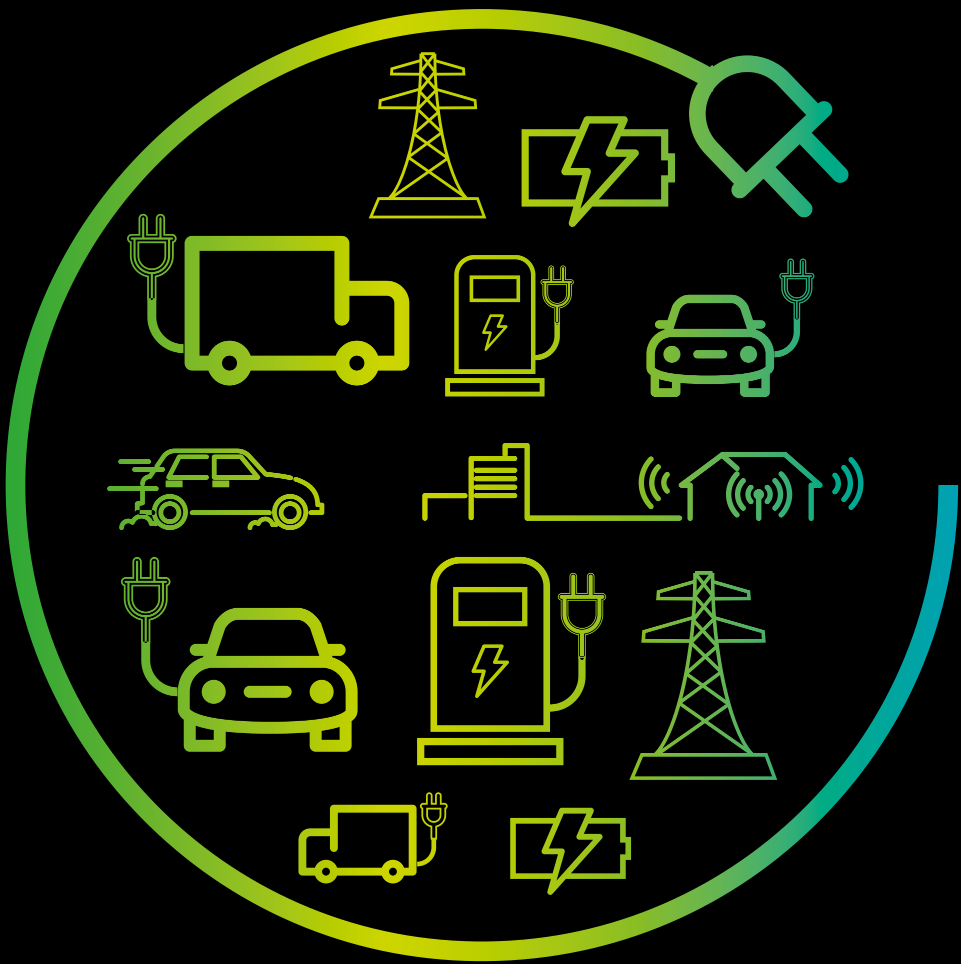


Hurry up and... wait

The opportunities around electric vehicle charge points in the UK

Contents

1. Executive summary

How quickly electric vehicles (EVs) will become a major form of transport is a source of much debate. A shortage of public charge points will deter adoption.

We modelled three scenarios for what the UK market will need to 2030: a low case if uptake is slower than expected (two million EV units); the central case; and a high uptake case if the EV adoption rate exceeds expectations (10.5 million units). In our central estimates, we assume seven million EVs in circulation, requiring around 28,000 public charging points, and capital expenditure of around £1.6 billion between 2020 and 2030.

Charging will fall into four broad categories: Residential; Fleets; Around town; and En route. The first two are private segments – the infrastructure is only available to owners or designated users. The latter two are public segments.

This paper focuses on public segments. AC charging is currently the most common and is likely to remain so until at least 2022. DC fast-charging segments will be more suitable as a stand-alone commercial proposition. Due to the current technological limits for both cars and chargers, the viability of rapid and ultra-fast charging has yet to be proven.

The charging value chain has multiple discrete parts that are integral to an end-to-end service, and no single sector has a commanding advantage in all parts. The four main areas of activity are: electricity generation and distribution; charge point manufacture, installation and maintenance; software for network management; and customer services.

The EV charging infrastructure market is young and fragmented, and companies from a variety of different sectors are entering it. Those looking to get into this market need to act fast, but then be prepared to wait: it is expected to become profitable only when EVs make up at least five per cent of vehicles in circulation, or about two million units. The key question for participants is where to play and what activity areas to be part of.

We expect to see three business models prevail in the UK in the coming years. A public model, where government bodies offer funding that private companies use to recover at least a portion of the investment costs. A utility model, where electricity distribution companies (Distribution Network Operators and Distribution System Operators) finance and own the infrastructure, and recover the investment, operating and maintenance costs through electricity tariffs. And an integrated charging model, where independent specialists, auto original equipment manufacturers (OEMs), oil and gas majors, hardware manufacturers and other new entrants to the EV charging field operate in specific segments and work with partners to deliver a joined-up service.

The opportunities in this space are vast and varied, thanks to the different ways EV drivers can access charging. But pay-off will probably not happen until 2023 or after. This suggests that the most successful entrants will have deep pockets, or strong partnerships – ideally both.

2. Introduction

The rate of adoption of EVs[1] is expected to take off in the early to mid-2020s, thanks to cost parity with internal combustion engine (ICE) vehicles, and a wider range of models offering improved mileage per charge.

In the UK, there are a number of forecasts for the adoption of EVs. EV sales have been rising steadily in recent years, reaching 44,437 units in 2018 – 1.9 per cent of all vehicles sold.[2] The government has set ambitious targets for 2030, including through the Industrial Strategy Grand Challenges, for EVs to make up to 60 per cent of all new car and van sales in 2030, and 30 per cent of the total number in circulation.[3] At today's volumes, that would mean about 1.4 million units sold per year, and a total of 11.5 million EVs in circulation. The infrastructure for EV charging points would need to grow commensurately.

A shortage of public points would deter adoption as users still have 'range anxiety' about how far they can go on a single charge. At present, the most popular place to charge up an EV is at home or at work. Yet, this might not be the case going forward: as EVs are more widely adopted, the charging infrastructure will need to support drivers who do not have access to charging at home or at work, or who drive a lot for work and need frequent top-ups, or who take longer journeys.

EVs will require different infrastructure and behaviours compared to filling up a tank. EV drivers will have several options for charging up their vehicles.

