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The State of Play in Electric Vehicle Charging Services: Global Trends with Insight for Ireland

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The information and views set out in this report are those of the authors and do not necessarily reflect the official opinion of the DCCA or SFI.



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Executive Summary

Electrification of vehicle fleets, particularly in countries with increasing shares of renewable electricity supply, represents an important pathway toward low-carbon mobility. This report examines the role of electric vehicle (EV) charging infrastructure as a key enabler for EV uptake, and explores business models and policy approaches for promoting deployment. It then applies observed key principles to assess the Irish EV charging services market and identifies key recommendations for Irish policy.

Market & Policy Trends

The global market for charging services continues to mature, and companies employ a range of business models in order to provide charging products. Nonetheless, the economics of commercial public charging remain challenging due to the mismatched relationship between the importance of public charging access in dispelling range anxiety, and the clear preference of existing EV drivers for charging at home. Contemporary EV drivers tend to have high rates of home ownership and private parking access; a more mature EV market which includes drivers who have limited home charging will require a robust public refuelling network.

While home charging is most prevalent, workplace charging has shown to promote EV uptake, making drivers up to 20 times more likely to buy an electric car. Depending on fuel mix and hourly generation profiles, daytime charging at work can also promote consumption of renewable energy. Public charging, including fast charging, will be critical to enabling longer journeys, particularly when strategically aligned with drivers' behavioural patterns. Notably, concerns over the impact of fast-charging on battery life do not appear to be borne out by observed usage. Simulations and field studies demonstrate that drivers typically do not use fast-charging in a manner that impedes long-term battery performance.

Companies that provide public charging services and the business models they employ vary widely, from legacy oil or utility firms to dedicated charging network operators to auto manufacturers. This report identifies four key functions in the charging services value chain: manufacturing, development and installation, network operation, and sales and marketing. Policies that target only one function in this chain will be less effective if there are gaps in other areas of the value chain. For example, grants for individual charging stations target charging point owners, who want to offer charging on their property, but may not be equipped to manage installation of equipment. On the other hand, large auctions or tenders



may limit competition to a small number of established companies, though these companies may be best-suited to develop networks. Gaps in the charging value chain have also had damaging consequences for some charging companies and provide an instructive example of lessons learned, as in the case of equipment leasing or battery swapping stations. Holistic policy is needed to ensure such gaps are filled and do not become barriers to deployment of charging infrastructure.

Irrespective of business model, all market participants face high installation and grid connection fees which can make up a large share of the upfront cost of charging stations – 80-90% in some cases. Local electricity tariff structures constitute the main operating cost for EV charging stations. Tariff structures based on demand charges, for example, can comprise up to 50% of a typical commercial customer’s electricity bill and more than 90% for EV charging. Streamlined planning and network connection processes, as well as innovative electricity rate design, can help to alleviate both initial and ongoing charging costs.

While there is scope to reduce costs, and utilisation is forecast to increase with higher EV deployment (and would therefore boost operating revenues), EV infrastructure is often at pre-commercial stages and requires public funding and regulation to facilitate the roll out of a comprehensive, competitive charging market. In particular, strategic infrastructure such as fast chargers may be underutilised under current market conditions, and therefore merit public investment. Public funding should generally be raised through general taxation rather than from electricity ratepayers, however when utilities can show that all ratepayers benefit, it may be advantageous for utility-led development to be funded by ratepayers.

Local, regional, and national authorities can use fiscal measures and incentives to disburse public funds at and support private sector investment in charging stations. Such measures should be carefully designed to ensure efficient uptake and a long-term transition to sustainable markets. Widescale EV deployment will need to be accompanied by network upgrades and investment will be required to accommodate increased demand. Planning spatial and temporal demand of installed infrastructure through demand response mechanisms and collaboration between EV charger installers, network planners, and policymakers helps minimise network investment.



EV Charging in Ireland

Ireland was an early leader in establishing a national EV charging network, and boasts an impressive charger-to-EV ratio of one charger for every five electric vehicles. However, the future of Irish public charging is defined by two key, overlapping challenges: first, existing charging stations are aging and will become obsolete as technology improves. A previous regulatory determination regarding the ownership and operation of the infrastructure by semi-state energy group ESB and distribution system operator (DSO) ESB Networks had resulted in a lack of designated funding for network maintenance and expansion. Though the Irish regulator has recently approved an interim agreement for the ESB Group's continued operation of existing assets, future buildout could be undermined by the dearth of other established charging service providers. Second, the historical dominance of the legacy network operator in Irish charging station development and low EV market penetration means that the current market is underdeveloped, with few competitors active in Ireland. This is especially important given that public funding will likely move to a more competitive process, though some support measures are currently under review by government agencies.

The result of these compounding factors is that Ireland has not fostered a domestic market that is properly prepared or incented to supplement the legacy network. This outcome stands in stark contrast to the government's stated policy goals, and threatens to undermine Ireland's target of achieving 500,000 vehicles on the road by 2030. In order to promote address these issues and promote an effective, right-sized charging network that will enable future EV uptake, this paper outlines the following policy actions (more detail in Section 6: Policy Recommendations):

- DTTAS and DCCAE should leverage past investments in the national network by ensuring that Irish drivers are aware of the charging services available to them. This could involve standardized road signage or interface with GPS or mapping services to alert motorists to nearby charging stations. Such a campaign should reach beyond the community of drivers who already own an EV to raise awareness of charging availability among all drivers.
- Relevant bodies should conduct a detailed review of the cost drivers for EV deployment in Ireland, including both the upfront installation costs (i.e. planning and grid connection fees) and ongoing operating expenditures (i.e. retail electricity rates



and rate design). Future prices for fast-charging should be carefully considered in terms of balancing the need for prices that are low enough to ensure continued incentives for EV driving with sufficiently high prices to cover maintenance of the charger and discourage wasteful charging behaviour. Such a review should also identify specific policy and regulatory measures to mitigate these costs and promote charging development. Any lack of clarity around the responsibility of stakeholders such as local planning authorities and the network operator can lead to delays or cancelled projects, leading to costly uncertainty for market actors.

- Relevant departments/agencies should publicly communicate any planned incentives or support measures for future public charging development as soon as possible in order to attract new market entrants. Such schemes should be designed to take proper account of the underdeveloped Irish charging services market, and should be aligned with specific charging needs. These should include intercity fast-charging near motorways, standard on-street charging in dense neighbourhoods, and more home-charging access for multi-unit dwellings.
- Government, private actors, and the research community should collaborate to conduct more analysis around historical usage of the existing network, as well as evaluation of attitudes and behaviours for current and prospective EV drivers. This information can provide critical insight into planning for charging customers and siting future assets by eliciting drivers' needs and preferences for where and when they wish to charge. Robust analysis using driving profiles can ensure that public support for EV charging is spent efficiently and maximum impact.



1. Introduction & EV Market Overview

Decarbonisation of transportation is a critical component of governments' efforts to reduce greenhouse gas emissions in support of climate mitigation goals. Electrification of vehicle fleets, particularly in countries with increasing shares of renewable electricity supply, represents a key pathway toward low-carbon mobility. Electric mobility can also help to alleviate urban air quality hazards, which are increasingly driving state and local policy action (BNEF, 2018). Policy actions aligned with these environmental objectives, as well as rapidly dropping technology costs, have led governments and automakers to make considerable commitments to future electric vehicle (EV) deployment in recent years.¹ France and the UK, for example, have established specific conventional vehicle phase-out timelines (see Ewing, 2017 and Pickard and Campbell, 2017),² while major manufacturers such as Volkswagen, Volvo, Ford, BMW, Renault-Nissan, and more have increased EV production targets (see McGee, 2017a, McGee 2017b, and IEA, 2018a). Uptake has also increased in several markets: according to the International Energy Agency's (IEA) Global EV Outlook for 2018, more than 1 million electric vehicles were sold worldwide in 2017, with year-on-year growth of over 54%, and BNEF (2018) predicts 1.6 million EVs will be sold by the end of 2018. Based on existing commitments and announced new targets, the IEA forecasts continued growth in EV market share, with a global stock of 13 million EVs by 2020, and a total of nearly 130 million on the road by 2030 (IEA, 2018a).³

While predictions for future EV adoption point to ambitious growth, a successful, comprehensive transition will need to be supported by robust vehicle charging infrastructure. EV ownership requires that drivers have access to both public and home charging infrastructure so that they can feel confident in transitioning to EV ownership without fear that their driving behaviour will be curtailed due to refuelling limitations. This intuitive notion—that charging infrastructure is a key enabler of EV uptake—is supported by empirical studies that demonstrate the value of infrastructure in promoting EV adoption. Sierzchula et al (2014), for example, examine the explanatory power of factors such as model availability, financial incentives, and local auto production on increasing market penetration of EVs. They perform a regression analysis in 30 countries, and find that per capita public

¹ While some country targets are non-specific, the focus of deployment targets is generally on battery electric vehicles, but does not necessarily exclude plug-in hybrid EVs.

² The UK has included hybrid vehicles in its ban on internal combustion engine vehicles.

³ These projections are aligned with the IEA's central New Policies Scenario assumptions.



charging infrastructure is the best indicator of national EV market share. Sierzchula et al (2014) also note that public charging availability had a higher impact on EV uptake compared with financial incentives. They show that adding an extra charging station per 100,000 residents resulted in approximately double the impact on EV market share compared with providing an additional \$1000 in consumer financial incentives. Given that market conditions have progressed considerably since Sierzchula et al (2014), it is also worth noting that Hall and Lutsey (2017a) apply a similar methodology to the 50 largest metropolitan areas in the US, with similar results. They explore which factors are the highest indicators of EV market share. Hall and Lutsey (2017a) find a significant relationship demonstrating that increasing the number of charge points per capita is associated with increased electric vehicle adoption (these factors are also discussed, if not quantified, in Levinson and West, 2017; Berkeley et al, 2017; and Bonges and Lusk, 2016).

The market for EV charging is in its early stages, and considerable uncertainty remains as to how charging services should be provided, as well as which policies are best suited to support deployment. The regulatory frameworks, government incentives, commercial actors, and resulting business models in place to support EV charging vary widely both across and within jurisdictions. This briefing examines the existing market for EV charging, and in particular, discusses how EV charging infrastructure has been deployed, supported, and financed in a range of countries and regions. We aim to address the following broad questions:

- How and where do drivers prefer to drive, and what is the strategic role of different types and locations of charging services?
- What deployment models are currently in place for developing, operating, and owning charging infrastructure? What are the underlying cost and revenue drivers of EV charging stations?
- Which approaches have governments used to support deployment of charging infrastructure, and what role can policy and incentives play in this area?

The final section of the report examines the current charging network and market conditions in Ireland. This analysis should provide insight into the charging services market through a structured discussion of how charging infrastructure is used, how it is delivered, and which measures can promote its deployment. We focus primarily on discussion of the EU and US as markets to derive relevant and practicable examples of market-driven policy



interventions. Findings presented here are largely based on academic literature and policy reports, however, given the dynamic nature of the Electric Vehicle Supply Equipment (EVSE) market, these sources have been supplemented with news articles to ensure relevance and accuracy.

The review is structured according to the following topics: Section 2 details different modes and locations of public charging infrastructure, and how customers tend to use each. Section 3 provides an overview of business models EV charging, identifying the key functions in provision of charging infrastructure as well as the underlying economics of charging service providers. Section 4 outlines the role of government and policy in charging infrastructure, including public funding and incentives for deployment, regulatory policies with respect to network ownership, and managing potential grid impacts. Section 5 provides an overview of EVs and charging infrastructure in Ireland, particularly with respect to drivers' charging and range requirements. Section 6 concludes with summary observations and policy recommendations.

2. Charging Infrastructure Overview: Type, Location, Speed

In broad terms, it is clear that charging availability is a critical enabling factor for EV deployment. However, EV charging is available at different speeds, costs, and locations and these must be tailored to fit drivers' needs. Policymakers and market actors should consider the strategic roles of various charging modes, in particular, home charging, publicly-accessible charging, and charging at work in order to optimise charging deployment.

