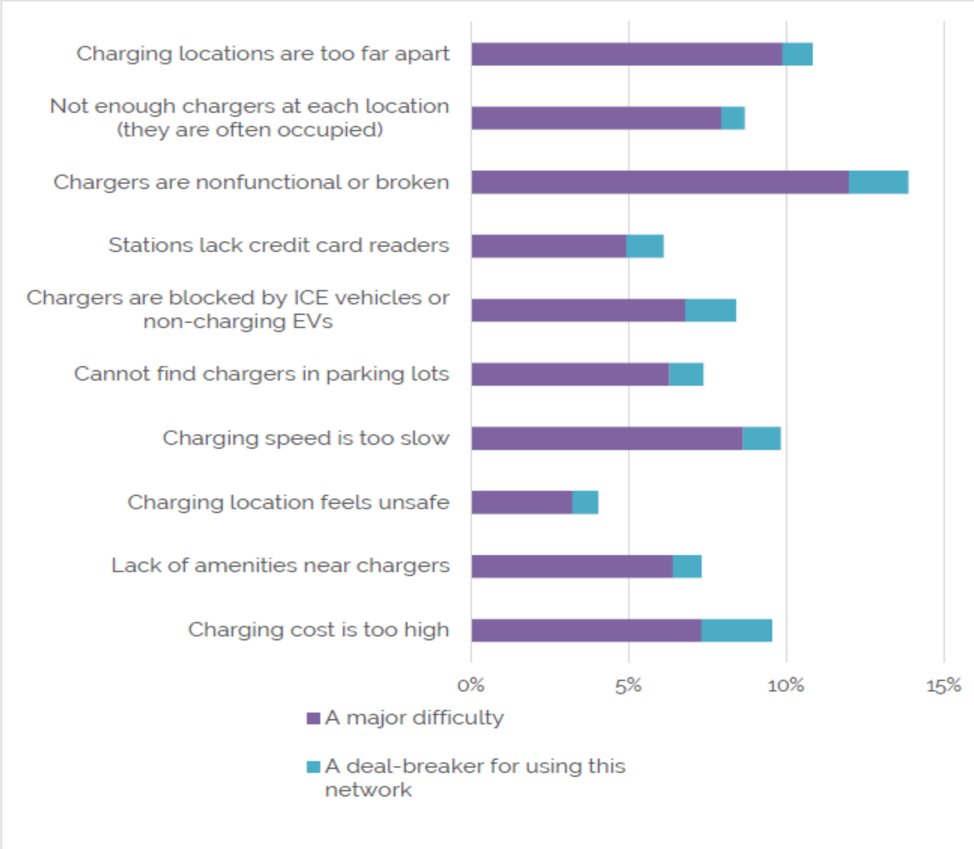
	When charging my EV	As an EV driver …
		– I need to charge my car when it works for me, so that my car is ready to use when I need it.
		– Charging at home, I need
		  – to charge at a time that works for me, so that I am not inconvenienced
		  – to charge when I am comfortable charging, so that I'm not worried about it
		  – the process to be easy, so that I can charge my car
		  – the reassurance my car will be charged, so I can use it when I need to
		  – to avoid having to change my charge point when I get a new car, so that I avoid hassle and additional costs.
		– I need to know my car will have enough charge, so that I can use it in an emergency.
		– Who gets a smart charger, I need setting this up to be easy, so I can charge smartly and save money.
		– Who smart charges, I need this to be reliable, so that I can get the financial benefit of charging when it's cheapest.
		– Who could benefit from being on a time-of-use tariff, I need to know how much better off I'd be, so I can make an informed decision about my energy.

Article	Key points
(Ofgem, 2022a)	Ofgem decided to remove the contribution to reinforcement for demand connections so that connecting customers pay for extension assets only. The costs of any reinforcements will be transferred to all Distribution Use of System (DUoS) bill payers. These reforms will be effective from 1 April 2023.
(Ofgem, 2022b)	EV tariffs (type and time of use) are available, some offering cheaper off-peak power for charging. Ofgem expects to see more tariffs come to market, responding to smart charging signals: shifting when an EV charges, or varying the charging speed. A number of billing models exist for using on-street chargepoints, such as subscriptions, fuel cards and pay-as-you-go. Increasingly, licensed suppliers are including charging at on-street locations as a service bundled with their customers' standard electricity supply contracts Domestic consumers may want to receive a single bill for when they charge their EV at home and on-the-go (home and roam). A licensed electricity supplier providing this service will combine a standard domestic supply with a roaming package (via commercial arrangements with CPOs and fuel card vendors) allowing for the use of public chargepoints: on-street, destinations and forecourts. A licensed supplier's commercial EV charging partners collect data each time a customer charges their EV (identified via an app, fuel or membership card, or EV car-charger identifier) and submit this to the supplier. The supplier includes this service as a separate line-item on their customer's electricity bill. Peer-to-peer is where individuals (or businesses) make their chargepoints available for other EV drivers to use. This can be on a firm's premises, or more likely on the driveway (or garage) of a home. In some cases, a householder's chargepoint will be installed at the roadside, taking its charge from the domestic supply rather than through a separate connection to the local distribution network. There are various apps available that match a chargepoint provider (the host) with a driver (peer) needing somewhere to plug-in. Where an employee charges their fleet EV at home, they pay via their domestic bill. This may lead to affordability challenges for employees. Many employers are looking for efficient and equitable solutions to this situation, with third parties now offering fast-track reimbursement services using real-time EV charging data, delivered via payroll, or even a bundled product with the employee's licensed supplier.
(Packroff, 2022)	The current EU Alternative Fuels Infrastructure Directive has led many EU Member States to already require ad-hoc payments, most often still via smartphone apps or QR codes, explains Jaap Burger from the Regulatory Assistance Project, a think-tank. "However, more recently some EU countries have introduced bank/credit card reader obligations, which is much more user-friendly," he added, referring to countries like Germany and Denmark. In AFIR, the European Parliament wants to go even further, and require operators of charging points to even retrofit existing stations, adding terminals that allow debit and credit card payments. The Parliament's chief negotiator, Ismail Ertug, says that "We cannot expect everyone to be familiar with Google or Apple Pay, QR codes or payment by an app. Subscription models and payment platforms can continue to exist – but there must be the possibility to pay ad hoc".
(Passingham, 2022)	Survey of 1,500 EV and PHEV Which? Members in the UK. Three quarters were dissatisfied with the charging infrastructure with nearly half of the drivers surveyed saying that finding charging infrastructure actually working in a significant hurdle, with 4 in 10 saying they've personally experienced non-working chargers. Almost half said that their nearest public charger was more than a 20-minute walk away, making dropping the car off for a charge and picking it up again a slog if you don't (or can't) have a charger at home. 1 in 5 survey respondents who no longer use public chargepoints said they were put off by the lack of availability. In a separate survey of 2,000 car owners, 2 in 5 respondents said the top reason they weren't considering buying an electric car was the perceived lack of chargepoints.

Article	Key points
	Around 8 in 10 EV owners who have used public chargepoints said they wanted to be able to pay using a bank card, avoiding the hassle of multiple apps and network payment (RFID) cards. One EV owner noted that as more people started to use EVs it became a pain to find a charger that wasn't in use, so the half-hour recharge stop could be an hour while waiting for a charger to become available. Another survey respondent was forced to spend the night in a hotel due to being unable to charge their vehicle while on the road.
(Peachey, 2022)	More than two-fifths (42%) of electric vehicle (EV) drivers are missing out on the best charging tariffs for their vehicles because they are not using a dedicated home charging point to charge their car, according to Delta-EE. A survey of 1,169 EV owners undertaken by Delta-EE across eight European markets (UK, Germany, Spain, France, Italy, Netherlands, Norway and Poland) also revealed that less than 50% of people have a time-of-use tariff, enabling them to take advantage of cheaper overnight electricity prices. Additionally, just three in 10 EV owners had a specific EV tariff with their energy provider. For those without a dedicated home charging point, almost a quarter (24%) indicated that they were planning to get one installed soon while 14% believe that there is no need as a regular electric socket is sufficient. The same number of people (14%) also stated that a dedicated charger was too expensive.
(Philipsen, Brell, Brost, Eickels, & Ziefle, 2018)	The authors conducted qualitative interviews (N = 24) and then a large-scale questionnaire study (N = 1021) with car drivers from Germany to identify refueling behavior in terms of behavioral patterns, refueling motives and conditions. BEV users and drivers of vehicles with combustion engines (CEs) differ significantly in terms of the conditions that are important for their charging or refueling decision. – Range-related conditions – the range-related conditions for charging and refueling were similar. The most important range-related criterion for drivers is that the current fill level of the tank or battery is sufficient for the next planned trip, with approval rates of 4.33 (out of 5) and 4.16, respectively. Tanks and batteries that have dropped to a certain level or have completely been emptied are the next two important reasons for a decision to refuel or charge. The least important among the range-relevant conditions was falling below a minimum tank/battery level (3.10 and 3.07, respectively). – Financial conditions – the biggest difference of opinion is evident in the spontaneous discovery of a favorable fuel/energy price as the basis for charging or refueling (1.38 and 2.94, respectively). The active search for favorable prices in the run-up to a charging/ refueling stop was not important for both groups of drivers (1.36 and 2.08, respectively). The least important consideration was the payment of the salary as a charging/ refueling time determinant (0.11 and 0.64 respectively). – Habit-related conditions – while habit does not seem to play a major role in the scheduling of the refueling process, the use of familiar charging locations (3.44), fixed routes on which charging is always carried out (2.80), and the use of every available opportunity for charging (3.43) were relevant for the electric vehicle users. The least important condition was to charge or refuel based on fixed time periods or times of day. About 40% of the BEV users charge several times a week, while the proportion of those, who charge several times per month is only slightly lower (28%). In contrast, 14.6% BEV users charge their vehicles on a daily basis and 7% charge less than once a month. In contrast, very few combustion engine users refill their cars several times a week (4.9%) and practically no one refuels every day (0.5%). More than half of CE users fill up several times a month (52%) with a slightly smaller proportion filling up less than once a month (43%). Among the e-vehicle users, occasional chargers dominated, outstripping those, who always run the battery as low as possible and then fully charge it, almost by a factor of seven. The distribution of combustion engine users is completely the opposite: twice as many drivers classify themselves according to the complete refueling pattern compared to filling up every now and then.

Article	Key points
	Both groups of vehicle users are still relaxed at tank and battery levels of less than 100% and 75%, respectively. However, if the level drops below 50%, the first drivers start to feel uncomfortable with the remaining amount. A drop of the filling level below 25% has a greater effect: Almost half of the BEV users already see this as a critical level, while only about 40% of the internal combustion engine users think so. Most of these CE users describe the burning of the warning light that indicates an almost empty tank or battery as their threshold for discomfort, while only about half as many BEV think the same. A quarter of the BEV drivers report that they do not feel uncomfortable with an active warning light, only roughly 10% of the combustion engine drivers remain calm under this condition. A large part of the variance in refuelling and charging behaviour could not be explained by socio-demographic user characteristics.
(Philipsen, Schmidt, & Ziefle, 2016)	The authors conducted an online questionnaire of drivers of battery electric vehicles (current users) as well as drivers of internal combustion engine vehicles (potential future users) to assess user requirements related to the charging process and the preferred locations for fast-charging stations (N=252). The BEV drivers were early adopters – typically male (97.5%), an average age of 43.81 years, and rather educated. 58.4% (n = 146) indicated they would be able to charge an electric vehicle at home; 41.6% (n = 104) did not have this option. Charging an electric vehicle at the workplace would be possible for 29.1% (n = 72) of the participants, 52.2% (n = 129) would not be able to do so, and 18.6% (n = 46) did not know if they could. Almost a third (31.3%, n = 79) reported using an electric vehicle. 75 of them used a BEV as first or second private car, while 13 used a BEV as company car. 70 users gave detailed information about their cars' connector types: 51.4% (n = 36) were equipped with fast-charging compatible plugs, like CCS, CHAdeMO, or Tesla-Supercharger, while 38.6% (n = 34) were limited to slow charging speeds. Outcomes show that motorway service stations, shopping facilities, and traditional fuel stations can be visualized as potential fast-charging station locations. Both BEV users and interested non-users prioritize motorway service stations and gas stations as important locations for fast-charging stations. All other locations were considered significantly more important by the non-users. Workplaces and educational facilities got fundamentally different ratings by users and non-users. Workplaces as suitable locations for fast-charging infrastructure were very important to non-users, while BEV users had a rather neutral opinion. All locations were rated higher by women than by men, especially gas stations, shopping facilities, and educational facilities. Age had a significant effect on the evaluation of different locations only in one case – shopping facilities. It is shown that users' willingness to accept waiting times or detours cannot be expected. Willingness to make a detour was the most accepted factor (3.47 out of 5); vacating the parking lot was slightly rejected (2.22) and accepting waiting times was strongly rejected (1.07). Prior experience with BEVs had significant effects on willingness to make a detour and willingness to vacate the parking lot after finishing charging. BEV users showed a higher willingness to make detours to reach a charging location (3.94) than non-users (3.31). Furthermore, non-users slightly reject interrupting an activity to vacate a parking space after charging (2.03) whereas users showed a rather neutral attitude (2.64). Men are more willing to vacate their parking space (2.36) than women (1.79). However, both genders reject moving the vehicle after charging in order to free the spot to another user. Neither the willingness to make detours, nor the willingness to vacate the parking space after charging, nor the readiness to accept waiting times was related to age. The most important consideration relating to the charging process was that charging stations should be open around the clock (4.93). A good lighting of the charging station was also perceived as important (3.39). A covered charging station received the lowest rating and, thus, this was not perceived as an important condition during the charging process (1.55). Prior experience with BEVs influenced the requirement for charging stations that are open around the clock. Although this condition is very important to both users (5.00) and non-users (4.89). Good illumination of the charging location is significantly less important to users (3.02) than to non-users (3.60). Additionally, gender had a significant effect on the evaluation of conditions related to the arrangement of the charging stations – a well illuminated charging station was more important to women (4.15) than to men (3.13). The lighting requirement was significantly related to age, too.