We expect to see four main segments develop:

- **Home charging:** this is a private model, available to the home or car owner
- **Fleet depots:** also a private model, for fleets of public transport vehicles, or taxis
- **Around town:** a public model where charging is offered as an amenity by businesses to attract footfall and increase dwell time
- **En route:** also a public model, with rapid and ultra-fast charging, akin to the petrol stations of today

We estimate that the UK will need around 28,000 **public** charge points and to invest a further £1.6 billion in the infrastructure by 2030. This includes AC chargers – which are dominant now, with about 83 per cent of the installed base[4] – and rapid and ultra-fast DC chargers, whose numbers have been growing at a faster rate. Installation of DC chargers will mean fewer charge points required per vehicle.

Companies looking to get into the market for EV charging need to act fast, but then be prepared to wait. There are first-mover advantages, both in terms of access to optimal sites and expected demand-side economies of scale. The technology and the cost profile are both changing rapidly.

EV charging is not profitable at present, but this should change once EVs make up at least five per cent of vehicles in circulation, or about two million units. In the most optimistic scenarios for growth, this will happen around 2023.

A number of companies have moved into EV charging, but at present none of them can operate the entire end-to-end value chain. As a result, there has been a lot of partnering, and even consolidation.

This paper presents some of the issues for firms looking to enter the purely public segments: Around town and En route.

Types of charging

Charge points differ in the speed at which they are able to charge up a battery. The two broad types of charging are AC (alternating current) and DC (direct current).

With AC charging, the electricity is drawn from the grid and converted to DC through a rectifier inside the vehicle. With DC charging, the rectifier is inside the charger, which delivers electricity directly to the battery.

The size of the rectifier determines the speed of charging. Because of the space constraints within the car, AC charging is limited to a maximum of 43kW of power, whereas DC charging generally starts at 50kW.

There are six power ratings:

- **Level 1 AC: less than 11kW of power (slow)**
- **Level 2 AC: 11–22kW (AC fast)**
- **Level 3 AC: 22–43kW (AC rapid)**
- **DC fast: 50kW**
- **DC rapid: 150kW**
- **DC ultra-fast: ~350kW**

A 2018 i3 BEV with a 42.2kWh battery would take about four hours to charge fully using an 11kW Level 1 AC charger (assuming it can accept the charge), and about 40 minutes using a 50kW DC fast charger. An iPace with a 90kWh battery would take over 12 hours to charge fully with a 7kW AC charger, and about two hours with a 50kW DC fast charger.

At present, AC is the dominant technology, close to 90 per cent of public chargers in the EU and 83 per cent in the UK.[5] This is likely to remain the case in the short to medium term. The rate of year-on-year growth in DC chargers has exceeded the overall average for public chargers, reaching 10.1 per cent in the EU in 2017.[6]

The choice seems to be between slow chargers that work with existing voltage and amperage but take time to power a vehicle fully, and fast chargers that require a much larger amount of power.

3. How many chargers will be needed?

How quickly EVs will become a major form of transport is a source of much debate. As a result, there is no consensus about the number of public charging points needed to support the growing number of EVs.

To come up with some idea, we modelled three scenarios for growth to 2030. We used National Grid's *Future Energy Scenarios* (FES) numbers to get a range of EV uptake possibilities. On to this, we applied the Committee on Climate Change's assessment of charge point demand. Both reference the government's stated targets to 2030. Our scenarios assume public charging supply will be a mix of slower, lower-cost parking-based segments, and higher-speed-at-higher-price segments.

Figure 1 shows the three scenarios: a low case if uptake is slower than expected; the central case; and a high-uptake case if the EV adoption rate exceeds expectations. The investment needed in the three scenarios ranges from £0.8 billion to £2 billion.

In our central estimates, this will mean around 28,000 public charging points for the seven million EVs in circulation, and capital expenditure of around £1.6 billion between 2020 and 2030. This estimate includes only the charge point equipment (including turnover of existing stock), installation and grid reinforcement. It does not include wider costs such as those for land, or ongoing operations such as rent, maintenance, or energy costs. See the Appendix for an explanation of our assumptions.

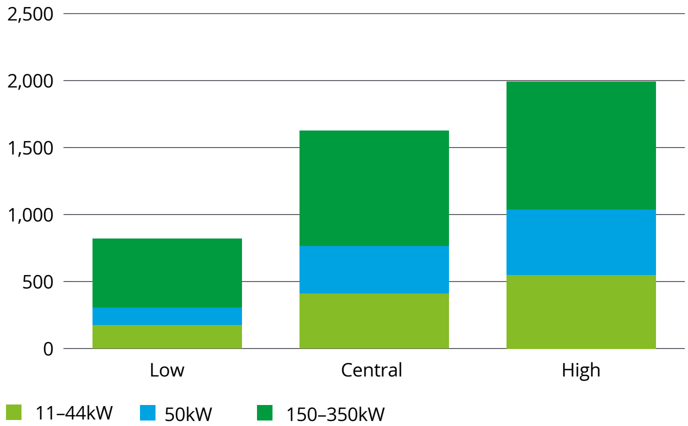
At present, the government has committed close to £300 million in a range of funding schemes, with £100 million in small-scale grants, and a £200 million contribution to the Charging Infrastructure Investment Fund (which it expects the private sector to match).

This leaves the bulk of the funding – indicatively over £1 billion – for the private sector to provide, on top of its contribution to the Charging Infrastructure Investment Fund. Beyond that will be an even bigger cost to keep the networks running.

This would complement the investment seen in homes and workplaces. As an example, oil majors BP and Shell have acquired independent charge point specialists to install rapid and ultra-fast charging points in their petrol station networks.

Frequently described as a 'chicken and egg' scenario, the central issue is that the investment case for both EVs and EV charging infrastructure depends on the pre-existence of the other. This means that the development of a charging infrastructure needs a continued uptake of EVs, to provide confidence to the market that there will be sufficient demand to warrant the investment.

Figure 1. Estimated investment required in EV charge points, 2020–2030: low, central and high growth projections (nominal £m)



Source: Deloitte analysis, Committee on Climate Change, UK Electric Vehicle Supply Equipment Assn. EVSE, Energy Savings Trust

4. Charging segments

Charging an electric vehicle is very different from filling up a tank with petrol or diesel. Battery limitations affect how much power the battery can take from the charger, and how long it needs to be charged.

For the foreseeable future, EV battery charging speeds, although increasing, will not be reduced to the time it takes to fill up at a petrol station. EV charging infrastructure will therefore need to accommodate a much wider range of charging behaviours.

The number of charging stations will be important, but so too will be where and how charging is done. Easily accessible AC charging points for side-of-street charging in urban centres will be needed for those lacking charge points at home or at work; and DC fast and ultra-fast chargers will be needed for people on the go or travelling long distances.