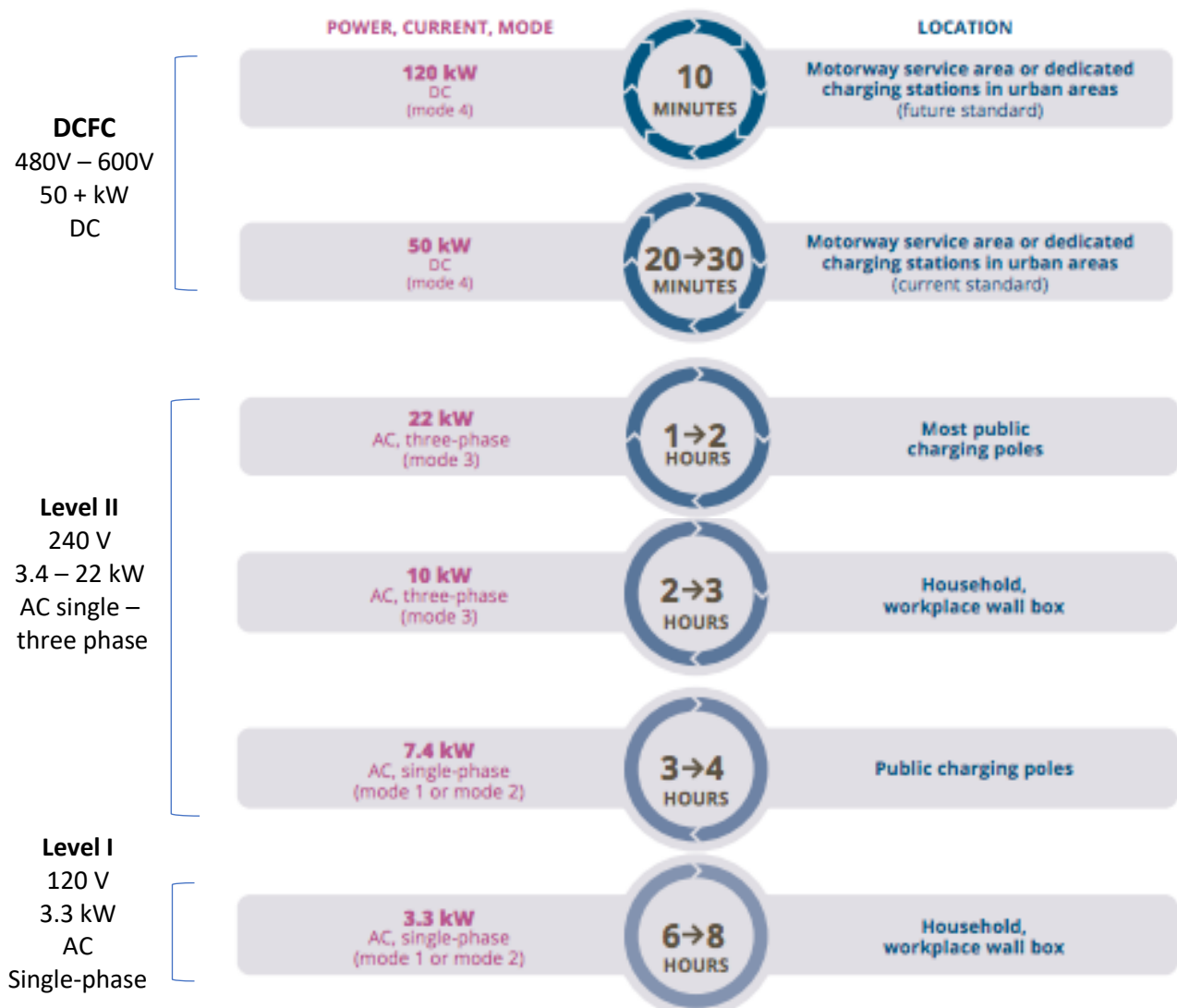
2.1 Charging Modes

Definition of charging levels is highly variable across academic, policy, and market literature and across country/region. We refer here to charging ratings using the terminology of Level 1 (slow charging), Level 2 (slow to fast charging using AC), or Direct Current Fast Charging (DCFC). The alternative rating system refers to charging mode 1 (slow), mode 2 (slow to semi-fast using AC), mode 3 (semi-fast to fast using AC) and mode 4 (DC fast charging).⁴ Figure 1 demonstrates the high-level alignment between Levels I, II, and DCFC and the four charging modes, which are more commonly used in Europe.

⁴ Charging ratings are set out by standard-setting bodies: in North America, the Society of Automotive Engineers (SAE) has defined charging levels for both AC and DC charging, while in Europe, the industry observes the four charging modes defined by the International Electrotechnical Commission (IEC). However, common definitions of these standards vary in policy and academic literature, and we therefore use common terminology rather than strict industry standards.



Figure 1. Charging Rating Comparison for 100 km of Driving Range*



Sources: EEA, 2016; Fitzgerald & Nelder, 2017; Falvo et al (2014)

*Charging times indicate the time required to achieve 100 km of driving distance

Charging capacity that is rated 3.7 kW or lower on a single-phase AC supply is classified as Level 1 charging. Level 1 charging may require 3 – 8 hours of charge time to achieve 100 km (~62 miles) of driving range, and for residential charging, can be accomplished simply by plugging the vehicle into a standard household electrical outlet. As such, Level 1 home charging can have effectively zero installation cost (except for an extension cord, where required for access), provided that the circuit breaker to which the EV would be connected can accommodate the additional load. Level 2 charging, generally up to 22 kW capacity with a single or three-phase AC power supply, can allow for 100 km of charge time in 1-3 hours.



Level 2 charging can be installed at home using specific equipment, and is often the type of charging provided at publicly-accessible charging locations. Public charging may also be 50 kW or higher DCFC, which allows for refueling to 100 km of range in 20 – 30 minutes.

2.2 Home Charging

Charging at home tends to be the most common approach for EV refuelling. 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 (IEA, 2018b). EV drivers therefore appear to rely heavily on private charging under current market conditions. In Norway, where the electric car market is most advanced in terms of market share, there is one public charger for every 19 EVs on the road (IEA, 2018a).). Behavioural studies and aggregate data regarding charging location indicate the dominance of home charging over other locations; a few examples are provided in Table 1, below, and more detailed data are available for Norway (see Figenbaum and Kolbenstvedt, 2016) and Sweden (see Granström et al., 2017).

Table 1. Distribution of charging by location: examples in literature

Jurisdiction	Home	Public	Workplace
US (Hardman et al, 2017)	75-85%	~5%	15-25%
Europe (McKinsey, 2013)	80%	5%	15%
UK (Neaimeh et al, 2017)*	72.5%	18.1% (~12% fast, 6% Level II)	6.7%

*2.8% of charging occurred at locations classified as “other.”

2.3 Public Charging

Home charging has been a sensible and efficient solution particularly for early EV adopters in the absence of widespread public charging installations. However, the prevalence of home charging under current market conditions should not lead policymakers to conclude that public charging infrastructure is not important for uptake. Indeed, during early market stages, the importance of public and workplace charging may be understated by considering only the proportion of charging events that occur in each type of location. Rather, 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. Figenbaum and Kolbenstvedt (2016), who evaluate charging behaviours based on survey data from Norway, found that EV owners charged most frequently at home or at work using slow chargers. However, the



surveys also showed that 60% of battery EV owners used public Level II charging at least monthly or yearly, and 10% used them at least once per week. While drivers in the study used public fast charging less frequently, 28% accessed fast charging at least monthly. Moreover, a clear majority of survey respondents lived in detached housing and had access to private charging capability on their own property. As more drivers without access to dedicated private parking (e.g. multi-unit apartment buildings) purchase EVs, public charging will become more important for this category of users.

Low utilisation of public charging compared with other charging locations (i.e. home and workplace) is often discussed as a paradoxical challenge. 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. Kley et al (2011) and Schroeder and Traber (2012) note that while private home charging at low power is sufficient to cover more than 50% of driving patterns, EV users “need a public charging infrastructure to be built in order to overcome range anxiety and feel comfortable when they drive outside their regular trip profile.” Neubauer and Wood (2014) conducted analysis using observed driver profiles to determine whether electric vehicles had sufficient range and charging access to support drivers’ desired journeys, using the metric vehicle utility, or miles driven vs miles desired. They find that increasing home charging power beyond Level 1 charging (at approximately 1.5 kW DC) had little impact on vehicle utility, but that access to Level 2 public charging infrastructure (at 6.5 kW DC power) dramatically increased total distance travelled, and brought many drivers to near 100% vehicle utility. At the same time, low utilisation rates make charging infrastructure difficult to operate profitably. The result is that governments wishing to support public charging network development must consider methods for facilitating efficient, strategic investments that provide necessary infrastructure, conscious of the challenge in achieving profitability. Policymakers should also consider that the historically 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. Empirical studies show that utilisation of different types of charging infrastructure changes measurably when EV uptake increases (see, e.g. Helmus et al, 2018). As such, continued analysis of driver profiles and behaviours should help to inform charging investments.



2.4 Workplace Charging

Charging at work can provide a critical opportunity for EV drivers who may not have easy access to home charging. An exhaustive survey project in the US found that a cohort of 30% of EV drivers charged only at work on most days (INL, 2015). 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. Hall and Lutsey (2017a) provide a helpful overview of workplace charging initiatives, which include up to 50% funding for employers offering free charging from the province of Quebec, 40% of costs per charge point for workplace charging or public charging on-site for French employers, and rebates up to £300 for UK employers installing workplace or fleet charging. Workplace charging can also be helpful in promoting electric vehicle uptake: Garas et al (2016) note the value of peer-to-peer communication as a driver of technology diffusion in general, and note that charging infrastructure located in social settings such as the workplace could help to facilitate EV adoption. Oleksak (2014) cites survey data from the U.S. Department of Energy's Workplace Charging Challenge, which indicates employees of companies that provide charging infrastructure are 20 times more likely to purchase an electric vehicle.

An added consideration for workplace charging is its potential to contribute to increased renewable energy utilisation, particularly in jurisdictions that experience an oversupply of clean power generation during daytime hours. One example is California, where large-scale distributed solar generation has led to large dips in daytime power demand, followed by sharp ramping to meet evening peak load. A 2018 study found that in a high-EV deployment scenario for California, controllable EV charging could avoid approximately 2 GW of renewable curtailment (Coignard et al., 2018). Similarly, Fang et al. (2017) use both average marginal pricing and marginal carbon and pollutant emissions rates to calculate the social cost of charging depending on the time incidence of charging events. This measure reflects the fact that if night time power demand is met by high shares of fossil-fuel generation, then EV charging during the night when electricity is cheap incurs higher social damage via carbon, nitrogen oxide (NO_x), and sulphur oxide (SO_x) emissions than lower-emissions daytime charging. Fang et al. (2017) examine this situation using Sacramento, California as a case study, and include carbon pricing to determine the most social optimal charging time. They find that when the social cost of charging is high (i.e. when using high estimates of the



social damage from emissions), EV charging from midnight to 7 AM becomes the most costly time to charge. Fang et al. (2017) therefore note that daytime workplace charging can promote cleaner electricity consumption, and that such behaviour could be encouraged if electricity pricing reflected the social cost of carbon.

2.5 Role of Fast-Charging

The location of chargers, whether at home, in public, or at work, is only one dimension for considering charging utility. Charging time and relationship to existing driver preferences and behaviours are also critical to maximizing utilisation and properly aligning charging networks with driver needs. 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 (Burnham et al (2017)). This will be true especially as technology moves beyond current fast charging equipment, which allows for charging between 50 and 120 kW, to charging capacity of 400 kW or higher, allowing for meaningful refuelling within 10-25 minutes (Wood et al, 2017). Here again, however, the economics of fast-charging provision can be challenging, as fast-charging stations are of high importance to users, but may experience low-utilisation rates, leading to poor (i.e. negative) profitability outcomes (Burnham et al, 2017). Hundt et al (2015) cite several barriers to public charging adoption in general, such as utilization uncertainty, hardware costs, installation complexity and cost, and difficulty in assessing revenue models, all of which are exacerbated by the relatively higher upfront cost of fast-charging stations (Section 3 of this report discusses these factors in more detail). Regardless of its initial costs, fast charging will certainly play a critical role in the continued deployment of EVs.

