State of Charge

Investment Opportunities in EV Charging

Industry Background From Longspur Research

19 September 2019
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Industry background research available to all professional investors under MiFID II as a minor non-monetary benefit

STATE OF CHARGE

Government bans on new fossil fueled vehicles in many major economies are likely to drive significant growth in electric vehicles ("EVs") over the next twenty years. This will create growth in electricity demand from EV charging. The volume of energy to be supplied creates opportunities for both supply companies and generators and the provision of charge points is already creating a new industry. However, the timing of this demand puts pressure on local distribution infrastructure. While smart charging and vehicle to grid technology offer solutions, we believe these will only be partial given likely charging behaviour and as a result there will be demand for additional grid capacity and for other solutions. These other solutions include charger located storage and distributed generation.

A major new source of electricity demand

EV charging could add up to 25% to UK peak electricity demand by 2050 if not managed. The timing of charging is also likely to magnify existing demand swings. The potential impact in other developed electricity networks is likely to be of a similar order. Smart charging and vehicle to grid ("V2G") solutions can mitigate or even eliminate these effects. We think these solutions will be limited by actual driver behaviour but even if they work nationally, local demand will vary and many locations will see demand pressure. This will put a significant strain on distribution infrastructure, and we expect the cost of connecting a charger to rise where grid reinforcement is required.

Welcome to the grid grab

As a result, there is a land grab going on now to find good sites with adequate grid connections. Those who have or can still find good sites and those who supply them look well placed. For weaker sites, options also exist to co-locate storage or distributed generation at charging points, creating further opportunity for those companies who can provide effective solutions here. We also think the wider impact will create opportunities for grid connected storage and other forms of flexibility.

Investment opportunities in public markets

Investment opportunities exist in a number of categories. Electricity supply companies are already carving a niche in supply for charging or other EV related services. Transmission and distribution companies should benefit from increased infrastructure spending although profitability will depend on regulation. Charge point operators and developers can do well if they can find the right sites. Storage system providers have already found early wins in charging and we see this market growing. Likewise, providers of distributed generation solutions should find demand.

Industry background from Longspur Research

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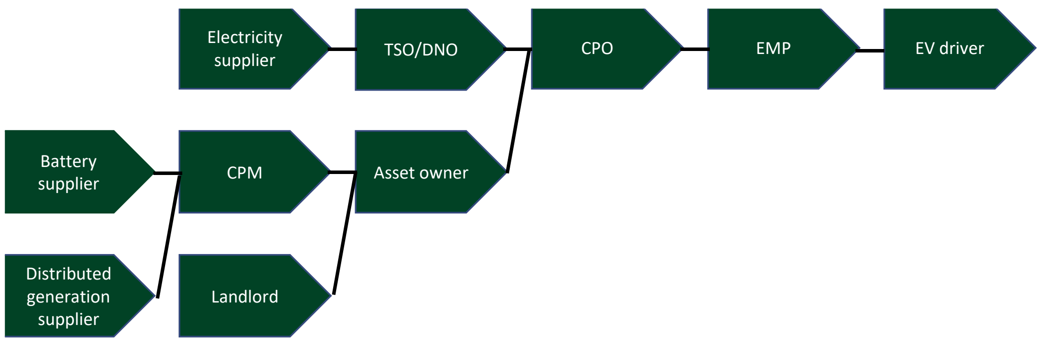
THE EV CHARGING MARKET

EV charging is location dependent and equipment focused. Perhaps the core role in the industry is that of the charge point operator ("CPO") who normally develops and manages charge points. The points themselves may be owned and financed by a third party and manufactured by a charge point manufacturer ("CPM"). Storage or distributed generation systems may also be provided either directly to the asset owner or through the manufacturer. The relationship with the EV driver is often via an e-mobility service provider ("EMP") who will contract with many CPOs to provide a charging service to drivers. The CPO will also contract with the grid (in the UK this is normally the local distribution system operator but in some cases the transmission system operator) and will arrange an electricity supply.