While the market is in a very early stage of development, and future charging behaviours are inherently uncertain, we expect that charging will fall into four broad categories. See Figure 2.

Figure 2. EV charging segments

Type	Location	Affected vehicles	Current charging needs		2030
Residential	Home charging	Owners with off-street parking	Around 90% of electric vehicle owners have access to private charge points at home or at work		**43% of car owners do not have a driveway or access to private charging.** Improvements in charging speeds and battery range mean they can charge quickly and frequently in a public network
Fleets	Car-sharing fleet	Electric fleets	**Car-sharing fleets** currently use an average of **1 fast charger for every 10 electric vehicles**		Ultra-fast chargers can service ~ **125 charging sessions per day**
	Public transport	Urban electric buses	Electric fleets need **one ultra-fast charge at the beginning and at the end of every route run**		**One charge per route run.** Inter-urban buses use **fast-charging plazas, or have their own charging depots**
Around town	Kerbside Destination	Electric vehicles without off-street parking	General view is that fast/rapid public charging infrastructure (fast-charging hubs + Around town charging infrastructure) can support a higher EV:charge point ratio (50–300:1)	Each charger can service 3 to 5 vehicles that do not have a private charging point **(assumes they drive 30-40km per day and charge every 3-5 days** for a ~ 140 km driving range)	**Kerbside** and **parking-based** infrastructure in public areas is necessary for those lacking access at home or at work
En route	Urban fast charging hubs Motorway service areas	All electric vehicles		N/A	EV charge points can be supplied at the same ratio as today's **ratio of petrol pumps per ICE car (1 per 500 vehicles)**

Source: Deloitte

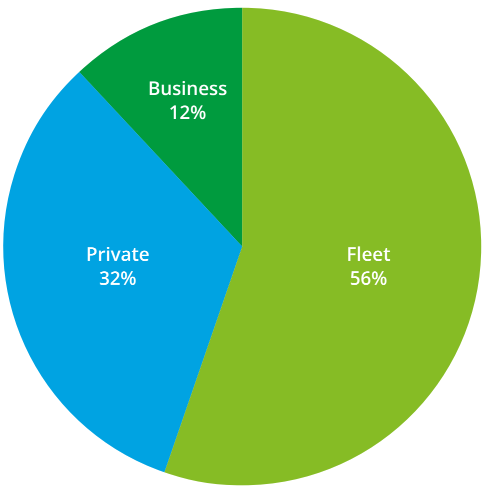
Residential

- A private segment: chargers are for the use of the home or EV owner.
- Home charging: this is how over 90 per cent of EVs are currently charged in the UK – in a designated parking area or on a residential street, and usually overnight.
- This segment mainly involves the sale of the hardware, with little or no grid reinforcement.
- Slow chargers are most commonly used as AC is supplied to homes, which have a maximum of 32 amps available.
- DC is not feasible for homes, given the power requirements.[7]
- At present, residential charging is subsidised through public grants to install chargers.

Fleets

- This segment is considered 'private': only the designated fleets can use these charge points. A member of the general public cannot.
- We estimate that fleet-focused charge points will amount to two to three per cent of the total installed base by 2030. These will require rapid chargers.
- Public transport: cities have begun to roll out e-buses, which charge up at designated depots.
- Private fleets: taxis, local authority or government fleets, car club vehicles, etc. charge up at specified depots or hubs.
  - Fleets have seen the fastest uptake of EVs, and currently make up the largest proportion of new vehicle registrations. See Figure 3.

Figure 3. New EV registrations in the UK, 2017



Source: Chargemaster, Barclays Research

Residential and fleet charging are seen as purely 'private', meaning they are not available to the general public. They are not included in the previous estimates in this paper for the number of chargers and amount of investment required. Our estimates apply to just the two main types of public charging: Around town and En route.

Around town

- Public charge points will be required for the 40–50 per cent of homes that do not have off-street parking,[8] or for drivers who wish to top up when they are out and about.
- This segment uses Level 2 or 3 AC chargers, as vehicles are assumed to be parked for an hour or more.
- Kerbside charging is provided in residential neighbourhoods for people who do not have off-street parking.
- Destination charging is offered at locations such as public car parks and retail parks, where there are available spaces and vehicles are parked for a longer time.
- Commercial establishments can be motivated to offer the service as an amenity, since they will be able to generate profit from the sale of goods and services while customers wait for their EV to charge up.

En route

- This segment requires DC rapid and ultra-fast charging, and is expected to be the fastest-growing in the coming years.
- Site operators earn profit from the premium charged per kWh for the cost of a charging session.
- Urban fast-charging hubs: the electric version of a petrol station.
  - Some of the Go Ultra Low Cities, such as Oxford, Bristol and York, are installing such hubs.
- Motorway service areas: these are equipped with a mix of rapid and ultra-fast chargers (when introduced) for motorists travelling long distances.
  - As the high-voltage transmission network runs along highways, National Grid has studied 50 strategic motorway locations where sites of up to 100 350kW chargers could be located.[9]

The particular characteristics of EV charging mean both the Around town and En route segments will coexist and complement each other. Drivers can access charging at a location, speed and price point that best suits their needs.

5. DC or not DC? That is the question

The recommended ratio of EVs per charge point is a matter of debate. With slow charging, the ideal ratio is about 10 EVs per charger (the EU recommends this). With rapid/ultra-fast charging, various research reports suggest that there can be anywhere from 80–1,800 EVs per charger.[10]

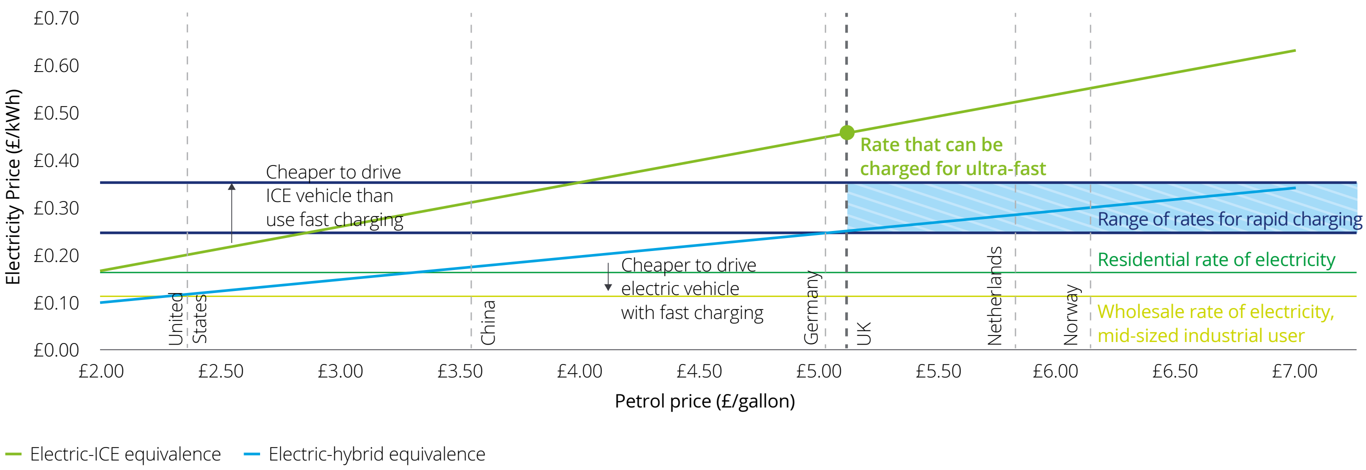
AC charging is currently the most common method, and is likely to remain so until at least 2022. Approximately 90 per cent of chargers in Europe and the US are AC, used in the home and in the workplace. Yet, their slower speed means that the business case for setting up independent AC charging in the future becomes less compelling as batteries become denser and are able to accept more power.