Article	Key points
	Dual use, reliability, and accessibility prove to be very important criteria for site evaluation of charging locations. Reliability (Mdn = 1) was the most important criterion, followed by dual use. The third most important criterion for site evaluation of charging stations was accessibility (Mdn = 3), followed by safety for the driver and passengers (Mdn = 4). Safety for the car (Mdn = 5) and habit compatibility (Mdn = 6) jointly occupied the penultimate rank. Connection to the public transportation network (Mdn = 7) was assigned the last rank. The experience with BEVs influenced the ranking with regard to dual use, reliability, and accessibility. Although reliability was the most important evaluation criterion for both groups, it was significantly more important to BEV users (Mdn = 1) than non-users (Mdn = 2). Similarly, there was a significant difference in the ranking of accessibility between participants with prior BEV experience (Mdn = 2) and without (Mdn = 3). Finally, BEV use affected the ranking of the dual use criterion. Unlike the previous results, dual use was more important to the non-user group (Mdn = 2) than the user group (Mdn = 3). In contrast, the capability of fast-charging did not yield significant differences regarding the ranking within the e-vehicle user group. Even though there were no differences regarding the overall median ranks between genders, dual use was more important to male than to female participants. Accessibility of charging locations was ranked higher by women than men. In contrast, there were no significant effects concerning age regarding the order of priority.
(Plananska & Gamma, 2022)	The authors conducted an online study with potential Swiss EV adopters (N=313) in August and September 2019 to analyze the effect of the most commonly applied bundle in practice – that of EV and charging services. They found that preferences of future EV adopters are heterogeneous – wider adopter groups tend to prefer more convenient solutions. They identified three customer segments with differentiated bundle preferences. *Likely non-adopters* are the least interested in the bundle offer and have the least interest in EVs; they are the only segment that would not opt for the bundle offer. *Tech-oriented adopters and Convenience-oriented adopters*, in contrast, are found to be likely adopters of two distinct bundle types. The former is a segment positioned between early and later adopter groups and prefers the currently offered, narrow and essential bundle containing an EV and charging services only. *Convenience-oriented adopters* already now represent more than half of the sample (55.9%), and are by far the largest consumer segment that they believe represents the core of prospective EV adopters. These consumers would obtain the greatest utility from a larger bundle that includes an EV and a plurality of additional services, alongside charging also insurance, battery assistance, and a green electricity certificate. The fact that insurance is perceived as the most important attribute, and battery assistance is preferred in its most complete form (both in Switzerland and Europe) might indicate the growing risk aversion of future EV adopters
(Plug in America, 2022)	In September–December 2021, Plug In America surveyed over 5,500 EV owners and more than 1,400 individuals interested in purchasing an EV. The most important economic factor in EV adoption cited by respondents was access to inexpensive home charging (~48%). Over 80% of owners indicated that they were *generally* satisfied with finding the information they needed to buy or lease an EV, but only 40% reported that they could find *all* the information they needed without difficulty. Approx. 18% of respondents had difficulty accessing information on public charging options and 10% had difficulty accessing information on home charging requirements. EV owners were somewhat satisfied with the purchasing experience. Only 15% of customers who shopped at a dealership rated the salesperson's knowledge about EVs as "very high." Dealers often need more tools to answer questions about the entire EV ecosystem, including charging infrastructure, rebates, and policies. Currently, most EV drivers live in single-family homes (85%), where it is easier to charge a vehicle. Apartments and condominiums may have a garage or parking lot with dedicated parking spaces, or a parking lot with non-dedicated spaces, or may not have parking at all (requiring residents to rely on street parking).

Article	Key points
	92% of EV drivers prefer to charge at home, with 24% of them using level-one charging, 71% using level 2 charging and 5% using both. The proportion using level 1 chargers indicates that charging speed is not the primary factor for many drivers. 3% most often used workplace charging, 2% primarily utilized public level 2 chargers, and 2% most often employed fast chargers. About 17% of respondents used multiple locations with equal frequency. While EV owners intend to continue EV ownership, they voice frustration with public charging infrastructure, with the most common issues being "broken or non-functional chargers" or "too few charging locations." On both topics, 34% of respondents noted this as at least a "moderate concern." However, there was significant variation by charging network, with the Tesla Supercharger network scoring significantly better than its competitors on every metric. Only 3% of Tesla users found broken chargers to be in the two most serious classifications of problems, and only 2% found insufficient charging locations to be of such severity.  *Figure 11: Challenges with DC fast charging*

Article	Key points
	Participants were surveyed on the characteristics of their EV. "Range" and "navigation system" had the most frequent ratings of "unsatisfactory," with the survey-wide frequency of that rating at 12% and 14% for the two categories. They specifically asked about navigation systems due to the key role these can play in helping EV drivers find compatible and available charging stations. EV drivers often rely on apps, whether on their phones or built into the vehicles. A well-designed navigation system can make an EV much more user-friendly. Charging speed is sometimes portrayed as a barrier to EV adoption; however, only 9% of respondents felt that charging speed was "unsatisfactory" for their vehicle, while 20% found it "exceptional." In general, newer models were more likely to be rated "exceptional" and less likely to be rated "unsatisfactory," although "satisfactory" was the most common rating for all models.
(Qian, Grisolia, & Soopramanien, 2019)	The paper is based on a stated choice experiment involving an on-line survey of 1,076 respondents conducted in different cities of China in January and February 2015. The sample included a higher than average level of car ownership, with 58% of households owning one car and 24% of households owning 2 or more cars. Charging service has a mixed effect, depending on the level of service provision and speed. Specifically, the availability of a home charging facility has the strongest influence on consumers' choice to purchase EVs and the service speed of public fast service stations is also significant. Chinese consumers generally do not find the availability of public service facilities important. Instead they prefer the perceived convenience of home charging facilities that they can use exclusively over the inconvenience of having to find public charging facilities. This is reasonable considering China's high population density and residential conditions. Most Chinese urban households live in apartments in multi-family buildings, so that many households do not have a dedicated parking space at home or face restrictions to install residential charging facilities; property management firms would very likely reject residents' requests to install such facilities for reasons concerning electricity safety or insufficient electricity capacity. Public/workplace charging facilities may be occupied, which forces users to wait in a queue or go to other service stations or charging places. This reduces the value of public service stations and public/workplace charging facilities in the mind of potential users. Those who live in Tier 1 cities are more concerned about both fast and slow service speed than those in other cities. Time is more valued by consumers in Tier 1 cities where the pace of life is faster and these consumers feel they are wasting time when they are waiting for their cars to be charged. Chinese consumers might buy BEVs but only if they have longer driving range because of the range anxiety attached to BEVs compared to petrol vehicles (PVs) and PHEVs. Chinese consumers generally perceive the annual running cost to be more important than the vehicle purchase price. This is consistent with a previous study which found that Chinese consumers are willing to pay nearly double premium for the running cost reduction than US counterparts.
(Savari, et al., 2023)	Customer privacy is a big challenge. One of the critical concerns of an EV user is the driving distance covered by the EV battery. So, whenever the EV's battery drains, the EV user must find a Charging Station (CS) to charge the EV. Currently, most EV users depend on a third party (aggregator) to reserve a charging slot to charge the EVs. The aggregators collect the details of the EVs from the user to provide the service. However, not all the customers may be interested in sharing their information, such as phone numbers. At least fifty percent of customers are highly concerned about their privacy, and the other fifty percent are worried about their confidentiality based on the situation. The aggregators depend on other service providers (i.e., independent system operators, independent power producers, etc.). Hence, the information exchange between the user and service provider becomes more complex. At present, EV users are charging their EVs through third-party aggregators. Aggregator acts as an agent between electricity producers and EV customers and represents a group of customers who responds to them with an agreement. Each aggregator must provide the requested power to the EV customers.

Article	Key points
	Besides, they can install communication and control devices (i.e., smart meters) at the customer end. They communicate with the electricity companies on behalf of their customers on the prices and power demands. This leads to customer privacy issues as the users must share all the details. The main concern about EV charging is not disclosing the user's details such as name, address, phone number, e-mail address, and banking details.
(Saxena, Grijalva, Chukwaka, & Vasilakos, 2016)	V2G communication systems are different from other existing communication systems in several ways, such as vehicle mobility, geographic location of the vehicle, charge and discharge operations, driving pattern, and limited communication range. In terms of security, authentication in the V2G network needs to be fast and efficient in order to support a large number of EVs expected to participate in dynamic charging/discharging. Confidential information, such as vehicle identity, vehicle type, charging and discharging time, and charging station identity (CSID), needs to be protected. Unlike traditional payment systems that accept debit/credit cards operated by third parties, thus incurring high processing times, V2G systems have stricter financial transactions requirements. V2G systems require very fast, secure (through cryptographic primitives with an advance amount in the vehicle owner's account at the utility) and efficient payment system with low processing times in order to accommodate charging and discharging transactions by a large number of vehicles in the network. With large amounts of frequent transactions, a payment solution must also provide anonymity while preserving vehicle owner privacy. **Vehicle owner perspective** Consider a scenario where a user parks their vehicle in the parking lot of a restaurant and connects the vehicle to the charging station. The user provides setting preferences, such as selecting whether to charge or discharge the battery possibly by entering a bid, the minimum threshold for the battery level the user would like to have in the vehicle, the minimum distance in miles that the user needs to travel, and the duration of time the user expects to be at the restaurant. New requirements, such as the need to leave the restaurant sooner or to visit other destinations, result in changes to the user options. The change in charging requirements will result in a new charging schedule for the vehicle. *Assuming that logic exists to determine the new energy charging schedule, the question that we need to address is how can the system ensure that the necessary exchanges of information among the user, the vehicle, the charging station, the payment management company, and the utility take place in a secure manner.*
(Scasny, Zverinova, & Czajkowski, 2018)	This paper is based on a survey of 2,156 respondents in Poland who intend to buy a new car. Polish car buyers prefer electric-driven vehicles significantly less than conventional vehicles. Decreasing the purchase price and operating costs, developing technologies that increase the driving range, and decreasing charging time can all serve to strengthen preferences for electric vehicles. In addition, the deployment of charging infrastructure can encourage the spread of BEVs in particular. Recharging time and availability of charging stations are currently the most influential barriers to increasing the consumption of plug-in EVs. On average, Polish car buyers are willing to pay about EUR 311 for each hour saved for charging a BEV, but they are not sensitive to this attribute in the case of a PHEV. Preferences for electric-driven vehicles increase sharply when the availability of fast-mode recharging improves from a low level (20% of fuel stations + several public locations) to a medium level (60% of fuel stations + half of public locations) or even to a high low level (90% of fuel stations + almost all public locations).

Article	Key points
(Schmalfuss, et al., 2015)	In a 5-month field study in Germany, 10 BEV drivers tested a smart charging system whose success relied on relatively high customer involvement. Participants had the opportunity to compare a conventional charging system to a smart charging system that involves controlled charging (CC) in their daily routine. Reported experiences indicate that it is possible to integrate CC in daily life as long as BEV drivers can predict when and where they have to be the next day, and how much BEV range they will need in order to plan the charging process and configure settings. As the system rewarded participants for their use of CC with a low MinSOC setting, they voluntarily reduced their flexibility, in favour of mobility and spontaneity. Planning ahead daily, in terms of mobility and using the MinSOC option appropriately also turned out to be a learning process. Users needed to acquire knowledge and skills for using the system, but participants' quotes indicate that this was relatively easy. Improvements are needed for the charging system itself (e.g., system stability, provision of access to CC from different devices) and the BEVs (e.g., battery capacity, charging durations) in order to increase acceptance of smart charging. Results showed that participants are not primarily motivated by financial benefits. Ecological motives and acting to improve society's and one's own well-being were primary motivators for CC usage. After experiencing the prototype system, use of the mobile application to remotely access the vehicle was reported as a benefit. Currently available BEVs, like the BMWi3 and the Nissan Leaf already provide similar remote access. Integrating a CC function in such an application might be beneficial for the usage of CC as the driver will be reminded of this charging mode when checking, for instance, the actual state-of-charge and he/she has just one app for all information and actions regarding the EV. For drivers of other BEVs that are not equipped with such a tool, a mobile application for CC that provides additional vehicle information and control elements could be a further motivator for using CC. Reported costs were reduced flexibility including less spontaneity, the need to better plan ahead, adjusting settings via mobile application, and less range due to utilization of MinSOC. These reported costs reflected the needed changes in daily practices. Another expected cost or concern prior to using CC was the lack of data privacy, but it was no longer cited as a drawback after experiencing CC. In the context of smart charging, participants in an online survey were somewhat willing to provide information that base on raw (e.g., departure time) and processed data (e.g., parking time). However, they reject providing information that includes threat potential of this data(e.g., household is unattended). The smart charging system was evaluated as effective, rather suitable for daily life and rather acceptable. Participants trusted in the system, although experienced medium negative effects on trust. CC was extensively used by the sample (approximately 80% of charging events). The main reasons why CC was not used were inability to access CC and technical problems. Interview results indicate that changes in charging behavior can be quite different depending on their prior charging behavior. People who seldom charged before CC charged more often, BEV drivers that had plugged-in every day continued with this behavior after the introduction of CC and some people reported to avoid charging when it was not rewarded.
(Secinaro, Calandra, Lanzalonga, & Ferraris, 2022)	Factors influencing the decision to purchase an EV include battery recycling and the potential of the individual consumer to find charging infrastructure or recreate it directly at their home. The lack of charging infrastructure could be a functional barrier for some consumers who may live in apartment buildings or condominiums with no charging station at home. If private facilities participate in the charging market, it would be convenient for electric car drivers to choose a remote charging station at the location closest to their travel destination.