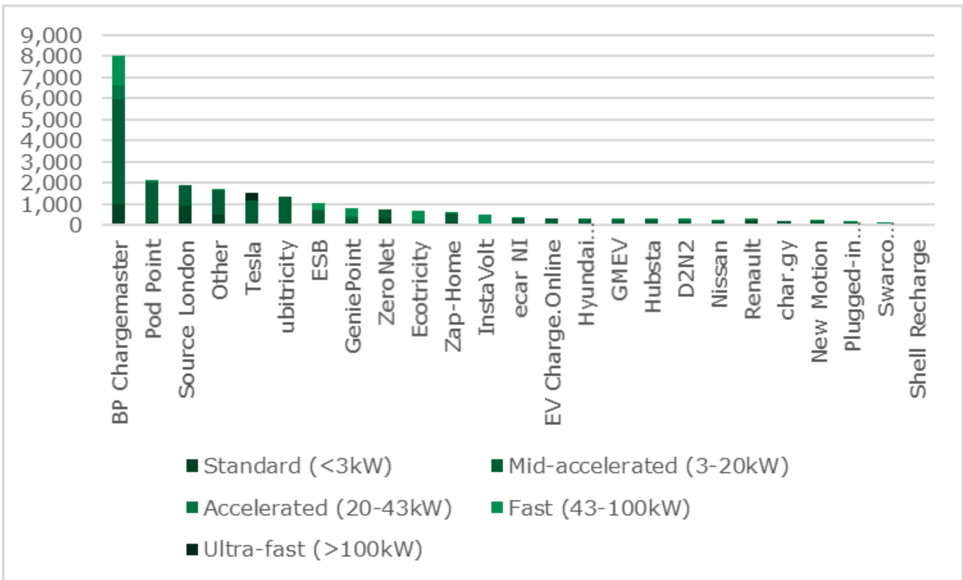
EV Charging Value System



Source: Longspur Research

The UK CPO market is currently dominated by BP Chargemaster although the market is evolving quickly and others are likely to raise their positions. Note that EMPs such as Shell NewMotion also have major postions but do not themselves own significant numbers of chargers.

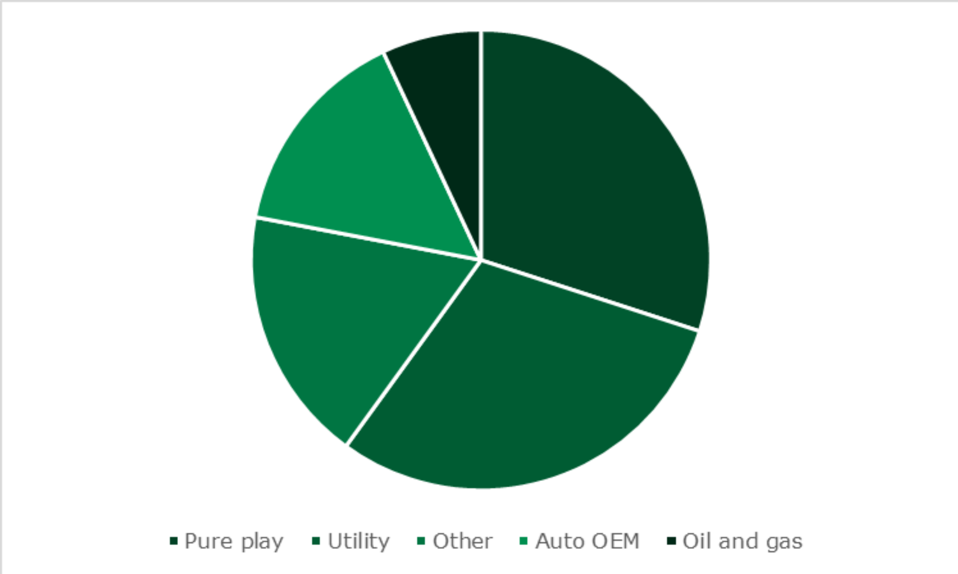
UK Public Charging Connectors by Operator



Source: BNEF EV Charging Points Interactive Database June 25, 2019

There are a number of pure play operators in addition to CPOs owned by utilities, oil and gas majors and automotive OEMs. Globally the majority of CPOs are either pure play or utility owned.