Both AC and the slowest DC chargers can work in the parking-based Around town segment. EV drivers 'top up' while going about their daily business. With their cheaper costs, they will be provided by businesses with other main revenue streams looking to attract footfall, such as leisure centres, restaurants and shopping malls.

DC fast-charging segments seem more suitable as a stand-alone commercial proposition. The upfront investment required can be substantially higher. On top of the more expensive hardware costs, rapid DC charging usually also requires new power connections or substantial reinforcement to the grid. Yet, faster speeds enable operators to charge a premium over the retail price per kilowatt, which means the model can be profitable even at lower levels of capacity utilisation.[11]

The key assumption is that the prices set by operators of EV charge points should be higher than the wholesale price per kilowatt, but lower than the equivalent cost of a gallon of petrol.[12] For example, medium-sized users (annual consumption between 500 and 2000MWh) pay a wholesale electricity tariff cost of around £0.11/kWh. The average residential charge (what it costs to charge at home) is £0.14/kWh. The price for rapid DC charging ranges from £0.25 to about £0.36/kWh, a margin of 14p–25p above the wholesale rate. The upper limit that prices for charging could go to reach equivalence with a gallon of petrol would be around £0.45/kWh, which is more than three times the residential rate. This upper limit is where we would expect ultra-fast charging to be priced. See Figure 4.

Figure 4. Pricing rationale for fast charging



Sources: Deloitte analysis, ICCT, Zap Map, Berenberg

Figure 4 suggests a few levers at the government's disposal to 'nudge' consumers to switch to EVs. Implementing the long-deferred rise in petrol tax would increase the cost per gallon and so the cost of running a conventional or hybrid vehicle (the diagonal green and blue lines) compared to an EV. The government could also increase the Vehicle Excise Duty (VED) or expand the scope and number of Low-Emission Zones (LEZs). Raising the price of operating conventional or hybrid vehicles should persuade some drivers to purchase EVs. The new upper limit of prices should also give charge point providers a wider range of prices that they can charge consumers, assuming the price of energy remains broadly the same.

Due to the current technological limits for both cars and chargers, the viability of rapid and ultra-fast charging has yet to be proven. But there is some activity in this area. Market players are looking to install rapid charging networks that are much larger in scale than earlier deployments, both in terms of the number of chargers and speed. As an example, in 2018 the UK's PodPoint committed to set up its first 150kW chargers, with plans to roll out 350kW chargers later.[13] Auto manufacturers are collaborating to fund open networks. See Figure 5 for examples of the various ultra-fast networks in operation or under development.

Research by Serradilla, Berenberg and the ICCT suggests that higher-priced charging can be profitable at certain utilisation thresholds, where EVs make up about five per cent of the total number of vehicles in circulation, and hardware costs follow the same downward trajectory that has been seen in the past for AC chargers.

Figure 5. Large-scale fast-charging networks in principal markets

Network name	Region	Number of fast chargers	Station types	Major partners and funders	Timeline
Electrify America	United States	About 1,800	CHAdeMO, CCS up to 350kW	Volkswagen	Cycle 1 to be completed in June 2019, with activities continuing until 2027
Ionity	Europe (19 countries)	About 400	CCS up to 350kW	BMW, Daimler, Ford, and Volkswagen with its subsidiaries Audi and Porsche	Under construction through 2020
Trans-Canada	Canada (Ontario and Manitoba)	102	CHAdeMO, CCS	Natural Resources Canada, eCamion, Leclanche, SGEM	In operation by early 2019
Porsche	United States	189 dealership locations	Unknown, 800 volts	Porsche (Volkswagen Group)	Unknown; likely to coincide with launch of Mission-E in 2019
State Grid	China	10,000 locations, 120,000 units	GB/T	State Grid	To be completed in 2020. 29,000 stations in 2018
Rapid Charge Points for London	Greater London, UK	300	Unknown	Transport for London	150 by end of 2018; all to be completed by 2020
Ultra-E	Germany, Netherlands, Belgium, Austria	25 locations, 50–100 chargers	350kW	Allego, Verbund, Smatrics, Bayern Innovativ, Audi, BMW, Magna, Renault, Hubject, European Union	Completed in 2018
MEGA-E	Central Europe, Scandinavia (20 countries)	322	350kW	Allego, Fortum Charge & Drive, European Union	Construction from 2018–2025
NEXT-E	Eastern Europe (6 countries)	252	50–350kW	E.ON, European Union, MOL Group, PETROL, Nissan, BMW	2018–2020

Source: ICCT

6. The infrastructure value chain

The value chain has multiple discrete parts that are integral to an end-to-end service, but no single sector has a competitive advantage in all parts. The four main activity areas are: electricity generation and distribution; charge point manufacture, installation and maintenance; software for network management; and customer services.

Power supply

This covers all aspects of power provision, from generation (including renewables and decentralised sources) to transmission and distribution. It also includes all aspects of grid investment: the medium-to low-voltage networks in particular will need to be substantially upgraded.

At current rates of EV uptake, grid capacity is not a constraint, due to the dominance of AC chargers. More power will be required in the future to support DC rapid and ultra-fast chargers, particularly those installed in urban fast-charging hubs or along motorways.