One concern regarding the use of fast charging is whether battery degradation may occur due to overcycling. Lithium-ion batteries generally lose capacity as the battery is



repeatedly charged and discharged over time, depending on factors like state of charge and temperature (Hoke et al, 2011). Availability of fast charging has therefore given rise to concerns that quicker charging times may accelerate the rate at which batteries lose driving range. Indeed, EV manufacturer Tesla has acknowledged that its battery management system may restrict the rate of EV charging under a range of conditions, including those which reflect high use of fast charging, in order to preserve vehicle range (Loveday, 2017). However, this effect does not appear to be typical for the general EV driving population, as behavioural literature shows that EV owners do not utilise fast charging in a manner that inhibits battery performance. A 2015 NREL study uses simulation to examine the impact of fast-charging on EV battery lifetime and temperature. The analysis found that drivers typically received 7.6% of energy from fast charging, up to a maximum of 41.5%. Access to fast-charging improved utility for most drivers with an average increase of 800 additional vehicle miles travelled, and a decrease in trips not taken due to lack of charging access of eight per year. Because fast chargers are used infrequently, the impact on battery capacity loss was negligible (Neubauer et al, 2015).

Idaho National Laboratory also conducted a small but notable field test exploring the effect of fast-charging on battery life issue comparing two 2012 Nissan Leafs charged twice per day with Level 2 charging and two charged twice per day with 50 kW fast-charger. The study examined battery capacity and temperature at 10, 20, 30, 40, and 50 thousand miles driven. Impacts on capacity after 10,000 miles driven showed no significant difference; after 50,000 miles driven, the Level 2 charged Leafs lost just under 25% of battery capacity from their original baseline, while the DC-fast charged Leafs lost approximately 27% of capacity (Shirk and Wishart, 2015). Additional insight into the effect of fast charging on battery lifetime given real-life driving behaviours could be gleaned from jurisdictions like China, where fast charging is highly prevalent in urban centres.



Section 2 Key Points

- As expected, empirical **evidence links public charging availability with increased EV uptake**. While the bulk of charging events occur at home, many EV drivers report at least occasional use of public infrastructure.
- Current EV drivers tend to have high rates of home ownership and private parking access; a more mature EV market which includes **drivers who have limited home charging will require a robust public refuelling network**.
- **Expanding public charging networks is expected to increase vehicle range** more substantially than boosting home charging speeds, which researchers estimate would have little effect on making EVs more practical for typical drivers.
- **Workplace charging promotes EV uptake**, making drivers up to 20 times more likely to buy an electric car. Depending on fuel mix and hourly generation profiles, daytime **charging at work can also promote consumption of renewable energy**.
- Concerns over the impact of fast-charging on battery life do not appear to be borne out by observed usage. Typically, **drivers do not use fast-charging in a manner that is harmful to long-term battery performance**.

3. The Charging Infrastructure Market

Charging infrastructure has historically been developed, owned, and operated by a range of different market actors, including public or semi-state enterprises, as well as private companies. Network operators typically include large incumbents like utilities and automakers, whose interest in EV charging is driven by their legacy assets and expertise, as well as new entrant charging companies with a focus on capturing revenues directly from charging customers or site hosts. Section 3 examines the value chain for developing and operating EV charging infrastructure, including the functions that the market provides and how different companies participate. We generally consider only approaches employed by actors who have developed or supplied publicly-accessible charging networks, rather than those who simply provide or install hardware on an ad-hoc basis. Section 3 also considers the underlying economic factors, including installation costs and payment schemes, that shape the market opportunity for charging provision.



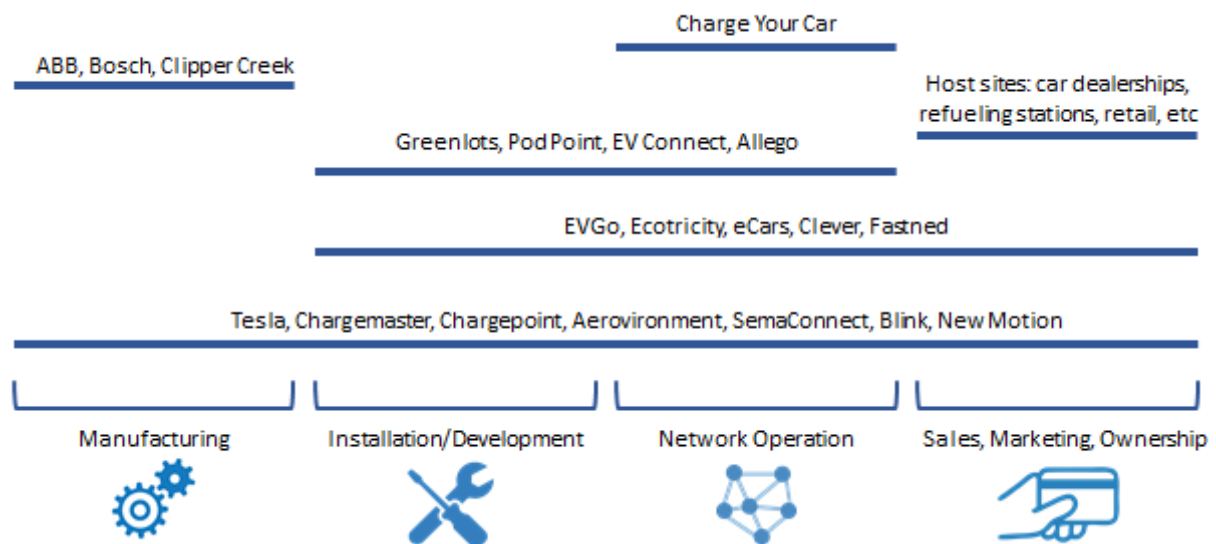
3.1 Key Functions

Several studies provide broad discussion of the business model for provision of charging infrastructure (see Madina et al, 2016 and Bohnsack et al, 2014), however no clear model has yet emerged for delivering this service, and few studies evaluate existing models in detail. For the purpose of clarity in discussing charging companies and their associated networks, we define here four primary functions in the EVSE value chain, drawing on EY (2011), Hall et al (2017), and Nigro and Frades (2015):

1. Manufacturing: the original equipment manufacturer who produces charging equipment such as mounted home chargers and standalone public charging stations.
2. Installation/Development: arranges and executes installation and sources financing
3. Network Operation: manages and provides maintenance and customer-facing services for the physical network and payment platform
4. Sales & Marketing: entity that hosts infrastructure, sets payment structure and prices, and/or collects or shares revenues from resale of electricity

A schematic demonstrating the range of functions across which a sample of charging companies engage is shown in Figure 2, below.

Figure 2. Companies' Activity in Charging Service Functions*



Source: own

*The companies noted are a representative sample and are not intended as a comprehensive market listing; companies are grouped here by main offerings as indicated through marketing materials and media reports



Companies may be organized around only one, or up to all four, of the key functions described above.⁵ In terms of single-function market participants, some electronics manufacturers operate in the EV charging market solely in the manufacturing function by producing and supplying hardware (i.e. charging stations). Others, like UK-based Charge Your Car, provide only a platform for network operation, but do not procure, develop, or directly market charging equipment or services to customers.

3.1.1 Charging Company Business Models

Among companies who are active across multiple market functions, the question of asset ownership is a key consideration in evaluating business models and considering prospective policy interactions. Some companies, like ChargePoint and SemaConnect, focus on installing and operating a network of charging stations, but do not retain ownership of the network. Garas et al (2016) label this approach the “network-operator model,” in which the company develops and maintains a network, but sells the actual hardware to host sites, which then manage billing and access to charging stations. This model allows host sites to set their own payment structures and fees, and to retain revenues gained, less fees paid to the operator. In such cases, the network operator shifts a large portion of business risk to host entities, who are exposed to both the upfront cost of the EVSE, as well as any fluctuations in future revenues. Depending upon the terms of the agreement between the network operator and host site, the host may also be locked into an agreement by which only the network operator may provide management services, restricting the ability of host entities to avail of more competitive rates from other operators.

Alternatively, some companies, like EVGo and Blink Network choose to develop, operate, and own their charging networks. Garas et al (2016) call this approach the “owner-operator model,” representing a vertically integrated set of functions in which the charging company supplies and owns hardware, manages billing and access, and collects revenues from the infrastructure. The owner-operator model is similar to a traditional mobile telecommunications company that invests in infrastructure and charges clients for the services provided by the infrastructure. In such cases, the network operator may partner with a private host to site charging stations, but retains control over pricing, as well as exposure to revenue risk. While downside risk due to low utilisation could present a challenge to owner-

⁵ Companies that provide direct end-customer services are often referred to as Electromobility Service Providers (EMSPs), however given the variability in the other functions EMSPs may perform, this report does not apply the general “EMSP” terminology for charging companies.



operators, they may also be better positioned to capitalise on future increases in charging demand or on favourable regulatory shifts compared with network operators described above.

Beyond the owner-operator model are still more integrated approaches, as in the case of companies like Tesla and Aerovironment, which are active across all four market functions, including manufacturing equipment, to installing and managing networks, to collecting revenues, though not necessarily in an integrated format. Under these arrangements, companies must recover their costs for charging infrastructure through user fees. Alternatively, Tesla offers charging for free by including the cost of developing a charging network in the upfront cost of its vehicles. Large equipment manufacturers that produce, own, and operate charging equipment may also find that managing a fully integrated EV value chain does not function well alongside traditional operations. Aerovironment, for example, sold off its electric vehicle charging business to German automobile supplier Webasto in June 2018 so that it could continue to focus on its core operations in unmanned aircraft and missile systems.

3.1.2 Types of Charging Point Host Sites

Charging points can be hosted by a range of different commercial or public actors who wish to provide charging access as an amenity on their property, as a benefit to their employees, or both. An early survey of charging locations in New York state found that retail and city centre locations made up a combined 24% of publicly-accessible charging stations, and sites such as commercial offices, universities, hospitals, and transport centres all had less than 7% each. The survey found that a plurality of charging points (41%) were located either at car dealerships or at petrol stations (WXY et al, 2012). Automakers indeed have an incentive to promote access to charging infrastructure, given that charging availability is a key factor in EV uptake (Karali, 2017). Car manufacturers Nissan and Tesla offer free charging access to customers who drive their vehicles (von Kaenel, 2016). Nissan provides US Leaf buyers or lessees an option to participate in a two-year free-charging programme, by which the driver receives a membership card valid for a range of public charging network providers; many Nissan dealerships also host charging infrastructure on site (Nissan, 2017). While Nissan has taken a proactive approach to facilitating infrastructure buildout, Tesla is instead developing its own proprietary fast-charging network for exclusive use of Tesla drivers, with locations in public-access areas that are near major highways in relevant markets (Bonges and Lusk, 2016). In addition to its Supercharger network, Tesla also



operates a Destination Charging programme, through which commercial entities may host Tesla charging facilities, which Tesla installs for free under certain conditions (Tesla, 2017). This approach is consistent with the model of vertical integration across all functions of the EVSE value chain. The proprietary characteristics of Tesla's network also raise challenges around market fragmentation and interoperability, limiting the degree to which Tesla infrastructure may contribute to a well-developed market for EV charging.