Industry ownership of selected CPOs



Source: BNEF April 23, 2019

INVESTMENT OPPORTUNITIES

Investment opportunities exist in a number of categories. Electricity supply companies are already carving a niche in supply for charging or other EV related services. Transmission and distribution companies should benefit from increased infrastructure spending although profitability here will depend on regulation. Charge point operators and developers can do well if they can find the right sites. Storage system providers have already found early wins in charging and we see this market growing. Likewise, providers of distributed generation solutions should also find growth.

A number of listed companies are exposed to the opportunities arising out of EV charging. This sector note does not contain investment recommendations and investors should undertake further research before considering an investment in any of these companies. Notably, we would highlight the tendency in the new energy space to focus on the opportunities of demand and ignore threats on the supply side such as competition and substitutes.

Site development and ownership - CPOs

There are limited public investment opportunities among CPOs. However the most obvious listed company in the EV Charging space is the recently Euronext listed Fastned (FAST NA). Fastned is a charge point operator and developer with locations across the Netherlands and expanding in Germany and the UK.

Utilities – Grids and major supply companies

TSOs and DSOs such as National Grid (NG/ LN) and SSE (SSE LN) should benefit from increased network expenditure although this will be tempered by regulation.

All the major supply companies are offering solutions in EV charging. Centrica (CNA LN) has signed an exclusive deal with Ford for home charging and also for Ford dealerships in the UK and Ireland. Centrica has also invested in Israeli EV charging software start up, Driivz. Some of the continental majors are going further and developing their own CPOs and EMPs. These include Engie (ENGI FP - EV Box and EPS), Enel (ENEL IM - Enel X), Fortum (FORTUM FH - Charge and Drive), EdF (EDF PF - IZivia) and E.ON (EOAN GR - Eon Drive).

Independent electricity suppliers

Challenger suppliers are also active.

Drax's (DRX LN) B2B retail arm has targeted commercial EV fleets with early success with SES Water.

Yu Group (YU/ LN) is offering buy, rent or hosting options for EV charge points as well as tailored supply contracts.

Perhaps most interesting has been Good Energy's (GOOD LN) acquisition of a 12.9% share in Zap-Map, the leading UK charging app. GOOD has an option to take this to a majority stake within two years.

Storage for charging

Swiss battery developer Leclanché (LECN SW) has been active in developing storage solutions for charging for some time providing storage solutions for a C$17.3m charging network for the Trans-Canada Highway, partnering with the UK's EV Network and Dutch based Fastned.

ENGIE EPS (EPS FP) is now a core part of the agreement between its major shareholder ENGIE and Fiat Chrysler Automobiles ("FCA"). Like Centrica's Ford deal this is targeting chargers for customers and dealers but the involvement of EPS, who have key storage expertise, suggests that this could lead further.

RedT (RED LN) is working with Pivot Power to provide long duration storage for the major Energy Superhub initiative in Oxford. The long duration flow battery should be a natural solution for EV charging.

Smart Metering Systems (SMS LN) has recently acquired Solo Energy which deploys and operates distributed energy storage systems for EV charging as well as developing distributed leger technology (blockchain) to connect and maximise the value from such systems includng a vehicle to grid solution.

Additionally Ilika (IKA LN) is developing its solid state battery as a vehicle battery that will support extremely rapid charging.

Distributed generation for charging

AFC Energy (AFC LN) has partnered with charge point manufacturer Rolec to provide ammonia fuelled generation at the point of charge as a solution to grid constraints.

EV CHARGING

Electric vehicles ("EVs") and in particular battery electric vehicles ("BEVs") look set to become one of the key transport options of the future. Several governments including China, India and the UK have committed to bans of new gasoline and diesel vehicles, leaving EVs as the obvious replacement in the market.