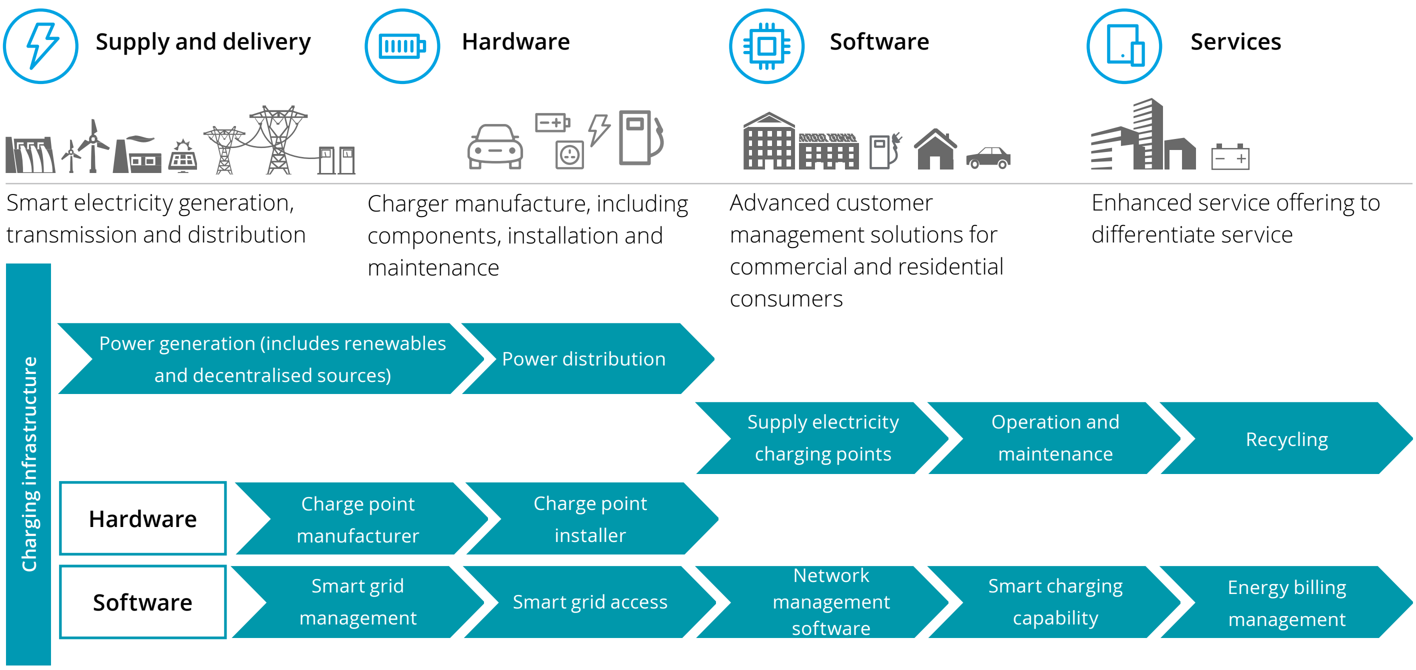
Charge point hardware

This is the manufacture of charge point hardware, including all parts and components, installation and maintenance, and charger retailing.

Since 2011, there have been substantial reductions in the cost of both AC and 50kW DC hardware. This trend is expected to continue in the future, although at a slower rate.

New technologies, such as inductive or 'wireless' charging, are being tested at present and are likely to be commercialised by 2030.

Figure 6. The EV charging infrastructure value chain



Software

A key part of commercial EV charging, the software component can come bundled with the hardware or as a stand-alone service. It includes the back-office functions, such as billing, with different pricing structures for time of use or speed, and metering. It also involves data provision for network management, and customer interfaces, such as apps that help EV owners identify empty charging points and book charging sessions.

In future, software will enable more complex features and services. For example, EV owners can enter parameters, such as when they need their EV fully charged, whether they want to use green energy, or when rates are cheapest. It can also link to retail organisations offering loyalty programmes or discounts on goods and services.

Services

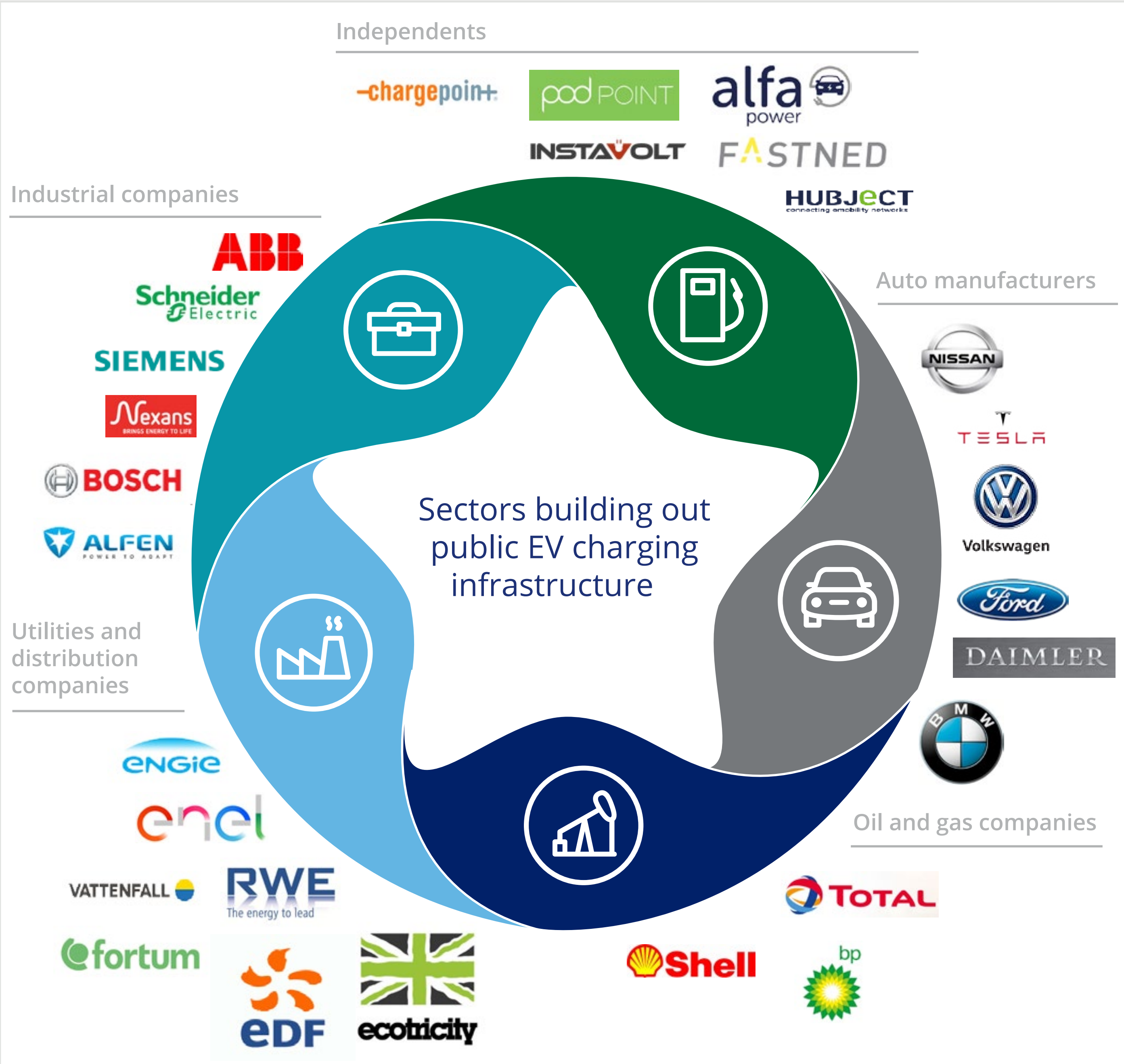
Charge point operators will seek to offer a range of services to differentiate themselves in an increasingly homogenised market. Site hosts will offer amenities for use while charging, and we foresee that new roles will be created in this evolving market, such as those of EV infrastructure designer or developer, or EV concierge connecting providers with customers, or developing incentive schemes.