3.1.3 Industry Lessons Learned

The EV charging market holds some examples of approaches that have not been successful, which may be instructive in considering future models worthy of support. Garas et al (2016) cite a leasing model that was once employed by the Blink network, under which host sites entered into agreements to lease charging equipment from a supplier. The arrangement proved to be unpopular with prospective host entities because it required them to execute the installation and development function with respect to preparing sites for construction of charging facilities, which they were generally not equipped to do. Planning, zoning, and grid connection, for example, can be significant hurdles (and therefore represent considerable risks) to successful EVSE installation. Policymakers should note that future approaches which rely upon hosts to execute functions like installation and development, as well as sales and marketing, may well be affected by the same challenges. That is, if host entities lack expertise and staff resourcing for infrastructure rollout, installations may be delayed or stalled entirely. From a regulatory perspective, clear, accessible protocols for siting and connecting prospective charging assets could make this model more attractive to prospective host sites. Ease of installation, combined with the lack of upfront capital outlay required of hosts under the leasing model, could ultimately encourage provision of charging services from small- and medium-sized businesses.

Another unsuccessful approach to EV charging infrastructure is the well-known Better Place, an Israeli firm that shuttered in 2013. The Better Place concept involved a model by which the company would retain ownership of the battery vehicle, with customers paying a mileage-based fee, and simultaneous development of a battery swapping and recharging network. Noel and Sovacool (2016) examine the primary factors that led to Better Place's ultimate bankruptcy. They observe that a confluence of social, technical, political, and management considerations contributed to the failure of Better Place, but ultimately conclude that uptake of EVs in general was too poor in Better Place markets Israel and Denmark to



support the business. Noel and Sovacool (2016) further suggest that significant barriers to battery swapping remain in the current market, particularly with respect to standardisation across manufacturers, as well as competitiveness with increasingly faster charging technology. Additional study of past battery-swapping business models and consideration of current market conditions would be critical to assessing the suitability of reattempting a similar concept.

3.2 Investment in Charging

Comprehensive data for charging companies and the overall market segment can be difficult to obtain and analyse, as many existing firms are privately held. The market for European EVSE is forecast to grow at a compound annual rate of 99% from 2013 to 2020, with over three million units worth up to €10.6 billion installed by the end of the period (Brusaglino et al, 2015). A recent report from Bloomberg New Energy Finance (BNEF) notes considerable consolidation among EV charging companies, as large energy firms acquire or invest heavily in infrastructure players. This includes Royal Dutch Shell's purchase of Dutch charging company NewMotion, with its 20,000 charging points, as well as Statoil's investment in Chargepoint, Engie's in EVBox, and Enel's in eMotorWerks. Various legacy companies have differing motivations for moving into the electric mobility sector: oil companies are motivated by an interest in protecting the prospects for retail petrol stations in an electrified future whilst utilities are acquiring charging assets in an effort to reduce customer turnover (BNEF, 2017). Given their institutional experience in building and maintaining electricity distribution networks, utilities are particularly well-suited for some aspects of the EV charging market. This has, in many cases, translated to strong involvement of utilities (suppliers and distribution network operators) and large energy companies in EV investment. Power companies are responsible for 35% of all public charging stations in Germany (IEA, 2017), whilst in California, the electricity regulator recently approved \$738 million worth of investment in transport electrification projects by three major utilities. Other US state regulators have approved or are considering similar utility proposals (CPUC, 2018) (see Section 4 for additional discussion of utility ownership of EV charging infrastructure).⁶

In addition to utilities, large automakers are also playing an important role in building out charging infrastructure, if not through direct investment in companies, then through large

⁶ This report includes subsequent discussion of the regulatory environment for utilities operating charging networks, however, comprehensive market data as to total utility sector investment in EV infrastructure is not readily accessible.



joint partnerships. For example, BMW, Daimler, Ford, and Volkswagen are members of the Ionity consortium, which plans to develop an integrated European fast-charging network IEA (2018a). The joint initiative was officially announced in November 2017, and aims to install a network of 400 EV fast-charging stations across Europe, each with an average of six chargers per station (Estrada, 2017). Other similar consortia include Ultra-E, of which manufacturers Audi, BMW, and Renault are among the core partners, and the NEXT-E charging network, which involves participation from manufacturers Nissan and BMW, as well as Hungarian oil and gas company MOL and Germany utility E.ON. As automakers continue to bolster their electric vehicle offerings, investments in charging infrastructure buildout would seem to be strategic, given the role that insufficient charging can play in deterring customers from EV uptake.

3.3 Economics of charging infrastructure

The underlying cost drivers for electric vehicle charging involve a combination of upfront installation costs and ongoing operating costs. Evaluating these components can provide some indication of which subsegments of the EVSE value chain have the greatest potential to bring down overall costs.

3.3.1 Upfront Cost Drivers

Upfront costs for EVSE include hardware (i.e. the actual charging station itself) as well as permitting, labour, and installation, which may involve considerable public works efforts. Depending on the site and the charging capacity of the planned infrastructure, upfront costs can also include connection and upgrades to the local distribution network. Non-hardware installation costs can also arise in the process of securing charging station access sites, such as parking spaces on public roads or in private parking areas. Smith and Castellano (2015) discuss these factors in detail. Table 2, below, indicates estimated charging costs for both hardware and installation (inclusive of network upgrades) from a sample of available literature in both Europe and the US.



Table 2. Estimated EVSE Unit and Installation Costs

Source	Country	Level I		Level II		DCFC	
		Hardware	Installation	Hardware	Installation	Hardware	Installation
Fitzgerald & Nelder, 2017	USA,	~ \$0		\$500 - \$6,000*		\$50,000 - \$300,000	
Hall & Lutsey, 2017	Multiple	N/A		\$5,000 - \$15,000		\$40,000 - \$100,000	
Emobility Sweden (2017) via IEA (2018b)	Sweden	\$600 - \$1,400		\$1,100 - \$1,200	\$600 - \$1,200	\$18,000 - \$29,000	\$5,800 - \$36,000
Energy Saving Trust, 2017	UK	£500 - £1,000	N/A	£2,000 - £19,000	N/A	£20,000 – £40,000	N/A
Smith & Castellano, 2015	USA	\$300 - \$1,500**	\$0 - \$3,000^	\$400 - \$6,500	\$600 - \$12,700	\$10,000 - \$40,000	\$4,000 - \$51,000
Brusaglino et al, 2015	Europe	€300 - €500	€100 - €200	€2,500 - €3,700	€4,100 - €5,100	€20,000 - €30,000	€10,000 - €20,000
National Electromobility Platform (NPE), 2015	Germany	N/A		€1,200	€1,000 - €6,000	€25,000	€10,000 +

* Ranges from off-the-shelf home charger with no installation cost to public charging with electrical work required

** Not including home charging where no hardware is required

^ Costs are incurred depending on whether a pedestal or dedicated circuit must be installed

As indicated, the cost of installing Level 1 charging for public access varies considerably, from installation of a new outlet in a commercial setting at \$200-\$500 to installation of a pedestal-mounted charging port at \$1,000 - \$3,000. Both Level 2 and DCFC installations may require considerable public works and electrical upgrades, including strengthening local



distribution networks, and can therefore require very high capital investments. Of course, specific site type and location, local regulations, and grid conditions can cause costs to vary widely, and economies of scale may reduce per-unit installation costs when installing multiple chargers at a single station. Nonetheless, high installation costs can make it difficult for a charging station to be profitable. Nigro and Frades (2015) calculate likely payback under current cost assumptions, and find that ownership of EV charging assets is not profitable under the current model, with a single DC fast charger resulting in developer losses of \$44,000 over a 10-year period, and Level 2 charger with five connections results in losses of more than \$26,000 over 10 years.

While these analyses provide some insight into charging station economics under a given set of assumptions, it is worth noting that higher utilization rates will, of course, improve capital recovery timelines. In the meantime, the cost ranges presented in Table 2 indicate that installation and grid connection can comprise upwards of 80% of upfront EVSE costs. Policymakers could usefully consider approaches to streamlining planning and permitting processes, as well as mitigating network costs (e.g. by combining installation with other electrical works or identifying optimal locations for adding network assets).

3.3.2 Operating Cost Drivers

Once installed, EV charging stations incur ongoing costs which include operations and maintenance services, as well as the purchase of electricity from a supplier or utility. The price of electricity and the structure of local electricity tariffs is a critical cost-driver for EV charging business models (Fitzgerland and Nelder, 2017b).⁷ This is true for both residential and commercial installations in terms of the impact of electricity price structures on providing EV refuelling services.

The different residential retail rate structures can drive considerable variation in the costs of home charging. For example, a study commissioned by the New York State Energy Research and Development Authority (NYSERDA) in 2015 estimated that households charging electric vehicles at home could save up to \$400 using a time-of-use rate, compared with the standard rate, depending on overall usage patterns (MJ Bradley Associates, 2015).

For commercial charging station hosts, such as malls, supermarkets, and petrol stations, a tariff structure based on demand charges can limit the economic viability of

⁷ Electricity rates can also be structured to incentivize charging during off-peak electricity demand periods in order to manage grid operation impacts, as discussed in Section 4.3.



charging. Demand charges are calculated on the basis of the customer's maximum demand during a given time period, e.g. the highest 15- or 30-minute increment of a year. For typical commercial consumers, these fees can make up a considerable portion of monthly electricity bills – sometimes 50% or more (Neubauer and Simpson, 2015). Given the high power rating of fast chargers, demand charges for EV charging companies and individual hosts offering 50 kW+ charging capacity can be particularly acute.

Some empirical studies attempt to quantify the impact of demand chargers compared simple flat-rate tariffs. In 2014, the Electric Power Research Institute (EPRI) calculated the impact of demand charges on an EV fast-charger under two sample rates (summer and winter) from a California utility: one rate charged on an energy-only basis (i.e. under a volumetric, per-kWh rate) and one which added a demand charge to the energy-only bill.⁸ The analysis indicated that under the energy only rates, the charging station was able to realise an average cost of less than \$5 per charge with only 25 charges. The same average cost under the energy-plus-demand charge rate required 150 charges per month.⁹

The Rocky Mountain Institute (RMI) (Fitzgerald and Nelder, 2017b) explored this topic in a more applied format using observed data from California charging stations operated by provider EVGo. The analysis applied both existing and proposed tariff structures to charging station data to estimate monthly utility bills. Comparing outcomes in different service areas throughout the state, the study shows that existing implementation of demand charges is highly variable, comprising between 0 and 94% of utility bills, which ranged from \$150 to \$3,313 per month. Under proposed rate structures for public charging customers, charging hosts in the Southern California Edison (SCE) service area, for whom demand charges currently constitute 70 – 81% of total bills, could save from \$1,125 to \$1,220 per month. Those savings translate to 58% - 73% reduction in total bills. The proposed rates implement a form of critical peak pricing in lieu of demand charges to ensure that utilities recover generation and network capacity costs.¹⁰ The same report also notes the potential to

⁸ The hypothetical charger in the analysis was rated at 50 kW and provided 20 kWh per charge

⁹ Results given here are for winter electricity rates; EPRI (2014) present seasonal analysis but no detail on seasonal price differentiation. However, as California is a summer-peaking electricity market, seasonal electricity rates tend to be lower in winter and higher in summer.

¹⁰ Critical peak pricing imposes a higher price for electricity used during peak hours throughout the year based on actual system outcomes, rather than a predefined time-of-use rate. In the case of proposed rates for SCE, a dynamic adder is charged to customers on a \$/kWh basis for the top 150 hours of system peak and top 200 hours of circuit peak,



use recycled electric vehicle batteries to mitigate peak demand from charging stations, allowing for further reductions in both demand charges and network costs.

At present, the costs of charging infrastructure remain quite high, both in terms of the upfront installed cost, and potentially on an ongoing basis, depending on retail tariff structures. Though not discussed in detail here, utilization rates can often be quite low: Helmus et al (2018), reporting on Dutch public charging infrastructure, indicate 4-5 unique users per week charging for 40 – 60 hours on average in recent years, while CGC (2015) report that utilization in New York state ranged from 3-4% in 2014. Low utilization rates, in turn, lead to poor cost recovery potential for many charging stations on an individual basis (portfolios of stations that include a mix of high- and low-utilisation chargers can help to ensure total costs are met). (. As such, charging payments may be insufficient to support a robust public-access charging network. In the near term, this means that public funding and support will continue to play an important role in encouraging charging deployment. In the future, network owners and/or operators may also be able to incorporate additional revenue streams through aggregation of network assets to provide demand response, or by offering flexibility or network services through vehicle-to-grid (V2G) arrangements (Hall et al, 2017).