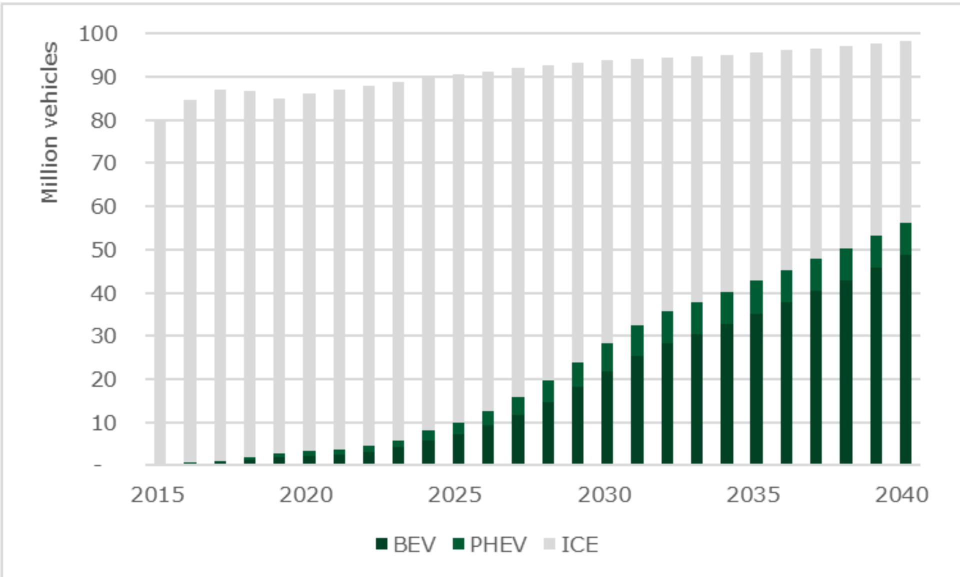
Government commitments to the end of sales of conventional vehicles

Country	Timing
Norway	2025
India, China, Slovenia, Austria, Israel, the Netherlands, Ireland	2030
Scotland	2032
UK, France, Sri Lanka, Taiwan	2040

Source: House of Commons Library Briefing Paper 28 June 2019

The broad view in the automotive industry is that electric vehicles represent the future with the 2019 KPMG Global Automotive Executive Survey showing that the industry expects BEVs to be the leading vehicle type by 2040. Bloomberg New Energy Finance has forecast that new sales of EVs overtake internal combustion engine ("ICE") vehicles by 2038.

Global EV sales forecasts



Source: BNEF 13 June 2019

In the UK, EV's are forecast to grow rapidly with National Grid's scenarios suggesting more than 35m EVs by 2050 with 80% of this figure hit by 2037 in the two most aggressive scenarios. These show 15m EVs by 2032 rising to over 38m by 2038. While the National Grid is very clear that these are planning scenarios rather than explicit forecasts, they are driven by the Government's 2040 target that remains in place and feels politically difficult to backtrack on in our view. The main difference between the scenarios is not the ultimate level of EV uptake but rather the time taken to achieve it.

UK EV penetration forecasts

Source: National Grid FES 2019

Demand per EV

BEV battery capacities range from 16kWh to 90kWh. Because progress in reducing battery density has slowed it is unlikely that individual vehicle battery capacity will grow significantly in the near term with existing lithium ion technology. The battery capacity is reflected in range and of course in charging time.