Article	Key points
	A theme of trust emerges with blockchain technology, which can allow proposing vehicle-to-vehicle trading schemes limiting energy anxiety.
(Song, Chu, & Im, 2021)	This paper compares the psychological and behavioral characteristics of electric vehicle (EV) owners in the United States and China by surveying 204 Chinese EV owners in March 2018 and 200 US EV owners in October 2018. US owners of EVs were more satisfied than Chinese EV owners. In the Chinese sample, 20% of users who responded gave an overall satisfaction score of three or less out of five. This figure was only 5% for the United States. Of those that were dissatisfied in China, 70.7% was due to a lack of charging facilities and difficulties with charging and 14.6% were worried about safety (battery explosion, etc.). Of those that were dissatisfied in the US, 30.3% was due to difficulties with charging, 30.3% was due to short driving range and none were worried about safety.
(Southern California Edison Company, San Diego Gas & Electric Company, and Pacific Gas and Electric Company, 2022)	**Pacific Gas and Electric Company Limited (PG&E)** PG&E has two ***residential*** EV rates open to customers, one for single-metered customers (EV2-A) and another for separately-metered customers (EV-B). The single-metered rate is a residential whole home rate that applies to both typical household electric load and electric vehicle charging on the same meter. The separately-metered rate is designed for customers who wish to bill their vehicle charging separately and requires the installation of a separate meter to do so. Both rate plans use an un-tiered TOU rate structure. They offer on-peak, partial peak, and off-peak energy prices. The separately-metered PEV rate remains a less popular option for PEV rate customers than the single-metered PEV rate. The installation of a separate meter for EV charging could be financially challenging for some customers. The single-metered PEV rate continues to be the more popular option for PEV customers wishing to offset their charging with DG. While PEV ownership has increased, it is still largely comprised of early adopters who are likely to be materially different than future PEV owners. Customers on both rates are shifting their usage from peak hours to off-peak hours. Specifically, separately-metered customers without Net Energy Metering (NEM) are completing, on average, over 70% of their charging during the off-peak period and less than 15% during the peak period. Single-metered customers without NEM are using over 60% of their energy during off-peak periods, as well. Even though charging is primarily occurring in the off-peak hours, the average household with a PEV will have a higher maximum demand. PG&E has two ***non-residential*** PEV rates - the Business Low Use EV Rate ("BEV-1") for customers with up to and including 100 kW demand for their PEV charging infrastructure and the Business High Use EV Rate ("BEV-2") for customers with demand equal to 100kW and over for their EV charging infrastructure. The BEV rates work as a monthly subscription charge based on customers' maximum monthly EV charging kW consumption. Both rate plans use a TOU rate structure. They offer on-peak, off-peak, and super off-peak energy prices. The energy usage is distributed relatively evenly between the three TOU periods, with slightly higher usage in the off-peak period. More charging could be occurring during the off-peak period than the super off-peak period due to the transportation needs of the customers. The super off-peak period occurs between 9 a.m. to 2 p.m. and many customers may need to be using their vehicles during this period and cannot be charging. BEV-1 customers are completing, on average, 70% of their charging during the off-peak and super off-peak period and BEV-2 customers are completing, on average, 68% of their charging during the off-peak and super off-peak period. There is still some charging that is occurring during peak hours (4:00 p.m. to 9:00 p.m.) which is likely due to inflexibility of business needs and/or use of public charging by customers on their commute home. Multi-Unit Dwelling (MUD) sites experienced weekday utilization peaks between 9:00 a.m. and 3:00 p.m., as well as at the end of the day between 7:00 p.m. and midnight. In contrast, weekday utilization at Workplace (WP) sites, on average, experienced one large peak during the middle of the day between 9:00 a.m. and 3:00 p.m. Given that commuters most likely visit workplaces during business hours, it is sensible that utilization would peak during the middle of the day. Similarly, utilization at WP sites during the weekend peaks between the late morning and mid afternoon – 11:00 a.m. to 4:00 p.m. Ports at MUDs showed, on average, higher usage during the weekends than WPs with a peak between 4:00 p.m. and midnight.

Article	Key points
	Peak weekday utilization at Fleet sites was significantly larger than weekend utilization and occurred during two intervals. The first was between the hours of 9:00 a.m. to 12:00 p.m., and the second, larger peak was between 4:00 p.m. and 6:00 p.m. These peaks are largely driven by schools that are charging buses. Weekend charging load was much lower than weekday charging and remained relatively flat throughout the day. **Southern California Edison (SCE)** Residential PEV owners with a separate meter for their vehicle on average charge 83 percent of their usage during the off-peak period in 2021. Commercial PEV owners with a separate meter on average charge between 69 percent and 77 percent during the off-peak period, depending on the tariff. This is a decline from around 90 per cent prior to 2020. The peak load for the single-metered residential PEV owners is much more consistent month-to-month, averaging 2.2 kW and occurring between 10 p.m. and 11 p.m, than households without a PEV. The presumed addition of PEV charging loads in the late-night hours augments household loads enough to surpass the demands occurring at other hours of the day. On weekdays, workplace peak usage per port average at 9AM and Destination Centers having a peak average usage per port at 10AM, while Fleet (Light-duty) peaks at 7PM, and Multi-Unit Dwelling peaks from 9PM to 10PM. On weekends, workplace charging is much lower and the shape is flatter. The peak for Destination Center is shifted slightly more toward the early afternoon hours from 2PM to 3PM when compared to the weekday load profile. The Fleet (Light-Duty) has peaks at both 7PM which is similar to weekdays and another peak at 10PM. Multi-Unit Dwelling peaks at 10PM on weekends which is similar to weekday load. **San Diego Gas & Electric (SDG&E)** Not all PEV customers have adopted PEV rates. Of the customers on PEV rates, the majority are on one of the single-metered rates. Of all the SDG&E customers who were on the single-metered PEV rates during 2021, 44% were also NEM customers, compared to 16% for the residential population. The separately-metered PEV rate remains a less popular option for PEV rate customers than the single-metered PEV rate, due to the expense of installing a new electric service and a separate meter. EV-TOU-2 (GF) customers (who are also NEM customers) consume over 80% of their energy during the off-peak and super off-peak periods. EV-TOU-2 and EVTOU-5 customers consume over 75% of their energy during the off-peak and super off-peak periods. Separate-metered customers respond very well to the signal created by the TOU price differential and consume on average almost 75% of their energy during the super off-peak TOU period. Customers with PEVs peak in the early morning (super off-peak) hours rather than in the evening (on-peak) hours. This is the effect of customers taking advantage of the super off-peak pricing to charge their vehicles. Weekends tend to have higher midday consumption because many customers are at home rather than going to work. Weekends also have lower charging levels during the early morning hours. The day of week patterns are similar for separate-metered PEV customers. These accounts peak in the 01:00 – 02:00 hour timeframe and have negligible consumption during the rest of the day. This would indicate that the rate structure and enabling technology are successful in encouraging charging mainly during the super off-peak hours. Single meter customers have a maximum demand more than twice that of the average residential customer, which is driven by the addition of the EV charging load to the base house load.

Article	Key points
(Sun, Yakamoto, & Morikawa, 2016)	This study explores how battery electric vehicle users choose where to fast-charge their vehicles, based on data extracted from a two-year field trial on BEV usage in Japan. BEV users are willing to deviate from the shortest paths to reach a charging station, but the length of the detour is different for private and commercial users, respectively, on working and nonworking days. Generally, private users are willing to detour by up to about 1750 m to charge their vehicles on working days and 750 m on non-working days, while the value is 500 m for commercial users on both working and non-working days. One possible reason for the shorter detour among private users on non-working days than on working days is that private users are less familiar with the charging stations along their trips on non-working days, so a greater detour may increase their anxiety of being stranded; this anxiety may encourage them to charge at stations requiring a smaller detour but where a fee must be paid. This argument implies that private users are price-sensitive and that their greater familiarity with stations along their trips on working days gives them the confidence to detour a greater distance to reach a free charging station. Another possible reason is that there is some degree of destination choice flexibility on non-working days, for example, a shopping destination which is near a charging station or whose route is dotted with charging stations. The smaller detour among commercial users probably derives from the following three reasons: first, an anxiety resulting from less familiarity with stations along the trips; second, the nature of the service business, which requires punctuality, speed, and so on, leads commercial users to charge their vehicles at stations requiring a shorter detour; finally, commercial users may be less price-sensitive and are more willing to charge at stations requiring a smaller detour but where a fee must be paid. Private users traveling on working days tend to charge at stations encountered earlier along their paths from origin to destination, but tend to charge at stations encountered later when choosing a station in peak hours, such change may be due to anticipated waiting time. On the other hand, commercial users tend to charge at stations encountered earlier along their paths on both working and non-working days, and this preference does not change significantly when they choose a station in peak hours. This may be due to the familiarity with stations and the nature of business, as mentioned previously, which might increase anxiety of commercial users that perhaps there would be no appropriate stations later in the trip, even for example stations requiring smaller detours. However, it should be noted that SOC also plays an important role in determining station choice for all BEV users, that is, the higher the SOC upon reaching a charging station, the lower the probability of charging at that station.
(Sun, Yamamoto, Takahashi, & Morikawa, 2018)	This paper examines choice behaviors pertaining to the time at which users of plug-in hybrid electric vehicle with 24 km electric range charge their vehicles after arriving at home under a dynamic electricity pricing scheme. Results suggest that users' willingness to charge become stronger with increasing driving distance when the driving distance is less than the electric range of 24 km, while tend not to charge when the driving distance is longer than the electric range. Users who return home at the cheapest time or during the day are willing to charge immediately after arriving at home. Electricity prices significantly affect choices to charge at the cheapest time for all users, and stay-at-home mother users and users returning home in the evening tend to charge at the cheapest time. Users returning home in the evening also tend to charge at other times, and being accustomed to charge at a certain time increases the probability of charging at other times. In addition, considerable variations are found across individuals with respect to their preferences for charge timing alternatives as well as for electricity prices.
(Tarroja & Hittinger, 2021)	A meta-review, which focused on behavior challenges to V2G, found the challenges included consumer concerns about convenience, distrust of external control, lack of understanding of the technology, and impacts on the useable range. A survey of drivers in Canada highlighted that potential support for utility-controlled charging among PEV buyers was 49-78% with concerns expressed about privacy and lack of control. For every 20% decrease in reliable range due to V2G related-operation, enrolment in V2G programs decreased by 7-12%. Discrete choice modelling for the United States showed that BEV drivers need to be compensated $US2,000-$8,000 per year to participate in V2G programs.

Article	Key points
	An assessment of public attitudes about V2G programs in Nordic countries found that drivers are willing to participate in V2G programs as long as they are autonomous, do not interfere with travel patterns and drivers are compensated. Also refers to (Schmalfuss, et al., 2015) and (Will & Schuller, 2016).
(The Association for Renewable Energy and Clean Technology, 2022)	The Electric Vehicle Consumer Code for Home Chargepoints applies to suppliers and installers of residential electric vehicle chargepoints in the UK, that are Code Members. The Code covers, for example: – **Customer service** – Code Members are required to deal with Consumers politely and quickly, and take steps to make sure that important information is passed to them clearly. In the case of vulnerable consumers or consumers in vulnerable circumstances, Code Members are required to provide extra care and support to ensure that Consumers understand the key documents, including the quotation, the Contract and the guarantee arrangements. This may, for example, mean involving a trusted friend or relative in any contacts they have with the Consumer, and arranging for such a person to be present during a visit to the Consumer's home. – **Data privacy** – Code Members must comply with their legal obligations in the collection and processing of the personal data of Consumers, in line with the Guidance for EVCC Members on the General Data Protection Regulations (GDPR). – **Pre-sale activities** – Code Members must act with integrity in all their selling activities, including advertising and marketing and telemarketing, when visiting a Consumer's home and particularly during sales visits. Code Members must not mislead Consumers in any way. – **Sales visits** – Code Members must not use any selling techniques designed to pressurise a Consumer into making an immediate decision. Prohibited pressure selling techniques include staying more than two hours at the Consumer's home to keep trying to close a sale; offering a Consumer an artificially inflated initial price followed by a discount, or equivalent (e.g. 'free' additional equipment or services) for signing on the day, agreeing to provide testimonials, providing customer referrals; and claiming untruthfully that there is limited availability of a discount or of the proposed Chargepoint or of any grant or other incentive in order to pressure for a quick signature. – **Pre-sale surveys** – a Code Member must carry out a pre-sale site survey and an assessment of the Consumer's property and the adequacy of the electricity supply in relation to installing a Chargepoint. Where the supply adequacy assessment indicates that there is an issue with the supply, the Code Member must make clear to the Consumer what action will be necessary to address any inadequacies (which may include uprating the incoming supply); and the potential costs and benefits of such actions, or point the consumer towards objective information on them, so that the consumer can choose whether or not to go ahead. – **Permissions, approvals and notifications** – Code Members must make Consumers aware accurately and in writing of all the permission and approvals that may be needed for the Chargepoint they offer, including planning permission, building regulations and connection requirements before any Contract is agreed. – **After-sale activities** – Code members must provide contact details for after-sale queries, manufacturers guarantees, clarity about any paid-for extended guarantees, a workmanship guarantee for a minimum of three years, and details of any regular servicing or maintenance requirements. – **Dispute resolution process** – which is a two phase process, the second phase of which is an independent arbitration service provided by the Code Administrator (Renewable Energy Assurance Ltd).
(The Fast Charge, 2022)	Seven lessons from Norway's EV transition: 1. Hold onto incentives 2. Foster home charging – unlike in the UK where nearly a third of households do not have off-street parking, in Norway, most people have access to a spot at their home, which makes charging significantly easier. However, the ability to charge at your home should be the go-to, with fast charging (that is