3.3.3 Payment and fee structures

As identified 3.3.1 and 3.3.2, charging service providers must cover the relatively high cost of hardware installation, particularly in the case of fast-charging facilities, as well as ongoing costs associated with maintenance and purchase of electricity for resale. Existing market participants commonly employ payment arrangements that are comprised of one or more fee types (Brusaglino et al, 2015). These typically include a fixed fee, such as an annual or monthly payment, a volumetric fee, under which customers pay for each kWh consumed, a time-based fee, under which customers pay for the minutes or hours spent charging, and/or a per session fee, under which customers pay a flat fee to connect to a charger. Companies like US-based Chargepoint, which manages networked charging stations owned by individual charging station hosts, do not set pricing at a corporate level; pricing is established in these cases by the charging station owner. Others firms, like Irish utility ESB, provide charging at no cost, particularly when infrastructure has been funded through public support. In order to capture a sample of typical trends in payment structures and revenue recovery, we provide in Table 3 an informal survey of publicly available pricing information of 32 payment plans on offer from 20 charging companies operating in the US and Europe.



Table 3. Representative List of Charging Companies and Fee Structures

Company	Country	Fee Structure
Tesla	Several	Free - charging stations are free to use for Tesla drivers
Aerovironment	US	Monthly Fee - \$19.99/month Pay by Session - \$4 (L2) - \$7.50 (DC)/session
Blink	US	Pay by Session - \$6.99 /session (DC)* Volumetric Fee - \$0.39 - \$0.49 (L2)**; \$0.49 - \$0.59/kWh (DC)* Pay by Minute - \$0.04/min (L2)*
Chargepoint	Several	Pricing rate and structure set by station owner
EVGo	US	Monthly Fee + Pay by Minute - \$19.95 monthly fee + \$0.20/min (DC) Monthly Fee + Pay by Hour - \$19.95 monthly fee + \$1.50/hour (L2) Pay by Session + Pay by Minute - \$4.95/session + \$0.20/min (DC) Pay by Hour - \$1.50/hr (L2)
SemaConnect	US	Pricing rate and structure set by station owner
Chargemaster	UK	Monthly Fee + Volumetric Fee - £7.85/month, £0.09/kWh (LE)
Ecotricity	UK	Volumetric Fee - £0.30/kWh
Charge Your Car	UK	Pricing rate and structure set by station owner
Autolib[^]	FR	Pay by Hour - €1/hour (first hour); €3/hr (after first hour)
Clever	DK	Volumetric Fee - 20 kWh for 175 DKK (~€23.50); 40 kWh for 350 DKK (€47.00); 100 kWh for 600 DKK (€80.57)
Elmo	EE	Monthly Fee + Pay by Session - €10/month + €2.50/charge Pay by Session - €1.50 (<10 minutes), €3 (<20 minutes), €4.50 (>20 minutes) (not differentiated for DC)
Enel e-go	IT	Pay by Minute - €0.25/minute
RWE ePower	DE	Monthly Fee + Volumetric Fee - €4.95/month + €0.30/kWh
Fastned	NL	Volumetric Fee - €0.59/kWh Monthly Fee + Volumetric Fee - €9.99/month + €0.35/kWh Monthly Fee + Volumetric Fee - €29.99/month + €0.19/kWh
Blue Corner	BE	Volumetric Fee - €0.36/kWh AC; €0.65/kWh DC Annual Fee + Volumetric Fee - €59/year; €0.31/kWh AC; €0.65/kWh DC Annual Fee + Volumetric Fee - €169/year; €0.29/kWh AC; €0.52/kWh DC Pay by Minute - €0.01/min AC; €0.25/min DC
ESB eCars	IE	Free - charging stations are free for all to use
New Motion	EU	Set By Owner
Pod Point	UK	Set By Owner
E.ON	DE	Monthly Fee + Pay by Session - €4.95/month + €5.95/charge or €8.95/fast charge

Source: internal analysis

* Fees listed are for network members; higher rates apply for non-members

** Varies by US state; range excludes Hawaii where rates are \$0.69/kWh for members, \$0.079/kWh for non members

[^] In 2018, Parisian authorities discontinued Autolib due to problems with its contracted operator.

Charges listed do not include small one-time set up fees or early termination fees

Of the 32 fee structures available, nearly 40% (12 companies) included a fixed fee. Approximately one third of plans included some form of a volumetric charge, one quarter



included a time-based charge, and approximately 15% (5 companies) included a flat fee to connect. The remaining companies used some other form of fee structure, including free charging and charging rates set by individual station owners.

The diversity in payment schemes indicates that a single model for collecting revenues from charging is not yet clear or suitable for all markets. Furthermore, in some cases, structures may reflect conditions specific to the regulatory framework in which companies are acting. For example, of the companies included in this sample, nearly all of the payment plans that were charged on a per-kWh rate were located in Europe. This may be due to a difference in regulation of electricity resale in European countries compared to US states. More broadly, the prevalence of the subscription model – present in a plurality of payment plans – is likely driven by the underdeveloped state of the EV market in general, meaning that low or sporadic utilization rates require companies to use subscription fees to ensure steady revenues. Kley et al (2011) suggest that due to the high importance but low utilization of public charging infrastructure under early market conditions, these assets could be more appropriately funded from home-charging as a core business. However, as EV ownership becomes more widespread and public charging volumes increase, it is likely that payment plans will continue to evolve. From a consumer protection perspective, a standard method for labelling refuelling costs would also be worth pursuing, as the range of different rates and billing types leads to little transparency for customers in terms of what they are paying to operate their car.

In terms of expanding the residential charging network, one emerging model for supplying charging services provides support for EV drivers who own home charging infrastructure to make their equipment available for public use, either for free or for a usage fee (von Kaenel, 2016).¹¹ In some cases, this has been executed as a dedicated platform, as with Swedish EIBnB, launched by Renault in 2016, which allows drivers to locate and contact a charging station owner (Burton, 2016), as well as Chargie, in the UK which uses a similar model (Krok, 2017). Another approach leverages existing sharing-economy platforms to establish partnerships between current market actors, as with Airbnb and Tesla (Penter, 2017).¹² While beyond the scope of this paper, it should also be noted that charging network

¹¹ This is true for standalone homes or those with access to dedicated parking and associated EVSE; multi-unit buildings do not generally offer drivers the same opportunities to own chargers and participate in the business models described here.

¹² These examples generally refer to charging at single-family homes, rather than multi-unit buildings, where charging costs may be allocated across multiple tenants.



operators – both residential and public charging companies – may develop storage aggregation for demand response and flexibility services under vehicle-to-grid arrangements, which could provide additional revenue streams.

Section 3 Key Points

- The EV charging infrastructure value chain is characterised by four main functions: manufacturing, development and installation, network operation, and sales and marketing. **Business models for charging services vary widely** and may serve one, some, or all four functions.
- These **commercial arrangements shape companies' risk exposure and market barriers**, and **policy mechanisms should be calibrated accordingly**. For example, grants for individual charging stations will target charging point owners, though these entities may not be well-suited to manage development and installation of equipment. Large auctions or tenders for charging networks, on the other hand, may limit applicants to large energy companies, but such companies are better equipped to deploy infrastructure more rapidly.
- Though in relatively early stages, the charging market can offer some **useful lessons from business models that have failed** in the past. Key examples include leasing models that relied on charger host sites to manage equipment installation, as well as charging providers who built expensive battery swapping stations and saw insufficient uptake.
- **Installation and grid connection fees make up a high percentage of the upfront cost** of charging stations – 80-90% in some cases. Streamlined planning protocols and a reduction of grid connection costs (e.g. by combining EV charging connection works with other grid upgrades or connection projects) should be considered as a means of reducing total installed cost of EV charging equipment.
- **Retail electricity tariffs are a strong driver of operating expenditure** for EV charging, particularly in the case of demand charges, which can comprise up to 50% of a typical commercial customer's electricity bill and more than 90% for EV charging. Policymakers and regulators should examine approaches from jurisdictions that have sought to **use time-varying or critical-peak rate designs to provide a more favourable price signal** to market actors.
- **Payment schemes are highly variable**, and may include a fixed monthly or annual fee, a per-kWh volumetric fee, a time-based fee per minute or hour spent charging, and/or a flat, per-session connection fee. Various fee configurations mean **that total refuelling cost is typically not clear to consumers**, and consumers are not able to easily compare the product offerings of different charging service providers.



4. Incentives and Deployment Approaches

EV charging services are clearly critical to the functioning of EV transportation, and represent infrastructure that can be privately or publicly financed and funded. The challenge in funding EV charging infrastructure through private financial sources is defined by many of the characteristics noted in Sections 2 and 3; particularly with respect to the poor economics of stations or network segments that are strategically necessary to suit driver preferences, but which are not profitable to operate. This section therefore considers the issues of funding and investment in future charging infrastructure. It addresses the questions (i) who should finance and fund charging infrastructure; (ii) what instruments should be used to disburse funding, and (iii) how EV charging infrastructure can be managed to avoid increased investment in network upgrades.

4.1 Public Funding and the role of Energy Suppliers

While many private actors are involved in the EV charging market, it is rarely fully privately-funded or owned. This is because EV charging infrastructure shows certain public good characteristics common to public infrastructure and in the early years of EV deployment merits some public financial support (Torrise, 2009).¹³ Because the likely social benefits are not limited to those who can pay, decisions about this infrastructure are an important public policy concern and should not be just a matter for private firms and investors (Whitmore and Schanzenbach et al., 2017). In addition, publicly-owned electricity generation and transmission utilities often own and/or finance EV charging stations, which makes them a matter for public interest. Public funding can be raised from the general tax base or from charges to electricity ratepayers, with implications for the distribution of the cost of supporting public infrastructure.

Fitzgerland and Nelder (2017a) note the need for public investment particularly in fast-charging infrastructure, which requires an adequate supply of “patient capital” to support high upfront expenditures that may not be returned to investors for several years, as EV usage grows and boosts revenues. They also point out that even with respect to Level II charging, allowing for public investment either through charges to ratepayers or general taxation is necessary for the early deployment of infrastructure. While in the short-term this may

¹³ For example, the deployment of EVs is a key element of strategies to decarbonise transport and mitigate climate change to the benefit of society.



represent cross-subsidization of wealthy early-adopters, in the long-term, robust EV use will be profitable and beneficial to a broad cross-section of society, not only EV drivers.

The role of utilities or incumbent energy suppliers in providing public charging infrastructure varies widely around the world and is the subject of great debate. Monopolistic development (by private or public entities) of future infrastructure such as EV charging could raise prices and prevent future competition, particularly where the supplier is also the electricity retailer. Yet at early stages of EV adoption, where profits from charging stations are low, other private actors may not have the capacity or resources to invest. In Europe, large energy companies have been responsible for a significant fraction of all public charging stations—for example, energy supplier RWE owns more than 2,800 charging stations across Germany and other countries (Hall and Lutsey 2017a).

Opening up utility ownership of EV charging infrastructure through regulatory policy has also been used in some US states, such as Washington, California, and Missouri, in order to promote deployment. Regulators have in some cases reversed earlier policies that prevented investor-owned utilities from investing in installation of EV charging infrastructure and passing the corresponding costs on to ratepayers (Martin, 2015). For example, in 2015, Kansas City Power and Light (KCP&L) became one of the first US utilities to launch a public charging network, and in 2016 was third among fifty US cities in charging infrastructure availability (Lutsey et al, 2016). While uptake was initially low due to a combination of modest incentives and low model availability, the city has since doubled EV deployment (Fitzgerald and Nelder, 2017a). Outside of the US, Tokyo also allows for utility ownership of EV supply equipment, and the Netherlands has created an auction system for all public charging station installations, in which utilities can bid competitively for funding to provide charging access (Hall and Lutsey, 2017a).