Battery sizes and ranges for selected EVs

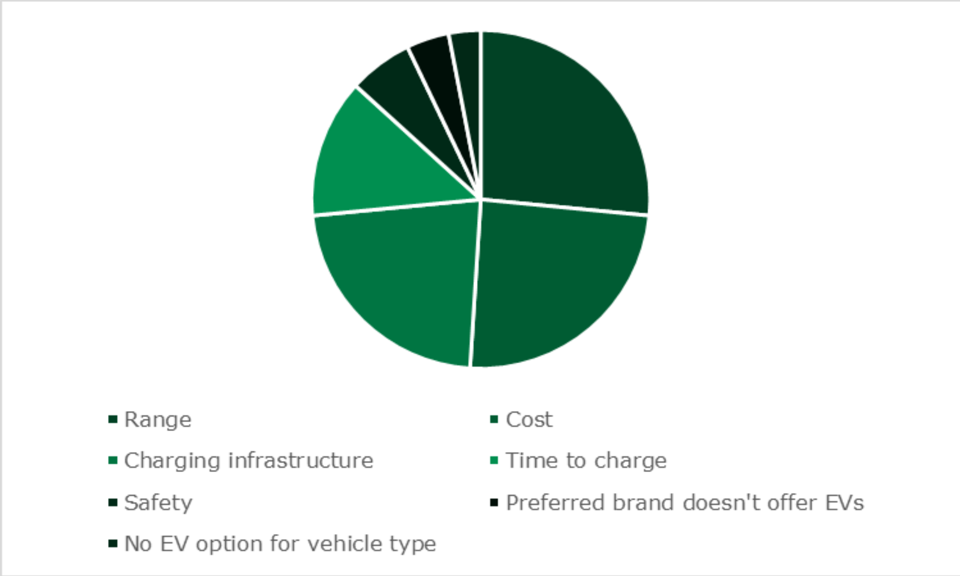
EV make	Battery	Range km (mi)
BMW i3 (2019)	42kWh	345km (115)
GM Spark	21kWh	120km (75)
Fiat 500e	24kWh	135km (85)
Honda Fit	20kWh	112km (70)
Nissan Leaf	30kWh	160km (100)
Mitsubishi MiEV	16kWh	85km (55)
Ford Focus	23kWh	110km (75)
Smart ED	16.5kWh	90km (55)
Mercedes B	28kWh/31.5kWh	136km (85)
Tesla S 60	60kWh	275km (170)
Tesla S 85	90kWh	360km (225)
Tesla 3	75kw	496 (310)

Source: Battery University

CHARGING

The abilty to access chargers is clearly key to EV uptake. While range and cost are the biggest barriers to EV uptake, lack of charing infrastructure and the time taken to charge are important issues to be resolved.

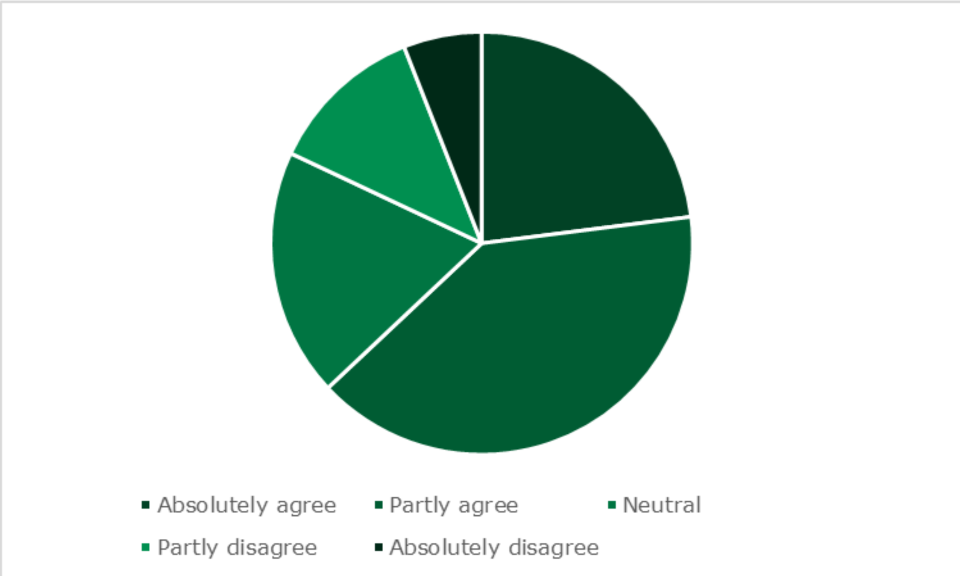
Customer concerns regarding BEVs (UK)



Source: Deloitte Global Automotive Survey 2018

The automotive industry has been cautious about issues around charging infrastructure.

"Battery Electric Vehicles Will Fail Due to Infrastructure Challenges"



Source: KPMG 2018 Global Automotive Executive Survey

Of course automotive industry executives might be seen as a biased sample but the issue remains that charging infrastructure is key to the EV industry.