Article	Key points
	chargers quicker than 50kW) should be “the safety net”. Norway has recently changed the regulations for apartment buildings saying everyone has a right to charge. “Local apartment boards can’t say no, they actually have to fix it”. In practice for landlords, installing extra cabling and electricity capacity is split among everyone, like the use of an elevator. However, the actual EV charger is paid for by residents wanting to charge up. 3. Cut red tape – to build charging stations 4. Think bigger – in Norway, 2 or 3 rapid chargers have been installed at different sites, but now need 8, 10 or 20 chargers at single sites. 5. Reliability is critical - roughly 50% of EV drivers found that the fast charging network in Norway didn’t work ‘occasionally or more often’. the reason many chargers are often out of action is that “we use them so much that they wear out.” “Many chargers burn out seven hours after continuous use.” 6. Customer experience is key - “access and payment for charging is a complete mess.” “There are roughly 10 fast networks, and for slower chargers, it’s even more. And each company has their own app, we don’t do the contactless payment on the chargers, so you need to be registered with each. It’s a hassle.” There are only a few chargers in Norway which have contactless payment options, everything is done through apps. 7. Be predictable – on the policy side. Note: quotes are attributable to Erik Lorentzen, Head of Analysis and Advisory Services at the Norwegian EV Association.
(Tooze, 2023)	87% of a sample of 817 of the UK’s public EV charging locations have poor lighting; 77% don’t have security cameras. A survey of 500 drivers found that 80.3% feel vulnerable when charging their EV, 62.9% don’t think security measures at charge points are adequate and 88.5% have chosen not to use a charge point because they felt unsafe at the location. Keele University interviewed 16 female EV drivers and found that most were concerned about charging late at night in dark, poorly lit, unsheltered, and relatively isolated areas. Many felt “trapped” inside their vehicles while charging, especially if there were no basic amenities close by. A disabled woman could be “doubly vulnerable” if charging at an unlit location and where accessibility to and from their vehicle to reach charging cables was more difficult. Following a frightening public charging experience, one woman now plans all her journeys in advance, always identifies three potential charging sites, and never lets her car’s estimated remaining range go below 15% in case one charging point isn’t working, and is borrowing money to turn her front garden into a driveway to install a home charger. As illustrated below, a charging station with good safety and security features is well-lit with 24/7 surveillance and has rapid chargers, accessible charging bays, contactless payment, and a number of shops and facilities.
(TRL Limited for Citizens Advice, 2019)	The attitudes and perceptions of current and prospective EV drivers, conventional vehicle drivers and business representatives in the UK were explored in relation to six smart charging options. There were 8 workshops with EV and ICE drivers, and 2 shorter workshops with ICE drivers – one with parents of young children and one with individuals with mobility difficulties – and 14 interviews with representatives of small businesses (up to 50 employees). Overall, views on each smart charging option were mixed, with some participants accepting them and others rejecting them. Nonetheless, all household participants felt that at least one of the options could fit in with their household. Generally, static time-of-use tariffs were preferred by most households. V2G services were also seen as a promising approach, and smart charging technologies were seen as a valuable tool to support implementation and engagement with other options. Third-party charge management schemes and dynamic time-of-use tariffs were the least favoured options among households. The overarching theme from business participants was that time-of-use tariffs were the least suitable offers for their business needs, irrespective of business size or whether they used EVs or not. Most business participants suggested that if they needed to use EVs to meet their operational needs, they would simply ensure they were sufficiently charged, whether this meant charging at peak times (and at higher prices) or not. Because of the cost savings associated with running vehicles on electric power rather than fossil fuel, business participants did not tend to place much weight on any potential additional savings

Article	Key points
	associated with smart charging. However, business participants saw the potential of V2G services and third-party charge management schemes to benefit their organisations financially. Participants stated that they would value information that is clear in terms of how a smart charging option would operate, the costs, and the finer details of the contract and associated fees. Being able to visualise the option was felt to be important, including elements such as an easy-to-understand app interface and how cost savings would be presented. Where claims are made about a smart charging option (for example relating to its environmental benefits), participants required evidence to substantiate the claim. In terms of sources of further information about the options, the vast majority of participants said that they would use the supplier's website or a search engine, or the app associated with the option.
(TRL Limited for Energy Technologies Institute, 2019)	The Consumers, Vehicles and Energy Integration (CVEI) Consumer Charging Trials measured the charging behaviors of Mainstream Consumers using EVs under two forms of Managed Charging (MC), and compared with charging behaviors when not participating in an MC scheme. It also measured preferences among consumers for various charging schemes after experience of MC. The trial ran from November 2017 to September 2018 and included 127 participants provided with a BEV and 121 provided with a PHEV for 8 weeks. Participants were randomly allocated to one of three charging groups: 1. User-Managed Charging (UMC) in which participants were incentivised to charge at times of day when the supply-demand balance is favourable through a structured tariff; 2. Supplier-Managed Charging (SMC) in which participants specified the charge they required and time they required it by, and were incentivised to allow the supplier to control the timing of charging to maximise cost savings; or 3. a Control group who did not experience a MC scheme and were not incentivised to charge in a particular way. Participants whose charging was not managed (the Control group) usually charged at home in the late afternoon/early evening (3-8pm), with a peak in weekday charging between 5-6pm for PHEV participants, and 6-7pm for BEV participants. At weekends the peak in charge events was less pronounced, with a greater share of charge events starting earlier in the day. Compared with unmanaged charging, the proportion of home charge events starting between 4-7pm was more than halved in the UMC and SMC groups. The greatest reduction was observed in the SMC group. The majority of charging was shifted to later in the evening (UMC) or overnight (SMC). This effect was observed for both weekday and weekend charging. A small minority of participants were responsible for the majority of away-from-home charging sessions, suggesting that some Mainstream Consumers adopted regular charging habits away-from-home. Participants' attitudes towards UMC and SMC after their trial experience were generally positive. Averaged across groups, just under 90% of participants indicated that, in future, they would choose either UMC or SMC over unmanaged charging, whether they had a PHEV or a BEV. Experience with UMC or SMC tended to increase the share of BEV participants who would choose the option they had experienced. Even participants in the Control group, who had not experienced MC during the trials, expressed a preference for MC over unmanaged charging: these participants were substantially more likely to choose UMC over SMC, resulting in an overall preference for UMC over SMC for the majority of participants. Choice experiment results showed that the value BEV participants attached to MC tended to be higher if there was nearby public charging, and it increased the nearer the public charging was to their homes. It is suggested that nearby public charging was perceived as a back-up in case the vehicle was needed sooner than planned and had not yet charged to the level required. Participants were found to be more likely to choose a MC scheme the greater the expected annual cost savings, but increasing the cost of charging at peak time reduced the scheme's attractiveness. An override feature enabling users to change charge event settings once input was seen as a desirable feature in SMC.

Article	Key points
(U.K. Department for Business, Energy & Industrial Strategy, 2023)	The U.K. Department for Business, Energy & Industrial Strategy commissioned a survey with just over 1000 EV drivers to help understand the public attitudes towards, and the current use of, smart charging at home and in the workplace. The survey was conducted in March 2022. The majority of respondents have access to a private driveway or garage (76%). 17% have access to a communal car park and only 6% of respondents do not have access to any kind of off-street parking. Respondents aged over 55 rarely charge away from home, and people who work (either part-time or full-time) are generally more likely to charge their car outside of the home than those who are retired. Only 3 people stated that they use their solar panels to charge up their car. A third (30%) of participants use workplace charging. Over 60% say that their workplace either does not have the facilities, that they do not go to a physical workplace or choose not to drive to work. Of those who do use workplace charging, over half of respondents stated that their workplace chargepoint does not allow them to schedule charging. The findings from this study suggest that there is an underutilisation of smart functionalities. Although the majority of dedicated chargepoints in private off-street locations have some level of smart functionality, they are typically not being used to the best of their ability. For example, 41% of drivers with dedicated chargepoints had functionalities which enable charging to be scheduled. However, out of these drivers, only 27% of BEV drivers and 14% of PHEV drivers use charge scheduling every time they charge. Over half (54%) of PHEV drivers never use the scheduling function, compared to 30% of BEV drivers. Other changepoints functionalities included connecting to their vehicle's on-board computer (39%) (21% always use; 27% never use), internet connectivity (36%), user interface (29%), home load balancing (16%) (45% always use, 10% never use) and integration with home energy system (10%) (43% always use, 14% never use). The Electric Vehicles (Smart Charge Points) Regulations 2021 mandate that all chargepoints installed in private off-street parking and workplaces from June 2022 have smart functionality. Therefore, for EV drivers with access to charging at these locations, smart charging will become widely accessible. Findings suggest that a key barrier to scheduling charging is the low availability and/or uptake of time of use tariffs. Three-in-ten (30%) were on static time of use tariffs, whilst the majority of respondents were on standard fixed-rate or variable-rate energy tariffs (59%). 34% of drivers with a dedicated chargepoint with the ability to schedule charging reported never using this functionality. Other reasons for not scheduling charging events include needing to charge as soon as plugged in (39%), and concerns about the privacy of smart charging (12%). 35% of respondents selected other, which included 4 that use the scheduled charging function within the vehicle rather than on the chargepoint, 2 that depend on solar panels to charge their vehicle and so do not have a regular charging schedule, and 1 whose charger and vehicle manufacturer apps are incompatible. Although the majority of EV drivers surveyed (69%) had access to a dedicated chargepoint at home, over half (54%) of participants primarily use a dedicated chargepoint to charge their EV whilst over a third (36%) primarily rely on a 3-pin cable to charge their EV. 26% of BEV drivers and 49% of PHEV drivers used a 3-pin cable which plugs into the mains socket as their primary method of charging at home. Those who own their vehicle are most likely to have a private dedicated chargepoint. The majority (62%) of respondents who have new cars have a dedicated chargepoint. EV drivers cited that the main reasons for not having a dedicated chargepoint at home were that 3-pin cables were fast/easy enough to meet their charging needs (39%) and dedicated chargepoints were too expensive (44%) or not enough space/too complex (16%) to install. Three mentioned they needed upgrades to their home electricity system and 3 mentioned location issues such as living above the ground floor or being unable to park directly outside their house. BEV/PHEV drivers appear to acquire their dedicated chargepoints through the most convenient means, with around three in ten (31%) of drivers acquiring one for free as part of their vehicle purchase. A quarter (26%) of respondents purchased their dedicated chargepoint directly from the manufacturer and 14% from an electrician/installer company while only 7% purchased it from their vehicle's dealership and 7% from their home energy provider.

Article	Key points
	Almost half (45%) of the participants chose to get a dedicated charge-point for a safe home charging option, 44% needed faster charging than a 3-pin plug, 43% to make it more convenient to charge at home, while 26% said that saving money was a motivator for purchasing and 19% stated that it was recommended by their EV car dealer. 14% were informed by an independent advice website.
(U.K. Department for Business, Energy & Industrial Strategy and Ofgem, 2023)	This EV Smart Charging Action Plan sets out the necessary actions to deliver energy flexibility from EVs, and to make sure the system is ready to respond in time for the upturn in energy demand. The identified challenges to delivering the vision include: – Consumers who are considering EVs are not always aware of the benefits of smart charging, or consumers are concerned about whether the vehicle will be ready when they need it and how to select the most suitable goods and services. – Today, households without off-street parking have more limited options for accessing smart charging, for example those living in flats or rental properties. – EV drivers are not likely to continue regularly smart charging if the economic savings or other form of incentives are not attractive to them, or if they are concerned about issues such as data security or privacy. – The cyber security and grid stability risks of digital, connected, smart energy assets (such as EV charge points) becoming integrated with the energy system need to be managed. Up to 70% of EV drivers with access to off-street parking have a dedicated charge point at home, most with some degree of 'smartness'. From July 2022, new home and workplace charge points were required to be automatically set with an overnight schedule as the default, to help make it even easier to do this, and to make sure that EVs play their role in delivering benefits for all. Of course, drivers have the option to change these settings: charge points will also allow the consumer to 'boost' by overriding their settings and charging their cars immediately when they need to. Some EVs allow the driver to set smart charging preferences through the in-vehicle interface or the EV brand's app. Many of today's EV owners can be categorised as 'early adopters' and may be willing to spend more time learning about, choosing, and setting up new products than future consumers. Clear financial rewards and convenience must be sufficient for mass market uptake. Other incentives, such as promoting the green electricity powering the vehicle could motivate some EV owners. A three-year vehicle charging behaviour trial in 2018 that explored how mainstream consumers (i.e., not early adopters) responded to time-of-use tariffs. The study found that 95% of drivers on the battery EV trial chose smart charging over simply plugging in and charging straight away even if the saving was relatively low. Today, most smart charging is done at home using a dedicated smart charge point, although in future more vehicles might enable on-board charging control. EV owners living in accommodation without off-street parking will predominantly rely on workplace or public smart charging options and lower income consumers will be over-represented in the group who do not have access to off-street parking. Even for those consumers who do have access to off-street parking, some potential smart charging users face non-financial issues with installing a charge point such as undertaking necessary works to the property or requiring permission from third parties. Presently, the number of EV smart charging complaints received by consumer organisations is relatively small. Consumer group feedback from today's limited complaints identifies the potential customer service issues around understanding the contract and effective complaint handling. The increase in bundled EV charging products such as a home charger with an EV purchase, a bundle of home and public charging services, a bundle with other products such as solar panels or perhaps in the future the provision of a home charger with an EV supply tariff could cause confusion for consumers to know where to turn for help. Consumers could find themselves being transferred between businesses and consumer bodies adding further frustration and delay before the issue is resolved. Product bundling can also make it more difficult for consumers to compare products on a like for like basis.