Whether funded directly by utilities or by private actors such as charging companies and automakers, Kalani (2017) notes that EV charging, and particularly fast-charging, should be regulated in a manner similar to that applied in electricity delivery. Under typical utility regulation in telecommunications and electricity, ownership of wires should be separate from the electricity they carry, ensuring access to infrastructure for users while allowing for competition in supply. Kalani (2017) points to these outcomes – ease of access and competitive markets – as necessary for keeping the overall cost to society for EV infrastructure as low as plausible. This also allows for interoperability, such as exists in



mobile phone networks. The success of charging infrastructure will be linked to the number of users it can attract. For example, clear agreements in the telecommunications sector in network sharing and separation of sales volume (e.g. for mobile data and electricity) has led to benefits for all.

The issue of whether energy suppliers or public authorities should finance charging infrastructure usually has implications for the question of who funds the infrastructure - electricity ratepayers or general taxpayers. Hall & Lutsey (2017b) note in their review of best practice that utilities using ratepayer funding (or “rate-basing”) to support EV charging can have varying implications for competition. Access to ratepayer funds can allow utilities to absorb early-stage losses, potentially enabling them to crowd out private actors. However, heavy utility regulation could also inhibit innovation and agility, putting utilities at a disadvantage compared to private companies. In either case, the paper notes that where utilities do own charging infrastructure, it may be beneficial for governments to promote public-private partnerships, and to target utility-led development to specific market segments that may be underserved by the private market, like apartment buildings and workplace charging.

Rate-basing the costs of installing and operating EV charging infrastructure is permitted in some jurisdictions if utilities are able to make a “compelling” case that rate-based expenditures on charging stations would provide a net benefit to all their customers (see for example the Oregon Public Utilities Commission) (Salisbury and Toor, 2016).¹⁴ Alternatively, public funds could be raised through general taxation; yet as with all taxation measures, there are potential distortionary effects associated with increasing taxes.

Rules governing retail sales of electricity can act as a barrier for current and prospective charging service providers. Fitzgerald and Nelder (2017a) note that some jurisdictions allow EV charging station operators to sell electricity directly to customers, whereas in other locations, only entities which are regulated as utilities may participate in the resale of electricity. A lack of certainty around these regulations can inhibit commercial charging operations entirely, or can impact payment structures as in some locations where companies charge for access to a parking space, but do not charge for electricity on a per-kWh basis. For example, in 2017 the state of Indiana changed its regulatory conditions to allow for resale

¹⁴ Public Utility Commission of Oregon. 2012. Order No. 12 013. Investigation of Matters Related to Electric Vehicle Charging. <http://apps.puc.state.or.us/orders/2012ords/12-013.pdf>.



of electricity for EV charging as long as customers were not paying a per-unit price (NCCETC, 2018). In the UK, full resale of electricity through commercial charging infrastructure is permitted, and a 2014 decision from Ofgem waived the maximum retail price allowable for suppliers in the case of EV charging (Ofgem, 2014). Ensuring access to the electricity service delivery market allows participants more flexibility in setting pricing and fee structures, and could be an opportunity for promoting additional development.

4.2 Support Schemes & Policy Design

A range of supportive policy measures at local, regional, and national levels of government can be used to bolster public EV charging networks. The 2018 IEA Global EV Outlook (IEA, 2018a) notes that effective policy frameworks create conditions to overcome key barriers to developing EVSE. This is achieved through a combination of measures, including the definition of clear EVSE deployment targets, supportive regulations, mobilisation of funding for direct investment and the provision of financial support.

Designing incentive schemes that promote development of charging requires policymakers to consider several factors: how and from whom funding should be collected as discussed in the previous subsection, how and to whom funding should be allocated, and how to plan for future impacts that arise from widespread deployment. Policy measures to support EV charging can be implemented in the form of ad-hoc programmes that provide incentives to individual EV owners or EVSE providers, or through more comprehensive investments in network development, or centralised network development tenders with implications for efficacy and equity for prospective recipients.

Existing public incentive programmes vary widely and exist at various levels. Given the broad range of policy options, it is critical that enabling actions and measures are properly aligned with the scope of authority associated with the actor, as well as with the intended outcome of the policy (i.e. which specific charging need is the policy designed to meet). For example, measures that involve local planning, permitting, and grants are generally best implemented at the local level. The buildout of residential charging infrastructure also requires the support of municipal authorities who must approve allocation of parking spaces for EV charging. On the other hand, large investments in multi-jurisdictional wide-scale network deployment may be best led by national or regional governments, with local engagement when necessary. Measures at both levels are usually necessary and complementary; national regulatory and funding frameworks enable local authority schemes



and/or local authorities implement national EV charging strategies.

At the local level, municipalities can provide incentives and support such as efficient processing of charging station siting applications or allocation of parking spaces exclusively for electric vehicles or charging activity. The city of Paris provides dedicated free parking spots for EVs, while Amsterdam uses a demand-based approach to deploy public access charging by installing chargers at the request of residents who purchase EVs when there is no private or off-street alternative nearby (IEA, 2017). More broadly, the UK's national programme for support of local authorities' on-street charging infrastructure deployment requires applicants to demonstrate a lack of off-street parking access (OLEV, 2016).¹⁵ These approaches optimise utilization by ensuring that public funding for chargers is aligned with the demand for charging services (Vertelman and Bardok, 2016). A rollout strategy that targets high utilization rates can also be beneficial in enabling charging assets to maximize revenues, supporting a profitable business case for deploying them (Fitzgerland and Nelder, 2017a).

Regional and national governments can address public charging deployment through policy interventions that address the high-need, low-use market characteristics of charging infrastructure.¹⁶ This can be done either through direct investment in public-private partnerships to build out networks, or by offering grants and other incentives to make development attractive to private companies. One example of a public-private partnership for charging infrastructure is the West Coast Electric Highway, a network of Level 2 and DC fast-charging stations (50 kW) located every 25-50 miles along major roads in Oregon, California, and Washington state (INL, 2016). The West Coast Electric Highway project received support from the three states in which it is located, as well as federal funding from the American Recovery and Reinvestment Act, as well as the Department of Transportation (Powers, 2014). Private entities, namely the host sites at petrol stations and rest stops along the network route, contribute to the network by developing, installing, and operating the chargers (Doyle, 2011). Another example of public-private partnership is Fastned, which operates a network of fast-charging stations in the Netherlands, and has agreements in place to expand to Germany and the UK. The network is raising funds for future buildout through a

¹⁵ IEA (2018a) note that Amsterdam's programme has proven more successful than London's, where the budget was not fully depleted due to a complicated approval process

¹⁶ In the EU, the directive 2014/94/EU on the deployment of alternative fuels infrastructure recommends a fast charger every 50km for example.



public bond offering, in which bonds are offered at 6% interest with a maturity of five years. Fastned reported the programme to be 94% subscribed as of December 2017 (Fastned, 2017).

The state of Connecticut, rather than investing directly in development of a network, launched an initiative in 2013 that offers grants to both public and private entities who install Level 2 charging equipment. A key provision of allocation of this funding is that recipients must ensure that supported charging infrastructure is available for public use (i.e. that it is not limited for use only by a hotel's guests or a restaurant's customers, for example). In addition, the state has worked with a local utility to roll out DC fast-charging, and by choosing to co-locate fast-chargers with planned Tesla Motors charging stations, was able to reduce costs during the construction period of the network (Powers, 2014). Powers (2014) also notes that governments who provide funding for private development of charging stations may require that such infrastructure be made available to the public. Similarly, the Norwegian government, via state agency Enova, introduced a support scheme in 2015 meant to deploy DC fast charging stations every 50 kilometres around a 7,500 kilometre road network. Under the scheme, network operators retained ownership and operational responsibility for charging assets, and competed for public funding to support deployment (Lorentzen et al, 2017).¹⁷

Irrespective of the type of public support provided for charging networks – whether through direct investment or through grant-funding and other disaggregated measures— incentive initiatives should be clear about any ownership stake or encumbrance implicit in accepting government support. For example in Ireland, following a DSO-led pilot project to roll out charging stations across the country using ratepayers funds, the regulator issued a decision stating that the DSO could no longer use ratepayer funds to install further stations and that assets should be sold off.¹⁸ Though the decision has since been replaced by an interim agreement for the ownership and operation of the network, the initial ruling led to some uncertainty regarding the future expansion of charging infrastructure and the management of the current asset. Such ambiguity can lead to underinvestment in network maintenance, resulting in long outages and general disrepair, which in turn can fuel hesitation among potential EV buyers (see additional detail in Section 5).

¹⁷ As an aside, the last two tenders of this project have yet to be completed, as no companies bid to build a charger in the very north or the Lofoten islands, even with 100% subsidy on the equipment.

¹⁸ Commission for the Regulation of Utilities (2017) ESNB Electric Vehicle Pilot and Associated Assets, Decision paper CRU17283.



The proposal for a new EU directive on electricity supply states that ‘*Member States may allow distribution system operators to own, develop, manage or operate recharging points for electric vehicles only if the following conditions are fulfilled:*

(a) other parties, following an open and transparent tendering procedure, have not expressed their interest to own, develop, manage or operate recharging points for electric vehicles; EN 81 EN

(b) the regulatory authority has granted its approval.’

Such conditions will be relevant to the future value of charging networks as prospective investors become more familiar with the EV charging model. If the infrastructure is initially publicly owned, arrangements will be needed if there is to be a transition to private ownership. For example, Dougherty and Nigro (2014) note that financial actors could play an important role in creating a secondary market in which existing infrastructure assets could be packaged as securities and sold to investors.

Ensuring clarity in asset ownership for infrastructure financed by governments or ratepayers should reduce the cost of such transactions, bringing down overall cost of capital and helping to mobilise private capital to leverage public investments.

4.3 Diffusion & Network Impacts

In considering the need for public and/or private funding of charging infrastructure, network investment may also need to be added to the overall system costs. The prospective uptake of electric vehicles at scale will precipitate a need for changes and upgrades to physical electricity networks to accommodate localized peaks and also less significantly an increase in demand for electricity (Mu et al, 2014). Managing electricity demand from EVs can reduce the need for future network investment by providing storage and other grid services. As such, charging network planning should consider both where and when changes in demand may occur, taking account of spatial planning and potential for network hotspots, as well as charging behaviour and temporal incidence of charging events.

Spatial distribution of both public and private charging infrastructure may be influenced by demographic and housing stock characteristics. With regard to likely uptake by area, EV ownership is often concentrated in urban or densely populated areas – as in Norway, where this demographic accounts for 90% of EV owners (Brooklyndhurst, 2015), and the US, where 82% of EV sales in 2015 occurred in the 50 most populous metropolitan areas (Lutsey et al, 2016). In the UK, surveys indicate that approximately 70% of households have garages



or off-street parking, suggesting that a high proportion of future charging demand could be delivered through residential infrastructure, though the percentage falls to only 30% in urban centres (Element Energy, 2015). A high share of urban residents living in apartment-style housing may also lead to a shortage of access to off-street parking and EV charging, which could inhibit EV uptake.

Separate from fiscal deployment strategies discussed in Section 4.2, residential charging may also be bolstered by national or supranational policy. In Europe, for example, the EU Commission has proposed amending energy performance standards, or building energy codes, to require new residential buildings, as well as those undergoing major renovations, with more than ten parking spaces to be wired for vehicle recharging, beginning in 2025 (EU Commission, 2016). In jurisdictions with such requirements, network operators could engage with development planning processes to track and forecast future charging demand.