Charging times

Chargers vary in their power output so charging times can vary.

Charger types

Charger Type	Electric Car Range added
AC Level 1 240V 2-3kW	Up to 15km/hour
AC Level 2 "Wall Charger" 240V 7KW	Up to 40km/hour
AC Level 2 "Destination Charger" 415V 11-22kW	60-120km/hour
DC Fast Charger 50kW DC Fast Charger	Around 40km/10 min
DC Rapid Charger 175kW DC Fast Charger	Around 200km/ 15 min
DC Ultra-Rapid Charger 350kW DC Fast Charger	Around 400km/ 15 min

Source: Western Power Distribution March 2019

The grid is AC and batteries are DC so to connect the two an inverter is needed at some point. EVs have inbuilt inverters to allow charging from AC chargers but in some cars this can itself limit the uptake of power. A DC charger has an inverter in the charger and bypasses the on-board AC charger to charge the battery directly.

Chargers of up to 350kW are now available although few EVs can work with them. The weight of the liquid-cooled cables required at this power rating makes them unwieldy and we think this is an effective limit under existing technology. Wireless induction charging may be a solution here although lithium ion battery limitations also limit charging speed with battery cycle life reducing with charging speed. It is interesting to note that the new Porsche Taycan was originally flagged to charge at 350kW but on launch this has been reduced to 270kW with the LG Chem li-ion batteries quoted as driving the limitation. In time newer battery technologies may overcome these limitations.

The table below shows charging times for a normal range EV with a 28kWh battery and a longer range EV with a 90kWh battery. Note that this is based on the assumption a full charge is given when the battery is 25% empty. Lithium ion batteries do not respond well to deep discharges and drivers are advised to recharge early. A survey in 2015 found that only 24% of EV owners let their battery state of charge fall below 20% before recharging.

Charger timings

Charger rating kW	90 kWh battery (hours)	28 kWh battery (hours)
3.5	19.29	6.00
7	9.64	3.00
11	6.14	1.91
22	3.07	0.95
43	1.57	0.49
50	1.35	0.42
150	0.45	0.14
350	0.19	0.06

Source: National GridLongspur Research

Charger locations

Chargers can be further categorised by location into residential home chargers, workplace and similar destination chargers and public en-route chargers.

Charger location

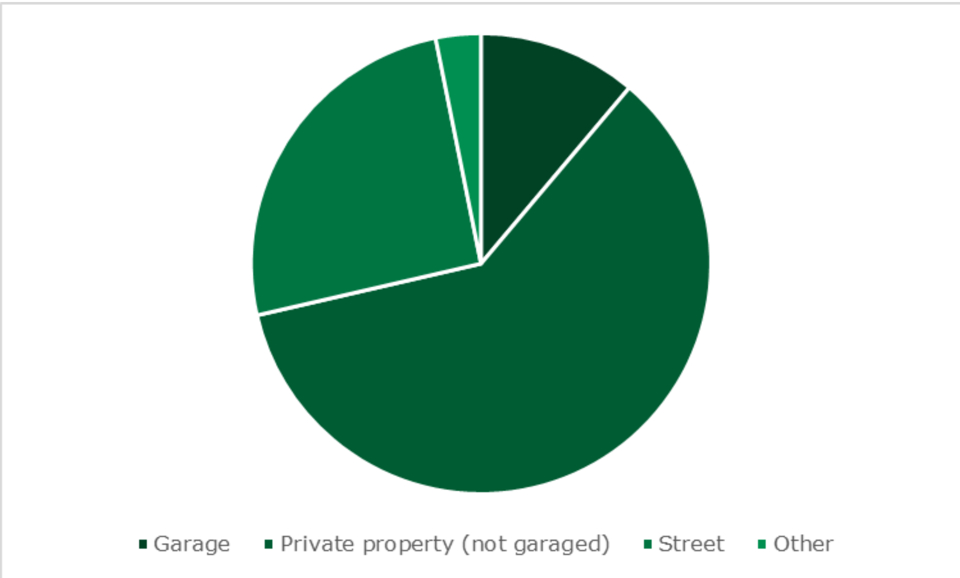
Location Type	Rate	Typical Usage Pattern	Deployment
Home	3-7 kW	Charging overnight	Highest deployment and usage
On-street Residential	3-7 kW	Charging overnight	Not yet common
Work	3-7 kW	Used by commuters during the working day	Low
Slow/fast Public	3-22 kW	Used for short opportunistic charging during the day	Highest public deployment but low usage
Rapid Public	50k W+	Used during the day to support long journeys and those without home charging	Reasonable but growing quickly