Article	Key points
	Additionally, consumer groups have suggested that there is a potential disparity in the ability to get redress between the regulated energy suppliers and the businesses that install private charge points or provide the load control services.
(U.K. Department for Transport, 2021)	The key phase one policy positions include: – Smart chargepoint functionality – the Government will mandate that all private chargepoints must be smart. – Cyber and data security – the Government will mandate requirements in line with an existing cyber security standard, ETSI EN 303 645. – Interoperability – the Government will require that chargepoints must not be designed so as to prevent compatibility with any energy supplier. – Default smart charging – the Government will mandate that, during set-up, chargepoints must require EV drivers to set charging preferences and schedules. In addition, these schedules must be pre-set to not charge at peak times. – Safety – the Government will mandate that chargepoints should operate in a way that prioritises chargepoint safety. – Monitoring and metering of energy consumption – the Government will mandate that the chargepoint must measure or calculate the electricity consumed and/or exported, the time the charging event lasts, and provide a method for the consumer to view this information. The British Standards Institution (BSI) Publicly Available Standards (PAS) 1878 and 1879 were published in May 2021. They provide both a standard for device-level requirements and a framework for Demand Side Response operation and are compatible with international smart grid standards being developed.

(U.K. Department for Transport, 2022a)	**Summary of final policies relating to public chargepoints:**
	– **Minimum payment** – consumers should be able to charge their vehicle and pay with ease, regardless of the chargepoint operator, as they would for any other service. In too many cases, a consumer needs a smartphone with internet and signal to pay for a charge. This means that paying for a charge is often frustrating to drivers who are used to paying with a card at petrol stations. In the worst case, some consumers can be unable to pay for a charge at a specific chargepoint, which is a particular issue if they do not have the battery range to reach an alternative. Almost all private individual respondents requested contactless, with slightly fewer supporting chip and pin payments as a payment method. Cash, text or phone payments were largely identified as not preferred and there was less confidence in these methods to pay. Almost all respondents stated that these requirements should apply to all chargepoints. The Government will mandate:
	  – A payment method that is not specific to a brand and does not require a payee's mobile or internet signal, available at:
	    – Newly installed chargepoint sites (above 7.1 kW)
	    – Retrofitting at existing rapid sites (50 kW and above).
	– **Payment roaming** - Simple payment solutions have emerged, but there remains no common method of access across chargepoint networks. Consumers sometimes need a different smartphone app or membership card for each network. This results in a more complicated experience than that enjoyed by petrol or diesel vehicle drivers or EV drivers on mainland Europe, where roaming solutions exist. This is particularly important for fleet vehicles who cannot rely solely on ad hoc payment. Consumers should be able to access and pay at all public chargepoints easily with membership cards or smartphone apps. The Government will:
	  – Mandate industry-led payment roaming, with enforcement to come into effect from 24 months after the legislation comes into force
	  – Allow a provision for Government to designate approved providers if industry does not demonstrate sufficient progress in this timeframe
	  – Provide information as to how operators can meet these requirements in the consumer experience technical guidance that will support these regulations.

Article	Key points

	– **Open data** - all drivers should be able to locate available and working chargepoints easily when they need to charge their vehicle. Consumers should have a choice between different methods of accessing the information they need, for example through their vehicle, phone, or another device. Currently, chargepoint operators only display static information such as location and power rating related to their network on their apps. More comprehensive private-sector led solutions are emerging, however, this data is not available beyond bilateral agreements, and a lack of mandated data provision standards means that chargepoint data can be incomplete and inaccurate. Nearly all respondents wanted open static data and live dynamic data, including marking charging bays unavailable on a live network map and identifying if chargepoints were broken or in use. The Government will:
	– Mandate the adoption of Open Chargepoint Interface Protocol (OCPI)[6].
	– Mandate that all static and some dynamic data are made openly available, as specified in technical guidance.
	– Progress its open data workstream to understand how it should open this data and specify this in technical guidance.
	– **Pricing transparency** – the cost of electricity drawn from public chargepoints is priced using a range of different metrics. A lack of a standard pricing metric prevents consumers from easily comparing prices. The Government wants consumers to be able to understand and compare pricing offers across the UK charging network to select the best available price. Nearly all of respondents favoured the pence per kwh as a standard pricing metric. Respondents wanted information displayed clearly for consumers so that pricing information is prominent and clear, and that the tariff should be available to the consumer ahead of starting a charging session. The Government will mandate that:
	– Pence per kWh is used at all public chargepoints.
	– The pricing offer is clearly displayed to the consumer before charging commences, whether this is on the chargepoint, through a separate device such as an app or website.
	– The price cannot increase once charging has commenced.
	– **Reliability** – broken or unavailable chargepoints undermine consumer confidence in the public chargepoint network. People's safety can be at risk if they are left stranded and unable to charge their vehicle. It is essential that the public chargepoint network is well maintained and that faults are repaired quickly. Consumers should be able to contact the chargepoint operator if something goes wrong, to get assistance and to continue their journey. Nearly all responses agreed with the 99% reliability requirement at a network level, while some suggested that each charging location should have 99% reliability. The Government will mandate:
	– A 99% reliable charging requirement across the rapid network, including the Strategic Road Network (SRN), trunk roads and Motorway Service Areas (MSAs). This will be set through a separate guidance document to be published alongside the regulations.
	  – It will monitor the market for improvement of reliability over the next 24 months.
	  – It will then take powers to mandate a 99% reliable charging network across the entire public UK network if progress has not been made.
	  – Ahead of this decision, it will list publicly the chargepoint operators who do not maintain a reliable network and enforce self-reporting until open data has come into effect.
	  – Reliability will be measured through open data.
	– That all charging networks for all public EV chargepoints have a free 24-7-hour helpline when consumers experience an issue trying to charge their EV.

Article	Key points
	Emerging policy areas: – **Consumer protection** – key themes arising during consultation: – ***Protection for low-income households*** - Consumers who are most likely to regularly use public charging are those without off-street parking, who are typically more concentrated in less affluent areas and in the rental sector. The impact of regulation must take into account these households to make sure that costs, including compliance costs, are not passed on by chargepoint operators. – ***Mis-selling of EV tariffs and bundles*** - Consumers need to be fully aware of the tariffs and the respective costs and benefits. We will need to challenge confusing messaging and occurrences of mis-selling at the earliest opportunity. – ***Exclusivity contracts at Motorway Service Areas (MSAs)*** - The exclusivity agreements that we understand to be in place for EV charging at MSAs restrict the choice available to consumers. – ***Information and data privacy*** - Detailed historical data collection could indirectly have privacy issues as it is possible to determine the home or business of a car owner or even the identity of the driver themselves, based on where cars are charging frequently. There should be robust security and protocols in place to prevent data breaches and fraudulent activity. – **Accessible and inclusive chargepoint design** – respondents raised a range of specific areas for improvement, including setting the minimum and maximum height for sockets (hip height for wheelchair users), no special/additional equipment required to access this; ensuring easy payment for all, and for apps to be included in this as an option. Some respondents highlighted that payment via smartphone can be easier for wheelchair users than accessing chip and pin or contactless payment interfaces. Most respondents answered 'no' or 'don't know' to providing supervised stations for those who require assistance. Respondents also highlighted the need for an inclusive physical environment for non-EV drivers navigating the streetscape, and that chargepoints should be designed with a view to reducing obstructions on the road and pavement, for those with reduced vision and mobility. – **Weatherproofing and lighting** – many responses stated that they felt a lack of universal coverings, means that they can often be exposed to poor weather whilst charging their vehicle. Additionally, chargepoints can be standalone in car parks and in unfamiliar locations at night. Without lighting this can make people, particularly women, feel unsafe. This issue is exacerbated as chargepoints are installed in an increasingly diverse range of locations, often in more isolated and exposed locations than is the case for petrol stations. – **Signage** – a dominant view was that signage requires some form of improvement. Respondents also stated that consumers need to be able to make informed choices, including around accessibility, before they reach a chargepoint location. Responses from drivers suggested a lack of signposting to public chargepoints along motorways, A-roads, at MSAs and destinations. Some respondents also raised the need for enhanced coordination with local councils around signage.
(U.K. Department for Transport, 2022b)	Charging should be a seamless experience for consumers. However, chargepoints can sometimes be difficult to find and may turn out to be in use or broken down when a driver reaches them. These issues matter because current EV drivers can experience unacceptably poor service and they deter others from switching to an EV by contributing to 'range anxiety'.
(U.K. Government, 2022)	The vast majority of drivers will do most of their charging at home, overnight. While around 70% of households with a vehicle in England currently have access to private, off-street parking, an estimated 24% of households with a vehicle park on the street overnight. 75% of EV charging is estimated to be residential charging with drivers plugging in after their last trip of the day (17:00-20:00). Charging at work accounts for about 15% of current EV charging demand, with drivers tending to plug in when they arrive in the morning (08:00-10:00). The use of public charging infrastructure (10% of current EV charging demand) is currently spread fairly evenly across the day.

Article	Key points
	Public chargepoints are needed for two main purposes: to enable long distance journeys, and to support those without off-street parking. It is critical of the sizeable minority without home charging, and 90% of all current EV drivers rely on it from time to time. Public charging options are residential on-street, residential charging hubs, on-route (for long distance journeys) and destination (e.g. gyms, supermarkets, shopping centres and transport hubs such as airports and train stations). While every EV driver wants access to a plentiful, reliable and fairly priced public charging network, they often experience poor customer service, opaque or excessive charging costs, poor reliability and complex access regimes involving numerous apps and smartcards. Public chargepoints can be difficult to find, difficult to use and may turn out to be in use or broken when a driver reaches them. For disabled drivers, the situation can be particularly challenging. In many places, insufficient thought has been given to inclusive access. Paying for charging can be unnecessarily complicated. It can require multiple apps or smartcards across different chargepoint operators. only 9% of all public chargepoints offer contactless payment. At rapid and high powered chargers (50kW+), only 41% of chargepoints have a contactless debit or credit card payment option. The U.K Government will regulate to ensure chargepoints are reliable and easy to use. This will include specific requirements on opening up data so that drivers can access real time information about chargepoints across the public network, mandating a single payment price so that prices can be compared quickly across different charging networks, standardising the payment methods so that paying for charging is easier whoever the charging provider and improving the reliability of the public chargepoint network so that it can be relied on (99% minimum reliability standard for all publicly available rapid chargepoints of 50 kW and over by the end of 2023). They will also develop chargepoint design standards to improve accessibility at public chargepoints for disabled users to allow drivers to easily identify which chargepoints are suitable for their needs, improve signage to chargepoint locations, and support fleet electrification by introducing payment roaming across the public chargepoint network. If people do have difficulties at a chargepoint, they will be able to get help and support. Connecting new chargepoints to the electricity system can be slow and expensive. This is a particular issue in remote areas, where new high power connections might be required, or locations where there is insufficient capacity in the existing distribution network, such as for charging of vehicle fleets in depots. Connection costs were the second most quoted barrier to the deployment of public chargepoints. Many people are already using smart charging at home and work. From June 2022, private chargepoints sold in Great Britain are required to be smart and meet minimum device-level requirements.
(U.K. Office for Product Safety & Standards, 2022)	PAS 1878 provides a technical specification that allows domestic appliances to operate in a Demand Side Response (DSR) system. PAS 1879 provides recommendations for the provision of DSR services by service providers. Together, these standards provide a framework for Energy Smart Appliances and DSR operation.
(U.S. Department of Energy, 2014)	The six Smart Grid Investment Grant (SGIG) projects evaluated more than 270 public charging stations in parking lots and garages and more than 700 residential charging units in customers' homes in California, Florida, Indiana, North Carolina, South Carolina and Wisconsin. The EV owners were early adopters. Key project experiences: – Charging behaviors: – The vast majority of in-home charging participants charged their vehicles overnight during off-peak periods. Where offered, time-based rates were successful in encouraging greater off-peak charging.

Article	Key points

	– Public charging station usage was low, but primarily took place during business hours and thus increased the overlap with typical peak periods. Plug-in hybrid owners frequently used the (often free) public stations for short charging sessions to “top off their tanks.”
	– Technology issues:
	  – Faster chargers may require more expertise to install in homes and public stations. Installing a 240-volt charging station, which typically charges 3-5 times as fast as a charger using a standard 120-volt outlet, requires permits, a licensed electrician and occasionally service upgrades.
	  – Some utilities found residential interoperability problems in communication between smart meters and charging stations. Sacramento Municipal Utility District (SMUD) found that the two devices only connected successfully about 50% of the time during load reduction events.
	Charging behaviors differ depending on whether the customer is charging at home or at a public station, and what type of vehicle they have—either an all-electric vehicle or a plug-in hybrid. IPL found that approximately 76% of the electricity used for charging occurred during off-peak periods, an additional 4% occurred during mid-peak, and the remaining 20% occurred during peak periods.
	Participants generally prefer charging their cars overnight at home. Time-based rates encouraged off-peak charging and provided savings for overnight chargers. The rates were especially convenient when customers could pre-program charging sessions to start when off-peak rates came into effect.
	Plug-in hybrid electric drivers often use public charging stations—especially where free public charging was available—before returning home. All-electric drivers more often chose to wait and charge their depleted batteries at home, in large part because of the longer times required to charge the all-electric vehicle batteries.
	Commercial and public stations were used mostly during business hours.