Practical utilisation of networks and behavioural charging patterns will have significant implications for how charging interacts with electricity infrastructure. Fitzgerald and Nelder (2017b) analyse charging events in the EVGo network in California, and find that the utilisation profile for chargers at all types of charging host sites follows the same pattern as overall system demand. This suggests that use of public fast-charging at wide scale could have the effect of exacerbating demand peaks, resulting in added costs for network operation and capacity. Indeed, Richardson (2013) provides a comprehensive review of literature on potential grid impacts of EV charging, and notes the importance of smart or responsive charging infrastructure in avoiding an increase in network costs. Retail tariff price structure can also be employed to manage the timing of demand. For example, EV owners in San Diego in 2013 (which had, at the time, a fleet of 3,300 EVs and 400 public charging stations) could avail of a time-of-use (TOU) tariff for separately-metered EV charging. These tariffs are credited with encouraging the high proportion of EV charging – more than 80% – which occurs between midnight and 5:00 AM (MJ Bradley Associates, 2013).

There have been several studies investigating the potential for EV charging to provide demand response and avoid network upgrades. One demonstration of responsive charging at residential scale includes the “My Electric Avenue” project in the UK. Funded by Ofgem and executed by a team of partner organisations, the project attempted to address prospective network disruption from future home charging through clustered demand side response trials.



The project established clusters of up to 12 Nissan Leaf drivers on the same low-voltage feeder and used demand response technology to dynamically monitor the network. By controlling the charging points, the researchers were able to curtail charging, i.e. prevent EVs from charging when network loads were high. As a control for the study, a group of individual users were also able to lease an EV and provide data to the project, but were not curtailed, that is, they were permitted to charge at whatever times they wished. The project concluded that utilisation of demand response for EV charging to avoid network upgrades in Great Britain could yield savings of approximately £2.2bn by 2050 (EA Technology & SEPD, 2016).

Section 4 Key Points

- While EV charging infrastructure remains non-commercial, **EV charging infrastructure requires public funding and regulation** to facilitate the roll out of a comprehensive, competitive charging market. Underutilised strategic infrastructure such as fast chargers may merit public ownership.
- Public funding should mostly be raised through **general taxation rather than electricity ratepayers**, however in particular circumstances such as when utilities can show that all their ratepayers benefit, it may be advantageous for utility-led development to occur funded by their ratepayers.
- Various fiscal measures are needed to **disburse public funds at local, regional, and national levels** and to support private sector investment in charging stations. Careful design of fiscal measures is needed to ensure efficient uptake and a long-term transition to sustainable markets.
- **Network upgrades and investment will be required** to accommodate future increased demand for electricity through EV charging infrastructure. Planning spatial and temporal demand of installed infrastructure through demand response mechanisms and collaboration between EV charger installers, network planners, and policymakers helps minimise network investment.



5. EVs in Ireland

Ireland's 2017 National Mitigation Plan (NMP) identifies a key role for electrification of transport in future emissions reduction efforts. The NMP proposes several actions to support deployment of electric vehicles, including maintenance and review of existing grant programmes and investment in infrastructure and behavioural change interventions. Due to limited market penetration, little has been published to date on the electric vehicle market in Ireland, and the country's position relative to future deployment. Ireland also provides an interesting case study in deployment of EVs and associated infrastructure, due to its low uptake relative to key indicators such as charging availability, purchase incentives, and vehicle model availability.

5.1 Incentives and Uptake

In 2009, Ireland set a national target of transitioning approximately 10% of its passenger and light commercial vehicle stock to electric vehicles by 2020, a figure which has since been revised to 50,000 EVs due to slow uptake (DCCAIE, 2017a). The 2017 National Development Plan (NDP) renewed Ireland's future EV deployment ambitions by setting a target of 500,000 electric vehicles on the road by 2030, with supporting charging infrastructure to follow. Current incentives aimed at stimulating demand for EVs take the form of cash grants to defray purchase costs, and favourable treatment on vehicle registration and road tax which improves long-term ownership costs. Consumers who purchase an EV in Ireland have been eligible for a grant of up to €5,000 since 2011; by the end of 2016, just over 1,700 vehicles had been supported by the grant (DCCAIE, 2017b). According to data available from the Society of the Irish Motoring Industry (SIMI, 2018), more than 4,220 plug-in electric vehicles have been sold in Ireland since 2008, and ESB eCars identifies 21 vehicle models available in the Irish market (ESB, 2017a). The 2018 budget package extended some existing supports, including the Vehicle Road Tax Relief and upfront purchase grant (worth up to €5,000 each), and introduced some new incentives. In particular, EV owners are now eligible for a €600 grant to support the installation of a home charger, and businesses will be subject to a 0% benefit-in-kind (BIK) rate on electric company cars for at least three years, as well as accelerated capital allowances for depreciating vehicle purchases (DCCAIE, 2018).

The scale of Ireland's forward-looking deployment goal can be considered in the context of global EV forecasts. In 2016, there were just over 2 million electric vehicles deployed worldwide (IEA, 2017). With its current penetration of more than 3600 electric and plug-in



hybrid vehicles, Ireland comprises 0.175% of the global EV market, which is approximately similar to its share of overall vehicles (approximately 2 million light duty vehicles in Ireland compared with more than 1 billion worldwide). Table 4, below, estimates the number of EVs that Ireland would have to deploy, compared with global electric vehicle forecasts, under low, mid, and high EV penetration scenarios. Irish assumptions are notional and based on possible high level targets; global scenarios are based on figures presented in the IEA Global EV Outlook 2017.

Table 4. Global and Irish 2030 EV Estimates

2030 Low	Assumptions	EVs
Ireland	Irish 30% CAGR*	127,813
Global	IEA RTS scenario**	58,000,000
2030 Mid		
Ireland	Target of 250,000 (39% CAGR)	250,000
Global	IEA Paris scenario	116,000,000
2030 High		
Ireland	Target of 500,000 (46% CAGR)	500,000
Global	IEA 2DS***	159,000,000

Source: internal analysis

*Compound annual growth rate of 30% calculated from 2017 - 2030

**implementation of existing policies and those currently under consideration

***50% probability of preventing temperature rise above 2 degrees Celsius.

Based on the estimates in Table 4, Ireland would need to increase its share of the forecasted global EV market by approximately 4% from its present proportion under the low scenario, and by approximately 50% under the high scenario. These estimations, though only notional, provide an indication of the scale of prospective EV uptake in Ireland if the country is to meet its high-level targets. All will require supportive policies and considerable investment in enabling infrastructure.

Quantifying prospective future EV uptake also provides some indication of what will be required from EV charging infrastructure under different adoption scenarios. For example, Ireland currently has just under one public charging station for every 5 electric vehicles on



the road, which is higher than in more developed EV markets.¹⁹ By way of comparison, Norway had approximately 9,000 public charging stations for 176,000 electric vehicles in 2017, for a ratio of approximately one charger for every 19.5 vehicles (IEA, 2018b). Table 5 shows the number of public chargers that Ireland would need to deploy in order to maintain its current 1:5 ratio under the low, mid, and high 2030 scenarios featured in Table 4. Table 5 also indicates the number of chargers required by 2030 if Ireland were to aim for compliance with the EU Alternative Fuels Infrastructure Directive (AFID), which recommends that member states ensure one publicly available charger for every ten electric vehicles.

Table 5. Chargers Required to Meet 2030 EV Needs

2030 Scenario	EVs	Chargers Required to Maintain Current Ratio (1:5)	Chargers Required to achieve AFID Ratio (1:10)
Low	106,006	21,200	10,600
Mid	250,000	50,000	25,000
High	500,000	100,000	50,000

In practice, the Department of Transport has stated in its 2017 Alternative Fuels Framework that the 1:10 ratio of chargers laid out in the AFID would likely never be necessary to support wide-scale EV deployment in Ireland. These overall ratios do not define the optimal split between Level 1, Level 2, and DC fast chargers. Furthermore, as higher capacity fast charging technology becomes the norm, public chargers will likely be able to adequately service a higher number of EVs, meaning charger ratios could be lower. In any case, it is important that Ireland set specific targets for charging buildout which are aligned with overall EV deployment. These targets can be modified and refined as best practices for charging location, speed, and mode become better developed.

5.2 Charging Network

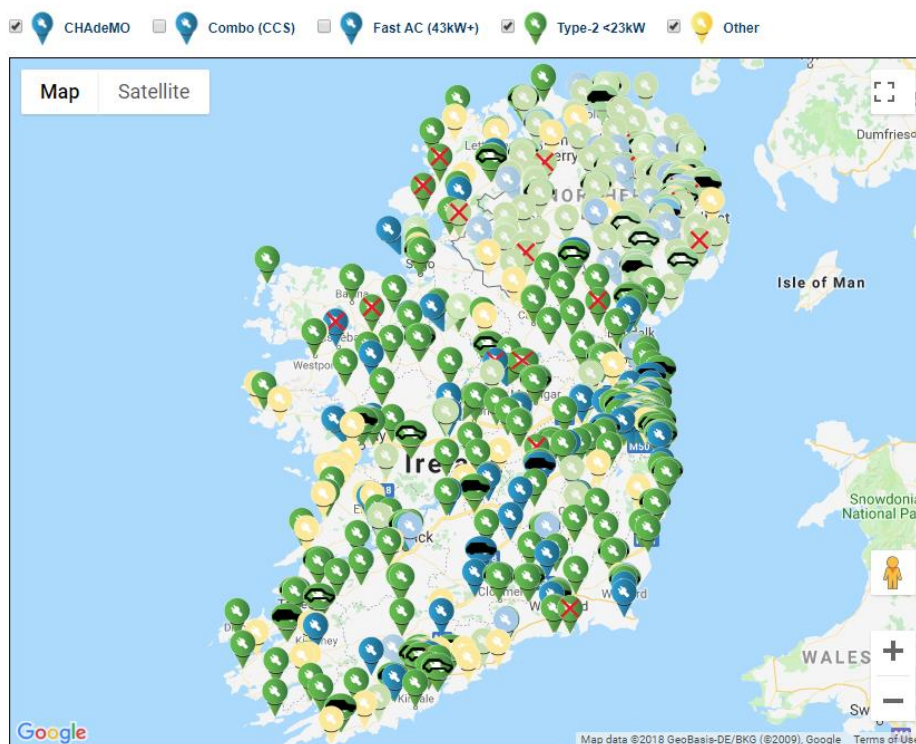
Until recently, the primary programme for installation of EV charging stations in Ireland has been the ESB Networks’ electric vehicle pilot programme. Under the initiative, the Irish DSO, ESB Networks, was directed to spend €25 million from ratepayer network user fees to build a public charging network and deliver value through research and grid

¹⁹ Assuming approximately 4,220 electric vehicles to 900 charging stations in the Republic of Ireland. These figures do not reflect the presence of multiple outlets at a single charging station.



impact assessments (CRU, 2017). Execution of the programme was managed by a separate commercial entity within the ESB Group, ESB eCars. ESB eCars has installed approximately 1,100 public charging stations in Ireland, including 300 in Northern Ireland. The majority of the public charging stations are rated at 22 kW. The programme has also supported 70 fast chargers in Ireland, as well as an additional 15 fast chargers in Northern Ireland (ESB, 2017b) (see Figure 3 below).

Figure 3. ESB ecars Charge Point Map²⁰



Source: ESB ecars, 2018

Heretofore, the ESB eCars charging network has been the only networked platform for EV charging in Ireland, and has therefore been responsible for development and installation of Irish charging infrastructure, as well as network operation, maintenance, and marketing.²¹ Few private charging companies currently operate in Ireland, and where they do, such operations generally occur on the basis of individual equipment supply, rather than through efforts to develop a comprehensive network. The dearth of commercial providers is

²⁰ Graphic represents a screen shot from 10:00 AM on 29 August 2018; semi solid vehicle icon indicates some connectors in use but others are available, solid vehicle indicates no spaces currently available, red x indicates connectors are out of service, and paler-coloured icons do not have the ability to communicate status.