Source: Western Power Distribution March 2019

There is an expectation that most charging will be undertaken at vehicle owners own premises using slow charging. One of the perceived benefits of EVs is that they can be charged slowly at home without a visit to a petrol station. Slow charging also helps maximise battery life and can place less strain on the distribution network.

However, this assumes that the car owner has access to off-street parking. In the UK 57% of households have access to off-street parking implying that 43% do not. This figure over-represents non drivers in dwellings without parking and the Department of Transport parking survey statistics give a clearer picture which shows that it is still a significant 25% of drivers without access to off-street parking. As EV penetration grows more owners will need to access public charging.

Where vehicle parked overnight

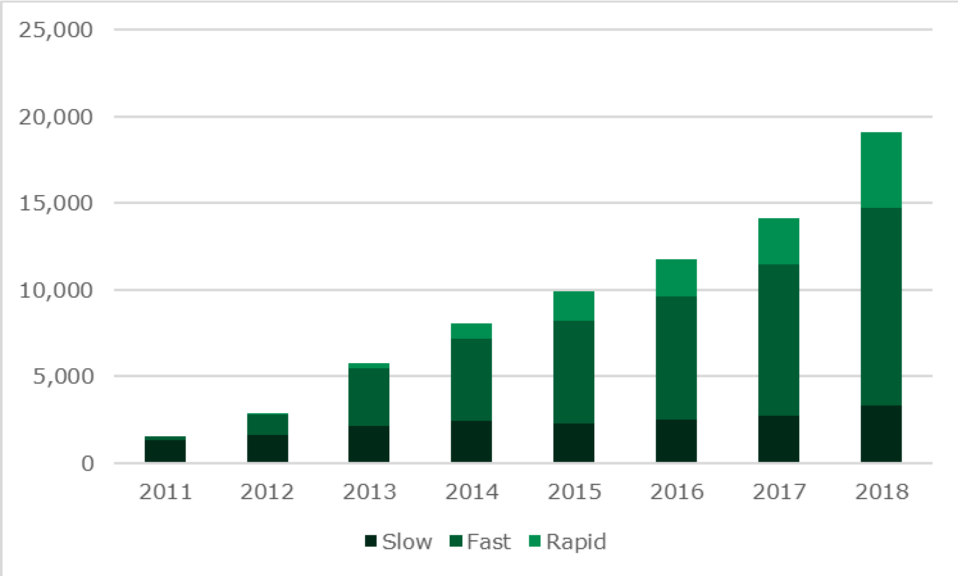


Source: Department for Transport National Transport Survey 2016

Even those charging at home will also want to charge during longer journeys or at other opportunities. Because many of these opportunities will not be overnight there is likely to be more demand at these sites for fast, rapid or ultra rapid charging.

We are already seeing fast and rapid chargers increasing their share of the market and we expect this to continue.

Growth in fast and rapid chargers



Source: Zap Map 2019

Where people charge

An initial assessment of where people charge can be had by looking at where they park.