Who is coming into this market?

The EV charging infrastructure market is young and fragmented, and companies from different sectors are entering. They need to act fast, but then be prepared to wait. EV charging is not profitable at present, but this should change once EVs make up at least five per cent of vehicles in circulation, or about two million units.

See Figure 7 for a sample of some of the market entrants.

Figure 7. Companies participating in markets for EV charging infrastructure



Source: Media analysis; companies' public information; Deloitte analysis

Energy companies

Utilities and distribution companies are set to benefit enormously from a switch to EVs. In addition to offering packages for their existing customers and providing services around EV home charging, many are moving into public charging infrastructure installation, particularly of DC charging points.

These companies have experience in many parts of the value chain. Their knowledge of the grid means they can identify good locations. Many have been actively acquiring smaller independents to add capability.

Industrial companies

Large industrial companies such as Schneider and Siemens are moving into charge point infrastructure, particularly as the market for fast charging expands.

The most successful companies will be those with expertise in power systems and which can offer hardware bundled with software. The record on this front for many of the big industrial conglomerates has been mixed.

Auto manufacturers

Original equipment manufacturers (OEMs) have the most to gain by ensuring sufficient infrastructure is in place to support EV adoption.

They do not manufacture the chargers themselves (Tesla is the exception here) but rather partner with hardware providers to supply homes and workplaces. They have relied on public networks to support EV drivers, although this has started to change; as Figure 5 indicates, they are now partnering to set up large-scale charging networks.[14]

Independents

Successful independents have maintained their market share against larger industrial companies thanks to their strong software and sales channels. Some are end-to-end providers, selling hardware, software and management of the network. Others focus on specific aspects of the value chain, from providing the charge points, to developing network management solutions, to payment provision.

A number of private start-ups are active in this space thanks to big-league backers: venture capital firms or private equity houses, as in the case of Instavolt, or investment from BMW, Daimler and Siemens in the case of Chargepoint, the largest provider in the US.

Many independents focus exclusively on a specific segment: in the UK, Hampshire-based Instavolt, which uses Chargepoint equipment, installs, owns and operates rapid EV charging hubs, and is vying to be the largest player in its segment. It plans to develop more than 3,000 locations by 2020. Another rapid-charging specialist, Engenie, has partnered with ABB, Swarco and Investec.

Oil and gas companies

Two of the largest independent charging operators in Europe were acquired by oil and gas companies. Shell acquired NewMotion, the largest network in Europe, in October 2017. BP purchased Chargemaster, the biggest network operator in the UK, in June 2018.

More deals are likely to happen in the future, as oil and gas majors with downstream networks seek to diversify. Total Oil & Gas purchased EV smart charging software provider G2mobility, and partnered with Nexans, a cable manufacturer, to develop an EV charging proposition.

Other companies

French conglomerate Bolloré has moved aggressively into 'electromobility'. It runs London's network, Source London, on behalf of local councils.

7. Models seen elsewhere

There are a number of models for charge point ownership and management.[15]

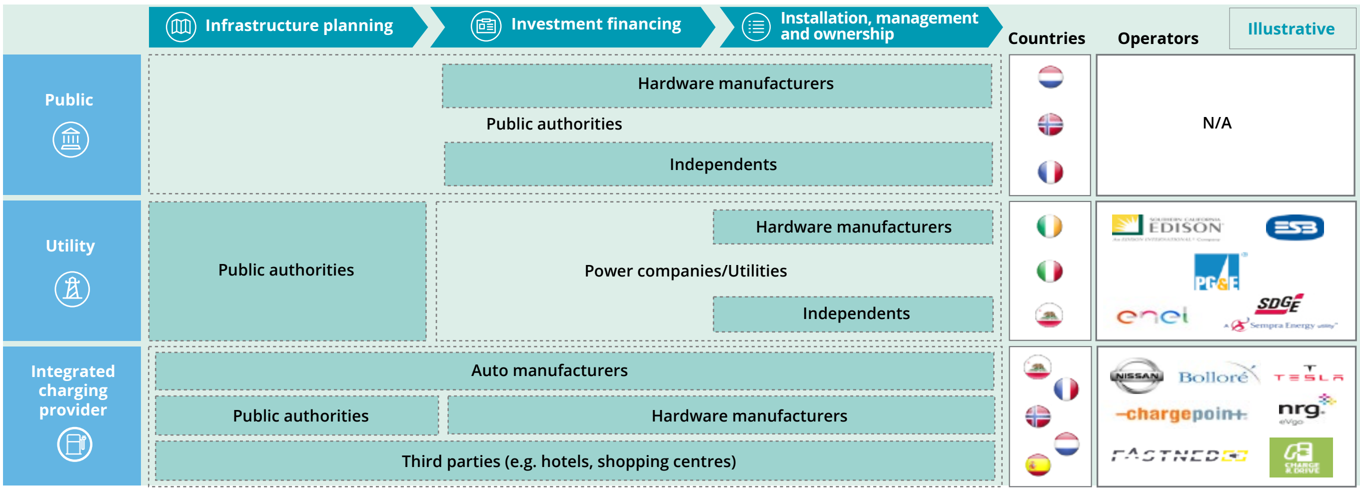
Public charging infrastructure is important for encouraging uptake, but it is unprofitable in the early phases of EV adoption. This has led to a variety of adoption models across the three main stages of deployment: planning; financing the investment; and installation, ownership and management. See Figure 8.

Figure 8. Charging infrastructure deployment models

Infrastructure planning
Governments in many advanced countries, such as EV market leaders Norway and the Netherlands, have drafted ambitious plans for EV charging infrastructure. It then falls to local authorities to carry out these plans through local planning, coordinating, and licensing.