(U.S. Department of Energy, Transportation Secure Data Center, 2023)	Analysis of the data from the 2019 California Vehicle Survey for residential EV users (N=451) indicates the following:
	– 38% have a PHEV and 62% have a BEV
	– When purchasing the PEV, the importance of home charging was rated 4.12 (out of 5), the availability of charging at work/school was rated 3.10, the availability of free charging at work/school was rated 3.11, the availability of public chargers was rated 2.75 and fuel cost was rated 3.46
	– 35% of BEV users recharge when the SOC is more than half, 40% at half, 55% at quarter, 25% at an eighth and 5% when the light comes on
	– 89% have the capability to charge at home:
	  – 63% in an attached garage, 8% in a detached garage, 4% in a carport, 28% in a driveway, 1% in a parking lot on the street, 2% in an assigned parking lot or garage, 1% in an unassigned parking lot or garage
	  – 60% have a level 1 charger, 58% have a level 2 charger and 4% have a DC fast charger
	– 51% incurred an expense to upgrade their electrical system
	  – 77% incurred the total expense and 23% had some or all of the expense covered by a subsidy
	  – The average cost was $US1,060
	– The most common time to charge was overnight, with 91% charging overnight on weekdays and 88% on the weekend. 59% charged on weekday evenings.
	– The electricity provider offered different rates for peak and off-peak usage to 81% of EV users (6% no and 13% not sure or don’t know). 76% took advantage of these rates.
	  – 33% received a special rate for charging their EV (51% no and 16% not sure or don’t know). For 88% the special rate applied to all electricity usage and for 12% it only applies to what is used on a separate EV meter

Article	Key points
	– The fuel costs of the EV were rated as much less expensive than a gasoline vehicle – 70% park at a work or school location in a typical week, of which 57% park there at least 5 times per week – Charging stations are generally not available. Where chargers are available, they are more likely to be level 2 chargers, with about half of these provided for free and half requiring payment – Public charging facilities are generally available for EV users (82%), with EV users travelling on average 4.60 miles or 9.15 minutes to access the public chargers – Public chargers are used on average 2.85 times per month, with some accessing daily – Public chargers are commonly level 2 (54%) or DC fast chargers (32%) – Only 10% of EV users had never been unable to access public charging because they were all being used, while 15% indicated they couldn't access them most or all of the time, 36% couldn't access them about half of the time, and 39% couldn't access them less than half the time
(U.S. Department of Energy, 2023)	There are a number of electricity laws in California relating to EV charging: – EV charging access: Municipalities may not restrict the types of EVs, such as plug-in hybrid electric vehicles, that may access an EV charging station that is public, intended for passenger vehicle use, and funded in any part by the state or utility ratepayers. – EV charging requirements: New EVs must be equipped with a conductive charger inlet port that meets the specifications contained in Society of Automotive Engineers (SAE) standard J1772. EVs must be equipped with an on-board charger with a minimum output of 3.3 kilowatts (kW). These requirements do not apply to EVs that are only capable of Level 1 charging, which has a maximum power of 12 amperes (amps), a branch circuit rating of 15 amps, and continuous power of 1.44 kW. – EV charging station billing requirements: EV charging station charging rates must be based on a price per megajoule or kilowatt-hour. All EV charging stations must be able to indicate the billing rate at any point during a transaction. Existing Level 2 EV charging stations installed before January 1, 2021, must be updated by January 1, 2031, and Level 2 EV charging stations installed after January 1, 2021, must comply upon installation. Existing direct current fast charging (DCFC) stations installed before January 1, 2023, must be updated by January 1, 2033, and DCFC installed after January 1, 2023, must comply upon installation. – EV charging station open access requirements: EV charging station service providers may not charge a subscription fee or require membership for use of their public charging stations. In addition, providers must disclose the actual charges for using public EV charging stations at the point of sale; allow at least two options for payment; install the Open Charge Point interoperability billing standard on each EV charging station; and disclose the EV charging station geographic location, schedule of fees, accepted methods of payment, and network roaming charges to the National Renewable Energy Laboratory. Exceptions apply. – EV charging station policies for multi-unit dwellings: A common interest development, including a community apartment, condominium, and cooperative development, may not prohibit or restrict the installation or use of EV charging stations or EV-dedicated time-of-use (TOU) meter in a homeowner's designated parking space or unit. These entities may put reasonable restrictions on EV charging stations, but the policies may not significantly increase the cost of the EV charging stations or significantly decrease its efficiency or performance. Restrictions may be placed on TOU meter installations if they are based on the structure of or available space in the building. If installation in the homeowner's designated parking space or unit is not possible, with authorization, the homeowner may add EV charging stations or a EV-dedicated TOU meter in a common area.

Article	Key points
	– EV charging station policies for residential and commercial renters: The lessor of a dwelling or commercial property must approve written requests from a lessee to install EV charging station at a parking space allotted for the lessee on qualified properties. Certain exclusions apply to residential dwellings and commercial properties. – EV charging station uptime reporting standards: Beginning January 1, 2025, the California Energy Commission (CEC) must assess the uptime of EV charging stations. The assessment must include considerations for equitable access to EV charging stations in low-, moderate-, and high-income communities. The assessment must be updated every two years. – EV parking space regulation: An individual may not park a motor vehicle within any on- or off-street parking space specifically designated by a local authority for parking and charging EVs unless the vehicle is an EV fueled by electricity. Eligible EVs must be in the process of charging to park in the space. – Mandatory EV charging station building standards: pre-wiring for EV charging station installation are required in parking spaces at one- and two-family dwellings with attached private garages, multi-family dwellings, commercial facilities, and public buildings. Public facilities must also install handicap-accessible EV charging stations when installing new or additional EV charging stations.
(University of California, Davis, 2020)	The survey results (N=13,000) show that more than half of the PEV owners charge only at home while 33% combine home with other locations. The 14% who do not charge at home use mostly work charging and, in some cases, fast charging opportunities. Many users start charging at or around midnight to take advantages of lower electricity rates and a second peak occurs around 9 am, when charging at work. Over all three years of the study, logged participants (N=264) owning PHEVs with larger capacity batteries plugged in more than did participants with PHEVs with smaller capacity batteries. Charger availability and the range recovered per charging event are significant factors in the decision to plug-in. For BEVs, the logged data shows that level 2 charging was the main source of energy and level 1 charging was used mostly in combination with level 2. Exploring the charging behavior at workplaces and with DC fast chargers (DCFCs) using the survey data, we find a variety of reasons for plugging-in, including the charging price (e.g., free DCFC and workplace charging) and travel behaviors that have an impact on the need for charging. Overall, owners of longer-range BEVs plug-in more frequently than do owners of shorter-range BEVs, but with lower kWh load at each charging event. Analysis of the distance of the charging event from home and the distance of the event from the vehicle's location at the beginning of the day suggests that the vast majority of the charging events that are not home events occur within the vehicle range (if starting the day with a fully charged battery). However, 10%-15% of the fast charging for Teslas may be correlated with trips longer than the range of the vehicles. The interviews show that some early PEV drivers continue to learn about their PEVs and charging infrastructure, even months or years after they acquired one. Other PEV owners may use their car based on habits and routines they developed early and have remained unchanged despite changes, such as increasing infrastructure.
(University of Oxford, 2019)	Go Ultra Low Oxford (GULO) was a trial of five different on-street electric vehicle (EV) charging technologies across 28 locations on public streets in Oxford. These included lampposts converted to include charging capability; three types of bollard chargers; and one type of home charger coupled with a channel dug into the pavement to allow for a cable to be trailed across the footpath. 16 private householders (6 with BEVs, 8 with PHEVs and 2 with extended range EVs (EREVs)) and 5 car club members (using EREVs) took part in the trial. The evaluation revealed a number of creative practices with respect to gaining access to chargers, and optimising battery range. These included adaptations to parking routines, driving style, route choices and the use of heating and air-conditioning when driving.

Article	Key points
	Charging habits varied widely between users, with some regularly charging overnight, and others plugging in during the day or more often on weekends. These factors varied according to how people used their cars. There were considerable differences in the charging and driving practices of BEV and PHEV users. Relying to a greater extent on chargers, BEV drivers suffered most when chargers could not be accessed or had broken down. Participants' charging practices changed over time, as they became familiar with the equipment and developed techniques. For instance, their bodily movements became more precise, and the time taken to plug-in their EVs reduced over time. Users reported a range of interactions with neighbours, friends and family relating to charging. Whilst most reported positive and supportive engagements, others expressed feelings of vulnerability when charging their vehicles. Stakeholders were surprised by the number of instances of vandalism and breakdown, which led to lengthy periods in which a few chargers were non-operational. Breakdown impacts BEV drivers more severely than those with PHEVs. Evaluation of the performance of the different chargers:

	Lamppost charger	Bollard-style charger	Home charger
Ease of access	New users must purchase cable and sign up with provider.	Chargers are deployed alongside dedicated parking bays. Some reports of parking difficulties, particularly where vehicles have sockets at the side. Type 2 charging cable required.	Installed on private property; not available to public. Parking close enough, and without cables sticking out into the road, can be a challenge.
Ease of use	Charging begins on plug-in with no need for further user interaction.	Users reported how design and lack of instructions made the bollards initially difficult to use. As with all chargers, participants improved their techniques over time.	Typically requires a long cable (>10m) which can be difficult to handle and manipulate into the pavement channel.
Installation footprint	Seamlessly integrated into existing street furniture.	Both charger and transformer need to be accommodated on the footpath. One that had a small footprint and low profile was subject to more vehicle collisions.	Appearance of box and RCD on front of house proved unpopular. Pavement channels integrate into streetscapes where storm drains already exist.
Robustness	Very few examples of breakdown or vandalism. Reported to be reliable by users.	Numerous examples of socket doors being damaged or removed, and sockets not working. Subjected to vandalism and vehicle strike.	Largely reliable and robust. In a couple of instances the cables became deformed and stopped working.
Maintenance and repair	Largely quick and straightforward to maintain and repair.	Several reports of one socket being non-operational for lengthy periods.	No information available on fault reporting

Article	Key points			
			One bollard charger not modular in design with a lack of replacement parts and units, and long repair times. Users complained of lack of fault reporting information on installations. When reporting via app, several complained of no response and no evidence that reporting had led to repair.	Cables appear to be vulnerable to deformation Lack of temporary replacement parts
	Price	Competitive with other public charge points, although the separate connection fee was perceived negatively by some users.	Electricity prices were competitive compared with other public chargepoints.	Integrated into home electricity supply, prices can be competitive, depending on users' chosen tariff.
	Data and billing	Provider app highly rated by those who used it. Many users preferred to use vehicle app instead, and had little awareness of charges due. Example reported of user not being charged by provider for >1 year.	Provider's smartphone app highly rated by users. Usage data can be downloaded. Data available for analysis in the trial was limited.	Separate sub-meter installed for chargers allows users to separately monitor their usage. Online portal available.
	Speed of charging	Median speed: 3.77kW. During the trial, installations were upgraded to enable speeds of 5.5kW. Users mostly satisfied with speeds.	No median speed could be calculated as data no available. Bollard chargers are designed to discharge at 7.4kW for BEVs and 3.7kW for PHEVs, and there were no reports from users of speeds being slower than expected.	Median speed: 6.48kW. Faster than a standard 3-pin plug, and very reliable speeds.
(Utility Dive, 2022)	A J.D. Power's 2021 Electric Vehicle Experience ownership study found that EV owners are worried about being able to reach destinations. A Forbes survey made a similar finding in the summer of 2022, with 62% of respondents reporting that they "always" or "frequently" feel anxious about their vehicles' ranges and adjust their travel plans to suit. The flip side of range anxiety is "charging anxiety". Charging anxiety comes from knowing that even if you're able to locate a charger – which may be tucked away in a corner of a parking lot with very little signage – and even if that charger isn't blocked by another vehicle, it may be broken. The Forbes survey found that 43% of respondents had encountered broken public charging stations. The funding requirements of the US's National Electric Vehicle Infrastructure (NEVI) program state that charging stations must be operable at least 97% of the time. They also state that charging stations must be capable of communicating their functional status via web applications to drivers on the road so they can make confident decisions about where to pull over and recharge when needed.			

Article	Key points
(van Barlingen, 2022)	Paying for public EV charging can be a complicated, confusing endeavour with different and often conflicting processes depending on the operator. An ISO standard, referred to as "plug and charge" (Road vehicles – Vehicle to Grid communication interface) is in development. The standard will eliminate the manual authentication required when plugging into a public charging station. Instead, authentication data will be stored in the vehicle and automatically communicated to a charger when plugged in. The charger will be able to determine who to bill without user input. The US is moving towards the National Electric Vehicle Infrastructure (NEVI) program, which requires interoperability between charging providers, as well as similar payment systems, pricing information, charging speeds, and other features that will significantly improve the user experience. Europe's "Fit for 55" proposals include legislation that aims to improve the user experience and strives for fair, open, and accessible charging infrastructure under the Alternative Fuels Infrastructure Regulation (AFIR). Ensuring EVs can be charged across borders is an often an overlooked consideration. Roaming in the context of EV charging will ensure drivers can use and connect to public chargers outside their home country. Roaming also means that drivers can charge at stations that belong to any other CPO networks with a single subscription. This enables drivers to charge at any publicly accessible charging point, without having to worry about extra fees or being forced to take up a contract with the provider managing that charging point.
(van Heuveln, et al., 2021)	The objective of the study was to identify factors that influence actual electric vehicle (EV) drivers' acceptance of Vehicle-to-Grid (V2G) charging. Twenty semi-structured interviews were conducted among Dutch EV drivers, including both regular EV drivers, as well as participants who had previously taken part in V2G projects in the last quarter of 2019. As EVs and V2G are new technologies, the sample of twenty actual EV users consists of early adopters. As such, their attitudes may not reflect those of the majority of future users. The subset of EV drivers was not representative of the larger population of private vehicle owners - 75% were male, and the majority had a University background and belonged to higher income groups. The factors that were found to be most important for fostering acceptance are: – Financial compensation – both the type of compensation and amount of compensation play a role. However, the degree to which different EV drivers were triggered by compensation was found to vary. – Transparent communication – Interviewees indicated that a user interface on the charging station would increase transparency and ease of use of the system and thus their acceptance. The user interface could, for instance, display charging and discharging information and allow the end-user to view certain settings of the V2G system. Most interviewees indicated that they would prefer such an interface. Public relations (PR) and communication were found to be essential to interviewees for fostering long-term acceptance. This included the provision of accurate information about V2G projects and communication of both the benefits of V2G and the possible risks. – Reliable control of the system by the user - Control over charging and discharging was mentioned by interviewees as a functionality that can contribute to acceptance. However, there were also some interviewees who did not want to have this possibility and just wanted the system to arrange everything automatically. On the other hand, the factors that were found to have a negative effect on acceptance are: – Range anxiety – users were worried about the availability of sufficient battery capacity in the EV, particularly for unexpected trips. – Discomfort experienced while participating – user-friendliness was mentioned by a number of interviewees as a precondition for the use of V2G chargers. A complex system with very little information or unclear information would block their acceptance. – Battery degradation – EV lessees were found to be less concerned about the effects of battery degradation than EV owners. They were more concerned about who received compensation for both the energy delivered as well as the battery degradation.