²¹ This does not include recent investments in charging infrastructure by Tesla, whose charging stations are for exclusive use of Tesla drivers.



likely not helped by the small size of the Irish market and its low EV penetration, which limit appeal to potential market entrants. In October 2017, the Commission for Regulation of Utilities (CRU) delivered a decision that the development of ESBN's charging assets be discontinued, and that the network be operated on a commercial basis until such time as the assets could be sold. As noted in Section 4, the reverse of this practice – amending regulatory policy to allow for utility ownership of charging infrastructure – is becoming more prevalent in other jurisdictions. Moreover, as charging assets age, outages become more common, and an underserviced existing infrastructure would lose functionality and reliability, undermining public confidence in charging availability and acting as a barrier to continued EV adoption. In response to these and other concerns raised by ESB Networks, the CRU made public in September 2018 its decision to agree a five-year termination agreement which would see the charging assets operated by ESB eCars, allowing ESB to raise revenues to support the network, and precluding any losses accruing to the regulated business, ESB Networks (CRU, 2018). Whilst this decision should ensure continued maintenance of the existing charging network, additional expansion and modernisation of public charging will need to be part of a broader effort.

Additional analysis is also needed to evaluate potential for home charging, given housing characteristics in Ireland. Proximity to parking options is not currently reported under the Irish census, however the National Policy Framework for Alternative Fuels Infrastructure for Transport notes that rates of private home ownership and private parking access are higher than other European countries, reducing the need for public infrastructure. In fact, this does not reflect localised conditions. Indeed, in 2016 apartments represented the most common housing type in Dublin for the first time, with 204,145 people or 35% of residents living in multi-unit dwellings (CSO, 2017a). In advance of potential EU requirements for EV charging in apartment buildings (noted in Section 4), Ireland could also consider introducing guidelines that require developers to ensure new apartment buildings are EV-ready, as in the city of Westminster in London, which has implemented a requirement that all new builds and retrofits must be socket-ready to accommodate EV uptake (ICF, 2016). Other relevant housing characteristics, for example estate-style housing developments, could be helpful in identifying a suitable shared-resource approach to charging infrastructure, as would payment capability that allows EV drivers to make their home chargers available to other users. More detailed housing data would also help to better quantify the proportion of



drivers who do not have access to off-street parking, and therefore require public infrastructure to charge at or near their home. A pilot programme in development by Dun Laoghaire – Rathdown County Council that will provide on-street charging through street lamps could serve as one model for this type of charging availability.

5.3 Range & Driving Distances

For the purpose of assessing public charging infrastructure needs in Ireland, a 2016 analysis of recorded charging events at existing charging stations found that public standard and fast chargers tended to have similar average consumption at 6.93 and 7.27 kWh, respectively (Morrissey et al, 2016). The authors suggest that this finding indicates that EV drivers who charge in these types of locations have similar consumption needs. The study also found that similar to other jurisdiction, Irish EV users charged at home with the highest frequency compared with public standard and fast-charging options (Morrissey et al, 2016).

Other geographic and demographic characteristics of Irish residents would seem to suggest suitable conditions for deployment of an efficient EV charging network. According to the Central Statistics Office (CSO, 2017b), the average Irish commute is under 15 km, with Dublin City (including South Dublin and Dun Laoghaire-Rathdown), Cork City, and Galway City commuters living within 10 km of their workplace.²² These CSO data for the cities represent over one half of workers who commute by car and more than one third of total Irish commuters (CSO, 2017c).²³ Residents in Laois experience the longest commuting distances, at just over 25 km (CSO, 2017b). As a point of comparison, this is similar to the average urban commute in New Zealand (22 km), where the government has determined typical commuting distance as a factor that renders it well-placed for EV uptake (Ministry of Transport, 2017). Ultimately, these indicators point to a relatively high number of private car commuters in Ireland whose daily round trip car travel is well within the bounds of a typical EV battery range. Indeed, the 2018 model of Ireland’s most popular EV, the Nissan Leaf, has an estimated range of approximately 378 km, depending on driving conditions. However, much of the existing EV stock would have a range more typical of earlier models, i.e. under 200 km. This makes infrequent long-distance trips more difficult, as they require refuelling mid-journey. While more data is needed to better understand driver behaviour and attitudes,

²² Commuting distances are calculated on a straight-line basis from home to workplace.

²³ Dublin, Cork, and Galway represent 512,449 commuters, 102,139 commuters, and 44,376 commuters respectively, for a total of nearly 659,000 people.



these longer trips may be more salient to prospective EV buyers compared to their typical daily driving distance.

5.4 Public Perception

Despite the high number of residents with relatively short commutes, a substantial proportion of Irish drivers feel unprepared to own an EV due to a perceived lack of availability of charging: a 2017 AA Car Insurance survey found that approximately 30% of respondents would be “very likely” or “somewhat likely” to purchase an electric vehicle for their next car, however, 54% of those unlikely to purchase an electric vehicle attributed their hesitation to a lack of charging infrastructure (Aldworth, 2017). Additional survey results and other insights into public sentiment toward EVs, particularly with respect to where and how prospective EV owners might require charging access, will be critical to informing future network rollout. Future policy should accommodate the considerable variation in charging needs for urban drivers compared with rural ones. For example, a 2016 simulation of localities across the US found that available, affordable BEV technology was suitable to replace 87% of vehicle-days (i.e. driving needs on a given day) without recharging. However, the vehicle-days for which BEVs fell short occurred more commonly for residents of urban areas (Needell et al, 2016). Similar determinations of range and charging requirements should be explored in Ireland. Additional surveys on attitudes toward EV ownership and charging needs would also allow for a more precise understanding of the degree to which range anxiety in Ireland is driven by lack of awareness of existing infrastructure compared with true range shortfalls.

Given the high ratio of chargers available for EVs in Ireland, it seems that at least some of the concern over charging access could be alleviated by awareness or marketing campaigns. The West Coast Electric Highway in the US, for example, uses a standard symbol to direct users on major roadways toward EV charging stations (Jin & Slowik, 2017). Such an approach could be applied to the Irish charging network. Furthermore, with a per-EV charging access ratio that far exceeds more developed markets, it seems likely that some infrastructure may be installed in locations where charging is not required, or that charging infrastructure in high-need locations is lacking. As the first iteration of Ireland’s charging network was executed on the basis of ensuring nation-wide infrastructure, the next wave of installation should be better aligned with observed and likely driver profiles and network utilisation data to ensure assets are strategically sited. This may include fast-charging along



major intercity corridors, as well as on-street residential charging in densely-populated cities and towns, multi-modal locations (e.g. at commuter rail stations), and car parks and retail. Specific analysis is required: Morrisey et al (2016) note that fast charging in Irish car parks received higher daily utilisation than other location and mode combinations (e.g. Level 2 charging in car parks and petrol stations, and fast-charging in car parks), but does provide detail as to geographic dispersion.

With respect to support or scepticism on behalf of the public, the IEA (2017) notes that air quality issues are a prominent issue for cities interested EV uptake. According to the EPA data, as reported by the World Health Organisation (WHO), urban areas in Ireland that fail to meet safe levels of particulates include Galway, Dublin, Longford town, Armagh, Bray, Belfast, and Derry. The EPA notes that this is due to use of coal and peat for home heating, and to vehicle traffic (WHO, 2016; EPA, 2016). It is unclear the degree to which residents are aware of or concerned about local air quality, however, providing support for local authorities in areas particularly affected by vehicle emissions could prove important in facilitating the rollout of EVs and corresponding infrastructure.



Section 5 Key Points

- Ireland’s EV charging infrastructure has primarily been developed by a single semi-state network operator. Few additional actors have participated in this space or are active in the Irish market at all, and as a result, the **competitive marketplace for charging services is underdeveloped**. Future policy design should note that companies offering charging in Ireland will incur some cost for new market entry.
- Despite a strong early start to national charging infrastructure deployment, the future of charging development is unclear as **public charging incentives are still under development** and commercial charging remains pre-competitive.
- The recent agreement between the regulator and DSO regarding **maintenance of the existing charging network should ensure functionality and reliability** in the short term. However, additional investment in and expansion of public charging networks is necessary and would be essential to ensuring user confidence in a high-EV future.
- The average commute for Irish drivers (less than 15 km one way) indicates that most Irish drivers’ daily needs are well within the current vehicle range. However, despite short commuting distances, a majority of people surveyed indicated that their **concern over lack of charging infrastructure is a barrier to purchasing an EV**.
- Given Ireland’s high ratio of chargers to EVs (approximately 1:5 in Ireland compared to 1:19.5 in market leader Norway), **concerns over charging access may be due to a lack of awareness** about the existing network. **Improved marketing and standardised road signage** could direct drivers to existing chargers, or make prospective EV drivers more secure in the availability of charging resources.

6. Policy Recommendations

EV charging infrastructure is a critical enabler of deployment of EVs. This report has sought to highlight key concerns in its rollout in terms of the private actors, business model, and regulation, particularly in the case of the Irish market. Broadly, we find Ireland’s EV deployment targets could be more feasibly achieved through implementation of a variety of policy supports and incentives. We propose here four recommendations for Irish policymakers; all are focused on policy or regulatory action, and are informed by the market characteristics of the EV charging industry.

As an initial step, in order to leverage investments already made in national charging infrastructure, policymakers could consider an awareness or branding campaign for the existing charging network. In addition to charging station map-based apps, which generally



only inform drivers who already own an EV, such a campaign could include uniform signage at charging locations, as well as similarly branded road signage to make all drivers aware of nearby stations. Participation in the initiative could be a requirement for any future charging infrastructure supported by public funding. Similarly, given the important socialisation effect of workplace charging, an awareness campaign could include or be leveraged by an associated effort to boost employer-provided charging access.

Second, relevant authorities should conduct a detailed review of the cost drivers for EV deployment in Ireland, including both the upfront installation costs (i.e. planning and grid connection fees) and ongoing operating expenditures (i.e. retail electricity rates and rate design). Such a review should identify specific policy and regulatory measures to mitigate these costs, and establish a clear protocol for actors involved in rolling out public-funded charging equipment. As detailed throughout this report, local and national authorities, network operators, and private charging companies all have important roles in enabling efficient deployment. A clear operational strategy for future deployment should identify which entities have responsibility for key implementation components such as siting, planning, network approval, and parking allocation. Lack of clarity around issues such as whom to contact in local or city councils or how to ensure parking is allocated exclusively to EV charging can result in delays or cancelled projects, causing costly uncertainty for market actors. This proposal would be consistent with the Irish Alternative Fuels Framework, which promises an “action package aimed at removing removing any administrative obstacles related to the deployment of public and private recharging points” by the end of 2018.

Looking toward future infrastructure planning, relevant departments/agencies should publicly communicate any planned incentives or support measures for public charging development as soon as possible in order to attract new market entrants. Such schemes should be designed to take proper account of the underdeveloped Irish charging services market, and should be aligned with specific charging needs. Rather than support additional infrastructure on the basis of providing grants or funding to any host site interested in installing a charging station, future funds should be strategically targeted to corridors, locations, or routes that are likely to have high charging demand. For example, residential Level 2 charging should be targeted towards areas that are home to EV owners without access to off-street parking, and therefore home charging access. This will help to ensure that investment in public Level 2 charging is directly mitigating the barrier to uptake that arises when prospective EV owners



lack access to home charging. Similarly, prioritising fast charging installation along heavily-travelled intercity motorway routes will extend the effective range of EVs to include common long-distance driving patterns. To develop a framework for measuring these impacts, incentive programme administrators should establish data-driven targets that incorporate international best practice in siting different modes of EV charging (Gkatzoflias et al., 2016).

Finally, government, private actors, and the research community should collaborate to conduct more analysis around historical usage of the existing network, as well as evaluation of attitudes and behaviours for current and prospective EV drivers. At present, operational data from ESB eCars is not readily available to the research community, and as a result, little independent analysis has been published. Beyond infrastructure usage, a broader transportation survey effort could capture the driving and refuelling habits, commuting modes, travel distances, and other driver characteristics which would be essential to establishing sophisticated driver profiles. Such information would provide critical insight into planning and siting future assets by eliciting drivers' needs and preferences for where and when they wish to charge.

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