Financing the investment
The active participation of public authorities is needed initially to create economic incentives. Private agents then take over the development of charging stations and kerbside posts. In some cases, the government continues to manage the equipment.

Installation, ownership and management
This phase is critical in the roll-out, especially in the earliest stages, as managing the infrastructure does not provide a revenue stream that enables the recovery of operating and maintenance costs.



Source: Media analysis; companies' public information; IA-HEV; ICCT; Monitor Deloitte analysis

We expect to see three models prevail in the coming years. The public model has been necessary to 'prime the pump' in most of the more mature markets. This is likely to continue, to ensure equitable distribution of public chargers as public goods. The utility model suggests a deep-pocketed player with a key competency can come into the space and own a large share of the value chain; we expect to see the oil and gas majors competing here by 2030. And the various approaches to charging mean that a number of smaller, independent firms can also find a niche to exploit. One thing is clear: multi-faceted and collaborative approaches have been the most successful in promoting the early build-out of the charging infrastructure.[16]

Public model

Public authorities set out plans and offer public funding that private companies use to recover at least a portion of the investment costs.

This is the most prevalent model to date in the UK. The government has come out very strongly in support of EV adoption and the supporting infrastructure. It has detailed a variety of policy initiatives[17] and followed up with an array of funding schemes. These include assistance to purchase EVs, and to install charge points at home, at work, and on public land owned by local authorities.[18]

As an example, the government created the Go Ultra Low City Scheme.[19] Cities across the UK competed for part of a £40 million pot by launching initiatives to promote EV uptake. The goal was to develop local networks and set an example for other cities. A total of eight cities were awarded grants: London, Milton Keynes, Bristol, Oxford, York, Dundee, Nottingham and Derby.

A parliamentary inquiry found that the record among UK local authorities is somewhat mixed. Many face significant challenges in three key domains: funding, technical expertise, and coordination with distribution network companies,[20] resulting in vastly different charge point coverage between regions and areas.

The public model is likely to remain dominant in areas where the business case is difficult for private sector players, either because the customer base is small or the costs of connecting to the grid are high. In particular, provision of rapid or ultra-fast charge points in rural areas will probably require some form of government subsidy. In such cases, local authorities will need to engage with other government bodies, motorist organisations, tourism promotion boards, charge point providers or electricity distribution companies to identify mutually agreeable solutions.[21]

Utility model

In this model, electricity distribution companies (Distribution Network Operators and Distribution System Operators) finance and own the infrastructure, and recover the investment, operating and maintenance costs through electricity tariffs. In some US cases, DNOs outsource infrastructure management to third parties.

This model, prevalent in Europe, can enable rapid deployment of unprofitable charging infrastructure, essential for the initial adoption of EVs, that private sector players are reluctant to develop, such as charging points in residential areas.

In the UK, the 'Big Six' and challenger energy suppliers are active in EV charging. Many already offer packages for customers who charge at home.[22] They are now stepping up investment in public charging infrastructure, either developing their own networks or managing the hardware for others.

As an example, the Irish state-owned utility ESB, through its subsidiary ecars, runs the Northern Ireland network, ecarNI, and also operates rapid EV charge points in London.[23] And Ecotricity, an independent energy supplier, runs The Electric Highway, a national network. It has partnered with motorway service operators Moto, RoadChef and Welcome Break (now part of Applegreen) to offer 45-minute fast charges.

Many of the big utility-owned networks active on the continent are coming to the UK. Swedish energy company Vattenfall announced in April 2018 its plan to launch its (Nordic) network InCharge in the UK. It has partnered with South Norfolk Council to install and operate 20 charge points in five car parks.[24]

Some companies have sought to build out their EV charging capability by acquiring smaller independents. Engie acquired Dutch charging manufacturer EVBox, one of the biggest in Europe, in 2017. And Centrica invested in Driivz, a software company specialising in managing EV fleets and charging networks, to create a new offering, Centrica Electric Vehicle Services (CEVS).[25]

Integrated charging model

Here, private companies lead: independents, auto OEMs, oil and gas majors, hardware manufacturers and other new entrants to the EV charging field operate in specific segments and work with partners to deliver an integrated service. Generally, the infrastructure is installed and managed by its owners or by specialist companies to which the owners outsource these activities.

The role of host is an important aspect of this model. Hotels, shops, car parks and others install charge points at their facilities as an incentive or additional benefit to customers. Motorway service operators have become major partners with the hardware, software and power companies to take advantage of their locations.

The main challenge facing this model is the reliability of future revenue flows to recover the investment, and the operating and maintenance costs, particularly if the primary objective is to provide an additional service to customers. As the number of EV cars in circulation grows, utilisation rates should also increase, and this will improve financial performance.

A word about the grid

EV uptake is likely to grow once rapid and ultra-fast chargers become more widespread.

The expansion of fast charging networks will need to be managed in concert with grid upgrades. This will be particularly important in locations where EV uptake is high, where the existing network is weak, or where high-power charging is required (urban fast-charging plazas, motorway service areas and fleet depots).[26]

For rapid and ultra-fast hubs, utility upgrade costs represent a significant part of the investment. In an analysis of the 50kW chargers at the Rapid Charge Network stations along the highways, hardware costs ranged between 50 and 60 per cent of total capex; site preparation ranged from 26 to 31 per cent; and new power connections and installation 12 to 21 per cent.[27]

Strategies can be implemented to alleviate the impact. One is smart charging: EV drivers respond to signals from the grid (such as pricing or energy supply) to stop, start or moderate charging.

Another approach is to build chargers at locations with ample capacity and low installation costs. According to National Grid, 60 per cent of the 165 motorway sites in England and Wales are within five kilometres of the transmission network infrastructure, and 20 per cent of those are within one kilometre. They estimate that establishing ultra-fast charging at 50 strategic motorway service locations would enable 95 per cent of drivers in England and Wales to be within 80 kilometres of a charging station. The cost for grid upgrades at these 50 locations would be £500 million to £1 billion.[28]

A third strategy that National Grid is working on is to combine fast charging with stationary energy storage. It has embarked on a £1.6 billion programme to install a 2GW battery network spanning 45 electricity sub-stations across the UK over the next five years. To date, three sites have received planning permission – Southampton, Carlisle and Norwich – and another ten are in the pipeline for 2020.[29]

8. Next steps

The opportunities in this space are vast and varied, thanks to the different ways EV drivers can access charging. But it requires patience.

It is reminiscent of the Wild West of yore: a lot of eager prospectors dream of striking it rich and are coming in to stake their claim on a particular patch.