Article	Key points
	V2G charging point location was not found to have a large influence on users' acceptance. Some interviewees commented on the societal contribution by reducing emissions, and concerns about a lack of standards/protocols. Other important factors influencing acceptance were: – EV driver profile characteristics – knowledge of batteries, EV motivations, eco-values, technology innovativeness, possession of solar panels, V2G familiarity, previous charging behaviour, EV ownership (noting that 50% of drivers in the Netherlands lease cars) – Trust – operational reliability, trust in aggregator, trust in system designers and trust in service providers. The study showed that the majority of the interview participants accept V2G albeit with some reservations and caution. Many interviewees expressed scepticism regarding the operation of V2G, especially the incentives for end-users, the adequacy of compensation, battery degradation and its conflict with charging the vehicle for mobility.
(Visaria, Jensen, Thorhauge, & Mabit, 2022)	This paper analyses user preferences related to electric vehicle (EV) charging decisions. The analysis includes both a qualitative (literature review and 11 interviews with Danish EV users) as well as a quantitative assessment (survey of 558 EV owners conducted in March-April 2020). The sample comprised 88% male, average age of 50, higher than average income and 80% had taken some form of higher education. **Literature review** In a study from San Diego, USA, researchers interview 29 early EV adopters to better understand the social norms and etiquette related to charging at locations away from home, which mainly includes public and work charging. They find that people lack good services that allow them to find public charging locations and the status of these locations in real time. Moreover, the users are in doubt about how to deal with problems like non-EVs, car-sharing EVs, and taxis occupying spaces meant for public charging. Additionally, they are unsure what the norm is around disconnecting the charger from a car that has been charged and connecting to their own car. **Interviews** Out of the people interviewed, ten were male and only one was female. Moreover, four were Tesla users. All, except one respondent, had some sort of home charging ranging from basic charging using an ordinary socket to a dedicated home charging unit. Charging at work was possible for four of the users. Most of the respondents had a membership with a charging network provider, however they generally emphasised the need for interoperability and that it would increase their user experience if payment systems and pricing structures could become less complicated. Overall, the charging behaviour was a mix of contextual and subjective triggers, and hence no general daily charging pattern except overnight home charging and work charging (where applicable) was found among these respondents. A few of the users had tried using charging points available at supermarkets or malls while shopping and these users were pleased with this service. While there was a constant trade-off being made between convenience and cost, the biggest driver for EV usage was lower operating cost compared to conventional cars. Most users took long trips with their EV at varying frequencies in a year. For these long trips, they planned ahead and identified their charging options on the route taken. Additionally, a few of the users commented on how using EVs had in fact improved their driving behaviour. Taking breaks for charging, driving at moderate speeds to maximise battery efficiency, and just the overall EV experience had made the long trips a more pleasant experience. Key factors to look at while selecting charging locations were the charging speed, charging cost and surrounding facilities. Overall the Tesla users were more pleased about their driving experience. This was due to the larger driving range, free fast charging locations available across Denmark and the overall user experience. This is possible as Tesla has complete control over the whole process from the car to the charging. Most of the respondents had faced no major issues with using chargers or charging their cars. They showed willingness to adopt future technologies like bi-directional charging (V2G) or be a part of services like renting out home charging space.

Article	Key points
	Lastly, one major point of criticism was the lack of socially acceptable charging etiquette. Issues like EVs not moved from charging spots even after charging is completed and cases of taxis/car sharing vehicles taking up public EV charging spots, were highlighted as key points of frustration among the users. **Survey statistics** – Car parking – personal parking in driveway or garage (74%), public/street parking (15%), shared parking space in a complex (7%), reserved parking space in a complex (4%) – Home charging unit – installed (67%), possible but not installed (13%), not possible (20%) – Problems with charging on long trips – too few chargers (55%), chargers occupied/long waiting time (29%), only/mainly slow chargers (29%), payment solution (26%), connection to the charger (26%), other problems (15%) **Stated choice experiment 1: long-term decisions related to regular charging practices** Users were presented with various pricing options to get an idea of what trade-offs they would make. The alternatives were No Contract (NC), Flat Fee (FF), Monthly Subscription 1 (MS1) and 2 (MS2). Consumers are willing to pay a premium for the convenience of lower (per kWh) cost for everyday charging, and a premium for the convenience of interoperability across charging providers. **Stated choice experiment 2: decisions related to charging needs on longer trips** Users asked to choose which of three charging locations they would choose if they were on a long trip with low battery level (~20%). Consumers are willing to drive detours to arrive at fast-charging locations with more chargers available and facilities.
(Wang, Xing, Chen, Zhang, & Liu, 2022)	This paper analyses the data of 150 private electric vehicles (PREVs), 100 commercial electric vehicles (CEVs), and 50 official electric vehicles (OEVs) in Chongqing, China from December 2019. It finds that fast-charging users primarily access charging during the daytime (10:00-16:00), whereas slow-charging users mostly choose to charge when they arrive at the workplace in the morning (08:00-10:00) or at night (20:00-24:00) when the electricity price is lower and finish charging in the morning when they go to work (06:00-08:00). Slow-charging users who finish charging in the morning peak period accounted for 28.05%. Among the three types of vehicles, PREV users are more conservative about the battery level. They often stop charging and start their journey when the batteries are fully charged. Additionally, CEVs have the widest choice of routes, and they are also more inclined to choose fast charging, whereas PREVs and OEVs have relatively fixed route patterns, and they are more inclined to slow charging.
(Wang Y. , Chi, Xu, & Yuan, 2022)	In this study, consumers' attitudes toward charging infrastructure based on consumers' comments published on Chinese social media from August 2013 to June 2020 were measured and analyzed. First, consumers have been increasingly concerned with the charging infrastructure since 2013, and the proportion of months with positive attitudes accounted for 95%. Overall, consumer satisfaction has improved. Second, the top six pain points that cause consumers' negative attitudes are: 1. inconvenient charging – consumers cannot install private charging piles so they use the air-conditioning socket to charge at home leading to problems such as circuit cutting and the inability to pull the wire due to the high floor 2. charging dilemmas – consumers cannot install private charging piles so they need to use high-power sockets to charge at home or find public charging piles outside the community, thus facing the dilemma of inconvenient charging and high charging prices.

Article	Key points
	3. inability to install private charging piles – they cannot be installed because there are no fixed parking spaces, or the community property management firm obstructs the installation of private charging piles 4. unsatisfactory charging modes – the lagging construction of charging piles on expressways leads to worrying about the lack of charging piles on the expressway, and queues when charging on the expressway causing expressway traffic congestion 5. range anxiety – includes charging time, driving range anxiety, power loss caused by air conditioning, and whether there are charging piles in motorway services areas. 6. performance shortcomings of PEVs – including the limited travel distance of EVs, battery life, attenuation of the driving range because of turning on air conditioning, and long charging time. Analysis of different charging scenarios showed that 8.56% of the charging scenarios focus on "home", impossible to install private charging piles and can only use air-conditioning sockets for charging are the main negative reasons. 4.72% of charging scenarios focus on "expressway", the lagging construction scale of charging piles in expressway service areas is the main negative reason. Therefore, the most concerning aspect for Chinese consumers is the convenience of charging infrastructure. Consumers want to improve the charging infrastructure in four areas. First, it is hoped that the community allows to install the charging piles, and the property can agree and assist in the installation of charging piles. Second, it is hoped that the number of charging piles will increase, including the construction of more charging piles in urban areas and expressway service areas. Third, it is hoped that the driving range of electric vehicles will increase, and the battery attenuation will be less. Fourth, it is hoped that the charging software can be more intelligent, showing whether the nearby charging parking spaces are parked, and whether there are already cars charging in the charging piles.
(Wang Y.-Y. , Chi, Xu, & Li, 2021)	This study uses natural language processing technology to explore consumer preferences for charging infrastructure from consumer comments posted on Chinese public social media in July 2020. The findings show that consumers in first-tier cities pay more attention to charging infrastructure, accounting for 36% of comments. Consumers are most concerned about charging issues, national policy support, driving range, and installation of private charging stations. Direct current (DC) fast charging is more popular with consumers. The inability to find public charging stations in time to replenish power during travel or high energy consumption caused by air conditioning is the main reason for consumers' range anxiety. Increasing battery performance, improving charging convenience, and construction of battery swap stations are the main ways consumers prefer to increase driving range. Consumers' preference for charging at home is the main reason for their high attention to the installation of private charging stations. However, the lack of fixed parking stations and community properties have become the main obstacles to the installation of private charging stations. In addition, consumers in cities with different development levels pay different amounts of attention to each topic of charging infrastructure. Consumers in second-tier and above cities are most concerned about charging issues. Consumers in third-tier and above cities pay significantly more attention to the installation of private charging stations than consumers in fourth-tier and fifth-tier cities. Consumers in each city have almost the same amount of attention to driving range.
(Westin, Jansson, & Nordlund, 2018)	The possibility to charge the batteries at home, in the driveway or garage, facilitates EV ownership. A 2014 survey of car owners in Sweden (N=1192), including 494 EV owners found that EV owners are older and have a significantly higher income than other car owners, and that a large share of them have a university degree compared to the population at large. This group of car owners is likely to reside in suburbs or rural areas. High-income residential areas often have access to these charging facilities. In a Swedish context, though, power outlets for motor heaters are often available at parking lots, shopping malls, and residential parking places, which facilitates normal charging.

Article	Key points
	As lack of charging infrastructure might also be seen as a barrier to EV adoption it also becomes important to make this infrastructure just as visible (or even more) as ordinary gasoline/diesel fueling stations to reach the same purpose of normalization. When charging times become shorter as batteries and charging technology develops it is even more important to make cars and charging points more visible in order to showcase the ease of access and options for time spending when charging (such as visiting restaurants, etc. Since most EV adopters charge at home or at work public charging infrastructure is mainly a psychological barrier for before adoption, and not for actual use. Although public charging infrastructure might not be very important once an EV is adopted, the psychological importance before actual adoption should not be underestimated.
(Will & Schuller, 2016)	This paper considers potentially influential factors for the acceptance of smart charging. Most EV-owners have so far been unable to experience smart charging first hand and have thus no opportunity to adequately assess its potentials and risks. A survey was conducted in January and February 2015 of 237 early electric vehicle adopters from Germany. The sample was not representative of the German population but typical for early adopters of electric mobility – 90% male, high education and relatively high incomes. About 60% of the sample appraise ‘‘usefulness” of smart charging at an average score of 4 or higher whereas only 37% rate ‘‘satisfaction” at a similar level. Together, average evaluations are towards the positive end of the scale which indicates substantial approval of the concept of smart charging. However, ‘‘usefulness” is appraised more positively than ‘‘satisfaction”, indicating that smart charging is indeed seen as a valid concept but so far lacks optimal implementation. Key motivational factors for acceptance of smart charging are contributing to grid stability and the integration of renewable energy sources. The users' identified desire for an individual and flexible mobility in turn hampers acceptance of smart charging. The provision of customisation possibilities for data input is another noticeable but only weakly significant influential factor. Further well known influential factors like economic incentives do not seem to have a significant impact in the sample group under scrutiny. While the majority would request a discount (on average around 20% discount to their monthly individual charging costs), there is a substantial number of respondents that do not prefer a discount at all. Data privacy was considered as a influencing factor, but the effect was weak. Most respondents request an option to submit a minimum range (77%). The average minimum range requested in the sample is 70 km (median 50 km). The ability to override the smart charging process and charge directly is another highly demanded feature (76%) as well as the submission of a planned time of departure (71%). Other than the minimum range, 60% of respondents opt to submit a planned range which serves as an upper threshold beyond which no additional battery charge is necessary. Gentle charging for a prolonged battery life is specifically requested by 56%. Another 37% consider a variation range around their arrival time as useful. Only 3% of the sample do not request any features at all. Respondents also request options for the use of self-produced electricity from e.g. PV and V2G-functionalities.
(Wolbertus, van de Hoed, Kroesen, & Chorus, 2021)	This study analyses an empirical dataset of approximately 2 million actual charging sessions in the Netherlands in 2017. There is a chicken-or-egg dilemma related to charging infrastructure that could prove to be the largest bottleneck to facilitate a rapid transition to electric mobility. EV purchases have been restricted by three main barriers: price, driving range and available charging infrastructure. A lack of charging infrastructure is one of the main barriers for consumers to purchase an EV. Availability of home charging is the most important factor in the decision to adopt electric vehicles. Home charging in urban environments is often done at the kerbside located charging infrastructure. Charging behaviour is the result of the choice of an individual EV driver to charge its car. Charging behaviour is defined by its location, the time connected to the charging station, the energy transferred and the time until the next charging session. Analysis of charging patterns reveals heterogeneity in charging