Companies looking to enter the market need to get going now, and then be prepared to wait. Good sites will be important drivers of utilisation, and hence profitability. And network advantages will accrue to first movers. But the critical mass – around five per cent of cars in circulation – will not be reached until the mid-2020s at the earliest.

This suggests that the most successful entrants will have deep pockets, or strong partnerships – ideally both. It is difficult for any single player in this space to excel across all parts of the value chain, and partnerships will be key to delivering end-to-end solutions.

The viability of the business models will depend on a variety of factors: uptake in the local area, access to sufficient power, a good location, and adequate utilisation. It will also depend on how well companies can create a differentiated offering around convenience, cost and reliability; manage technological developments; and scale quickly.

Companies that choose to operate in the AC segment should be able to service high volumes, and have alternative revenue streams to package with the sale of charging. DC segments will not have to worry as much about amenities or other services, but will need to ensure they can provide sufficient power at the right price. If too low, they will not recoup the investment in a reasonable time frame; and if too high, customers will charge elsewhere.

In any segment, there are key drivers behind the strategy, delivery and technology required to succeed. Here are some points that should be considered.

Strategy:	• Do you have a winning strategy, including a clear market focus (by geography, or consumer segment)? • Is your strategy financially viable (do you have funding over a long enough time period)?
Delivery:	• Have you got a clear business model? • Do you have the capabilities you need to deliver your strategy? • Have you agreed ownership and governance with partners? • Installation, especially for rapid and ultra-fast chargers, will be a critical issue. Do you have a project management team with the right capabilities to manage installation? How about operations and maintenance?
Technology:	• Have you sorted out the back office? • Are you sufficiently future-proofed?
External:	• Have you made arrangements and secured the necessary approvals from the local authority? The DNO? Ofgem? Others? • Are you compliant with all relevant standards?

9. Appendix: Investment calculations

We used the following approach to estimate the required investment in EV charge points.

Define scenarios of charge point deployment to 2030
We undertook a review of the literature to assess the range of scenarios and the drivers of infrastructure growth around the UK for five types of EV charge points.

As a starting point for our estimates, we adopted the range set out by the Committee on Climate Change (CCC) in their 2018 *Plugging the Gap* paper,[30] which covers the parking-based Around town and the long-distance En route rapid-charging segments.

We made some adjustments, in particular replacing their Level 1 AC chargers (anything up to 11kW) with Level 2 AC charge points (11kW and faster), on the assumption that batteries will become denser and the driving range longer, so that more power will be needed to charge a battery fully (e.g. overnight).

We validated these scenarios by comparison with National Grid's *Future Energy Scenarios (FES)*[31] and UK government targets as laid out in the 2018 *Road to Zero* report.[31]

This gave us an estimate of charge point stock over time.

Estimate the number of new charge point installations needed
We estimated the number of new charge points needed in each year of the analysis. Taking the 2018 deployment data from Zap-Map and our 2030 end point, we calculated an annual deployment rate for the new stock needed per year. We then estimated the turnover of installed stock, assuming a lifespan of five to seven years.

Estimate unit costs
We undertook a review of the literature on charge point costs. We then used a range of approaches for the different technologies. For some, we used existing cost estimates and technology cost reduction curves (e.g. based on Berenberg estimates). For others, we used estimates from other sources (such as CCC's *Filling the Gap*, the Electric Vehicle Supply Equipment Association[33] and the Energy Saving Trust[34]. We then added estimates of grid reinforcement costs based on analysis by Serradilla et al. (2017) and the National Grid *FES*.[35]

Estimate installation costs
We applied the relevant unit costs of first-time installations and subsequent replacements to the estimates of new charge point installations and charge point replacements. See Figure 9.

Figure 9. Investment costs to 2030 in three scenarios

Uptake scenarios				Low	Central	High
Total number of cars in circulation				39.0 million	39.0 million	39.0 million
Total number of EVs				2.6 million	7.0 million	10.6 million
	Type	Speed	% of total chargers			
Around Town Model	Stock of charge points needed by 2030			13,500	27,000	35,000
	Level 2 AC	11kW	16%	£5m	£10m	£10m
	Level 3 AC	22–42kW AC	55%	£170m	£400m	£535m
	DC Fast	50kW DC	29%	£125m	£345m	£475m
En route Model	Stock of charge points needed by 2030			710	1,170	1,300
	DC Fast	50kW	16%	£5m	£10m	£10m
	DC Rapid	150kW	55%	£20m	£45m	£50m
	DC Ultra-fast	350kW	29%	£495m	£815m	£905m
Total				£0.8bn	£1.6bn	£2.0bn

Limitations
Scope: This analysis looks only at the capital expenditure for charge point equipment (including turnover of existing stock), installation and grid reinforcement. It does not include wider costs such as those for land or ongoing operations such as maintenance, or energy costs. Nor does it factor in broader benefits, such as reductions in greenhouse gas emissions due to EVs.

Accuracy: The estimates are indicative only, owing to substantial uncertainty in the estimates of EVs and for the EV charge point market.

Exclusions: These estimates do not take into consideration the deployment of all potential technologies, such as dynamic inductive charging. The analysis is deliberately simple and aims to focus on the key technologies within the period of analysis.

End notes

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10. Key contacts

Authors

Justine Bornstein
Insight Senior Manager
jbornstein@deloitte.co.uk
+44 20 7303 2569

Tom Bain
Economic Consulting Manager
tbain@deloitte.co.uk
+44 20 7007 3486

Contacts

Mark Lillie
Power & Utilities Leader
Energy, Resources & Industrials
mlillie@deloitte.co.uk
+44 20 7007 2395

Duncan Barnes
Partner, Deloitte Digital
Energy, Resources & Industrials
dbarnes@deloitte.co.uk
+44 20 7303 8529

Arran Taylor
Partner, Tax
Energy, Resources & Industrials
arrtaylor@deloitte.co.uk
+44 11 3292 1118

Julian Small
Industry Leader
Energy, Resources & Industrials
jsmall@deloitte.co.uk
+44 20 7007 1853

Oliver Holder
Financial Advisory Leader
Energy, Resources & Industrials
oholder@deloitte.co.uk
+44 20 7007 8688

Marc O'Connor
Consulting Leader
Energy, Resources & Industrials
maoconnor@deloitte.co.uk
+44 20 7303 5324

Tim Archer
Risk Advisory Leader
Energy, Resources & Industrials
tarcher@deloitte.co.uk
+44 20 7303 4484

Roman Webber
Tax Leader
Energy, Resources & Industrials
rwebber@deloitte.co.uk
+44 20 7007 1806

James Leigh
Audit Leader
Energy, Resources & Industrials
jleigh@deloitte.co.uk
+44 20 7007 0866

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