Article	Key points
	behaviour across users and different user types. Each EV driver has her own distinct charging patterns. The behaviour at the individual level is habitual, e.g. EV drivers charge at a limited amount of locations and often around the same time. It is therefore assumed that EV drivers attempt to charge at their favourite charging location, closest to their destination, which is often the home location or workplace. If the favourite location is not available, the driver searches for an available charging station in its proximity. It is assumed that distance is an important factor in location choice and that drivers have a maximum willingness to walk, which varies across drivers. Visitors, taxi drivers and electric car sharing services are important users of the charging systems. The behaviour of these other user types is not habitual but does have distinct patterns.
(Woollacott, 2023)	In April 2022, drivers on the UK's Isle of Wight discovered pornography appearing on the screen of EV charging points in the local council's car parks. The chargers had been hacked to redirect to a porn website following a change of network. Similarly, and around the same time, charging stations along Russia's M11 motorway between Moscow and Saint Petersburg started displaying pro-Ukrainian messages after being hacked. In an investigation conducted two years previously by the consumer group Which?, home chargers from Pod Point had been found to have suffered from a security vulnerability that exposed the full names, home addresses, and car-charging history of more than 140,000 customers. Cyber security risks include the disruption of operations, theft of customer information, including payment information, and fraudulent payments, as well as the takeover of charger networks for use as bots in distributed denial-of-service (DDoS) attacks. There are moves towards the introduction of security standards for EV charging stations. In the US, the National Highway Traffic Safety Administration (NHTSA) provides recommendations on software security for manufacturers. However, there are no mandatory standards. The UK introduced new legislation on EV charging security at the end of 2022. All home chargers must now comply with authentication standards and encrypt data. They must also allow owners to change settings to easily delete their personal data if they wish, and must be able to check regularly for security updates. They must conform to Secure Boot standards, run only signed firmware, and must not include hard-coded security credentials.
(Zhang, Ross, & Cain, 2021)	This study explored consumers' preferences and willingness to pay for on-street Vehicle-to-Grid (V2G). The study was challenging as on-street V2G is a future technology that does not currently exist. An online survey of car owners was conducted in England, UK, with 495 respondents. Based on a literature review, a number of features of V2G were considered for the study, including: – Driving range on full battery – the driving range of an EV is regarded as one of the most important features when consumers are considering adopting EVs. – Battery charging time – the time taken to charge an EV is another important factor when consumers are considering adopting an EV. – Pollution of EV on V2G contract – since EVs are known for their environment-friendly property, consumers are keen to know whether joining V2G would increase the benefit to the environment or not. – Guaranteed minimum driving range on V2G contract – although people showed interest in the idea of selling electricity back to the grid, they did not want to be left without enough battery charge in case of emergencies. – Required plug-in time per day to sell on V2G contract – people see high inconvenience cost with signing a V2G contract, due to factors such as people's desire for flexibility of car use, and their lack of awareness of how many hours their cars can be parked to sell electricity. – Monetary value on V2G contract – drivers are not certain about earning money from re-selling power back to power companies. Of these, two features were explored in the study – 'required plug-in hours per month' and 'minimum level of battery guaranteed'.

Article	Key points
	Potential on-street V2G users place a higher priority on ‘required plug-in hours per month’ than ‘minimum level of battery guaranteed’, but only have a willingness to pay more for an increased ‘minimum level of battery guaranteed’. When the total amount of cost is limited, potential users would like to spend the limited amount for an increase in guaranteed driving range, over a decrease in required plug-in time. In other words, people would like to pay more for driving range, rather than having more flexible access to their vehicles. On the contrary, ‘required plug-in hours per month’ was viewed as more important when consumers were stating their preferences. Consumers’ likes and dislikes do not determine their ability to purchase goods, and vice versa.

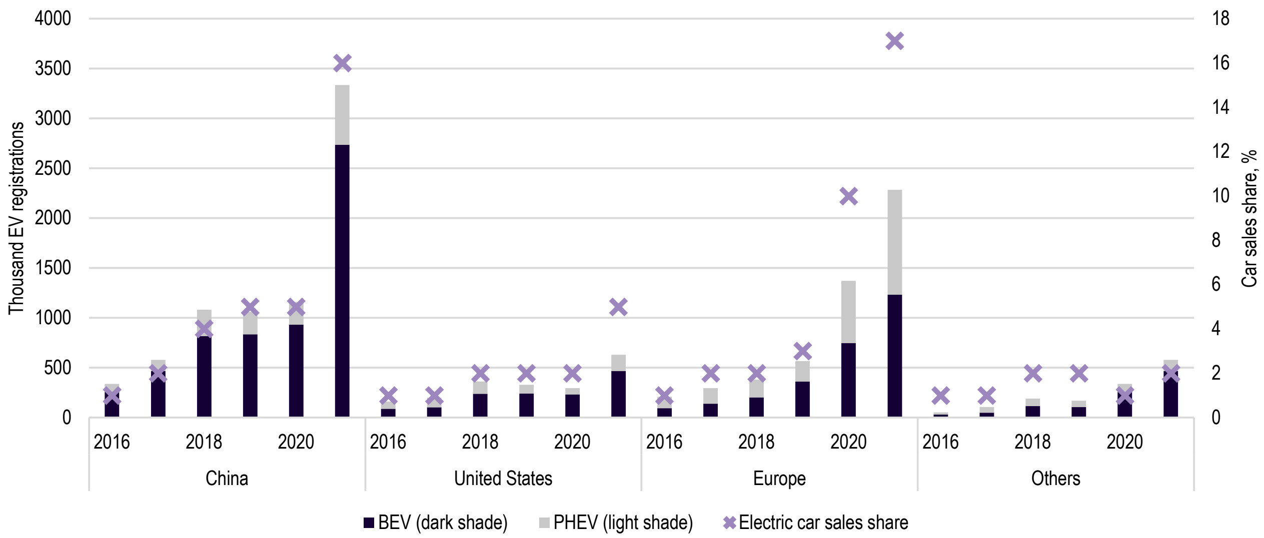
Source: ACIL Allen based on references cited

EV adoption rates

B

The EV adoption rates in China, the United States, Europe and other regions are illustrated in Figure B.1. By the end of 2021, EVs as a % of car sales was 17% in Europe, 16% in China and 5% in the United States. The proportion of EVs that were PHEVs was higher in Europe than in the other regions. The highest number of EV sales have occurred in China.

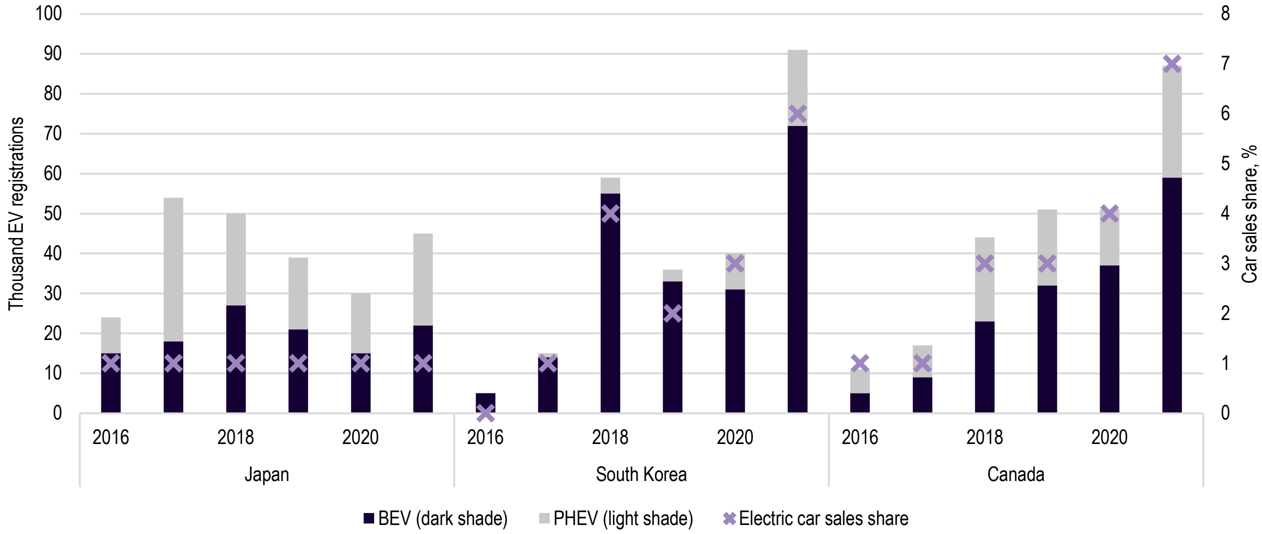
Figure B.1 Electric car registrations and sales share in China, United States, Europe and other regions, 2016-2021



Source: (International Energy Agency, 2022a)

The EV adoption rates in Japan, South Korea and Canada are illustrated in Figure B.2. By the end of 2021, EVs as a % of car sales was 1% in Japan, 6% in South Korea and 7% in Canada. While there has been substantial growth in the number of EVs sold in South Korea and Canada, the numbers have remained relatively flat in Japan.

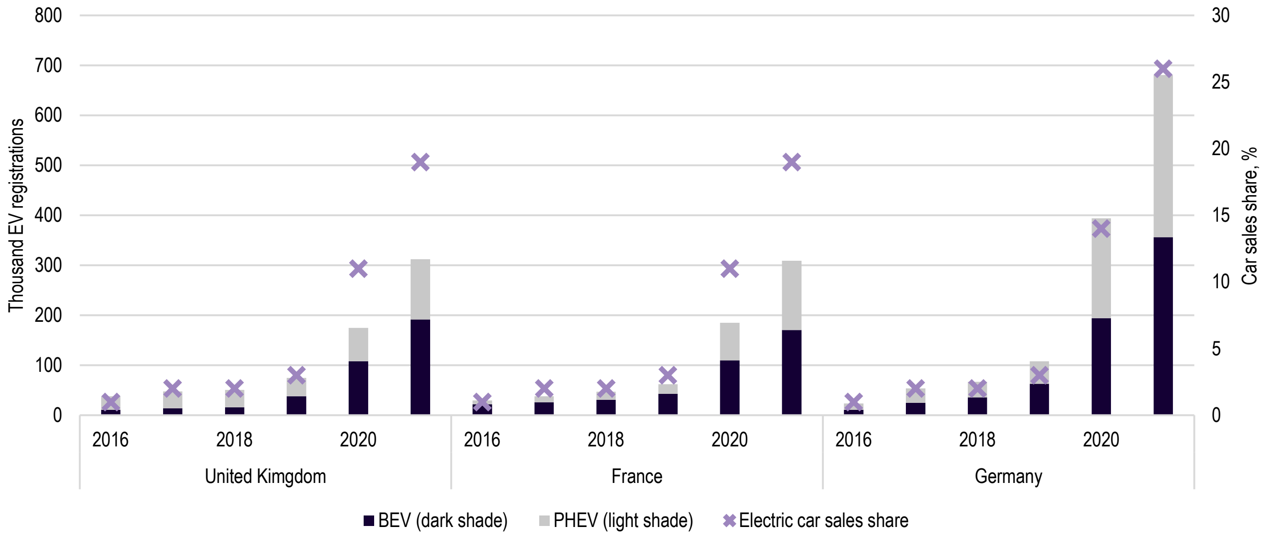
Figure B.2 Electric car registrations and sales share in Japan, South Korea and Canada, 2016-2021



Source: (International Energy Agency, 2022a)

The EV adoption rates in the United Kingdom, France and Germany are illustrated in Figure B.3. By the end of 2021, EVs as a % of car sales was 19% in the United Kingdom and France, and 26% in Germany. There has been significant growth in the sales of EVs in each of these countries over the 2016-2021 period, with a relatively even split between BEVs and PHEVs.

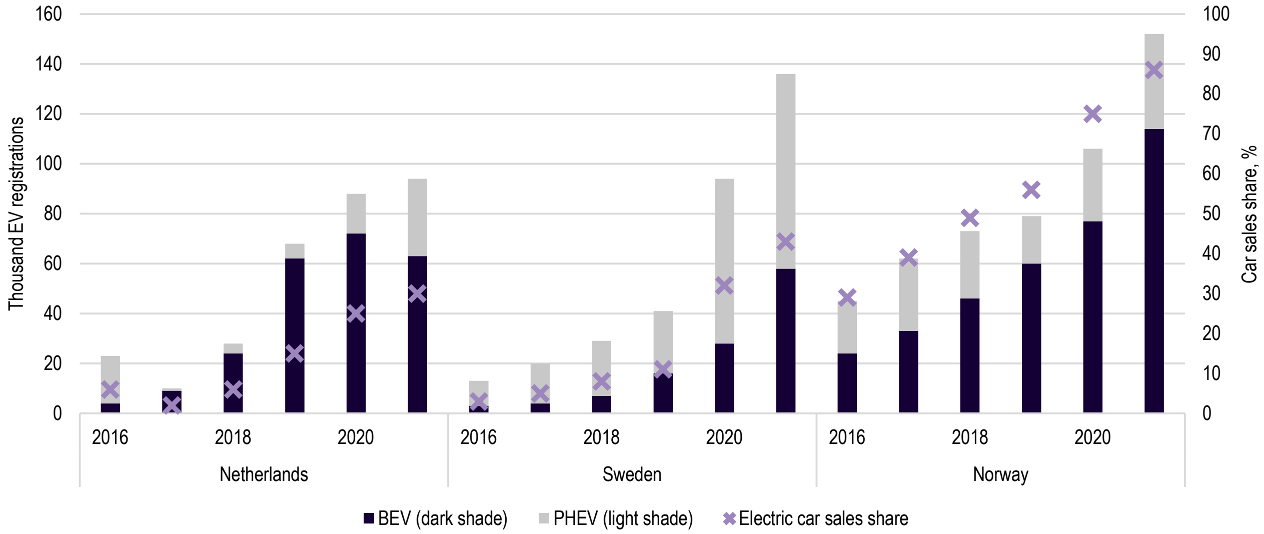
Figure B.3 Electric car registrations and sales share in the United Kingdom, France and Germany, 2016-2021



Source: (International Energy Agency, 2022a)

The EV adoption rates in the Netherlands, Sweden and Norway are illustrated in Figure B.4. By the end of 2021, EVs as a % of car sales was 30% in the Netherlands, 43% in Sweden and 86% in Norway. These countries have experienced the most significant growth in EV sales, albeit lower volumes compared to larger countries such as the United Kingdom, France and Germany. EVs are largely BEVs in the Netherlands and Norway and PHEVs in Sweden.

Figure B.4 Electric car registrations and sales share in the Netherlands, Sweden and Norway, 2016-2021



Source: (International Energy Agency, 2022a)

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