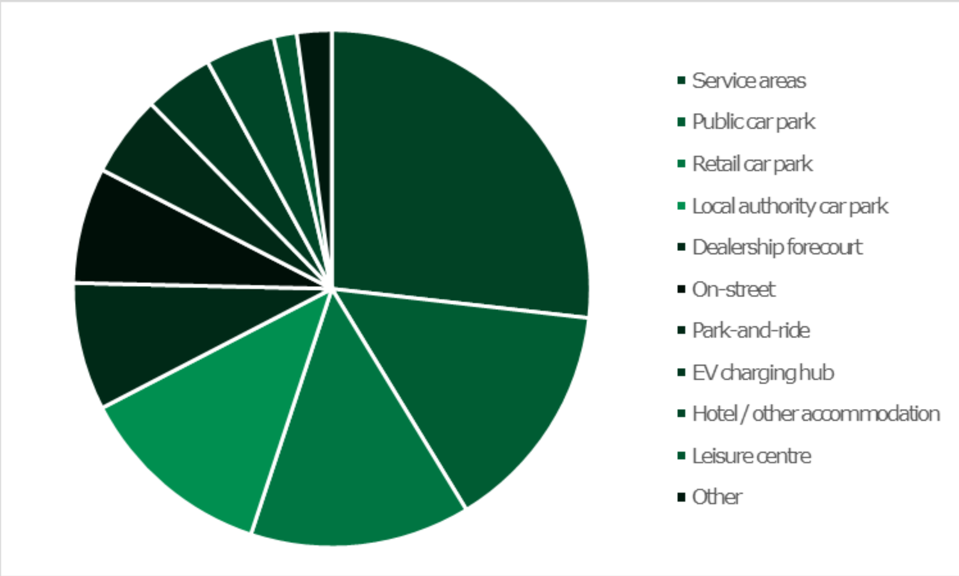
Parking acts by purpose and time

Purpose category	% of parking acts	Average duration (hours)
Work	28	7.6
Employers' business	6	3.5
Education	1	5.2
Personal business	9	1.5
Shopping	17	1.5
Social/recreational	10	2.5
Holiday	<1	12.2
Visiting friends/relatives	8	3.1
Escorting passengers	20	0.8
All purposes	100	3.5

Source: Department for Transport National Transport Survey 2016

A survey conducted in 2016 by Zap-Map shows that charging broadly matches parking with the exception of service station charging which accounts for 27% of daytime charging.

EV location usage

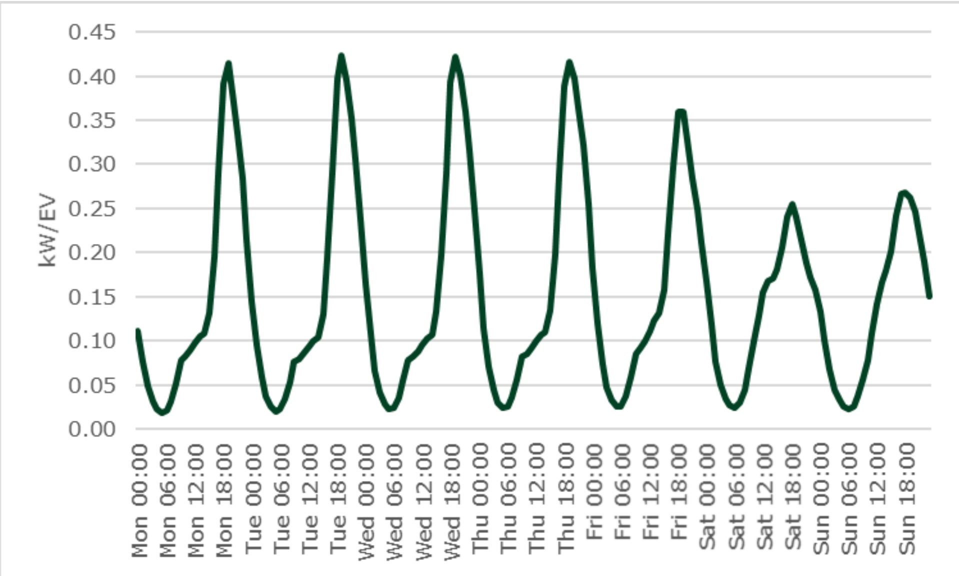


Source: RAC Foundation based on Zap Map July 2012

When people charge

As previously mentioned, most charging will take place at home overnight. This means that charging will start to ramp up from about 6pm with a maximum peak on weekdays between 7pm and 8pm.

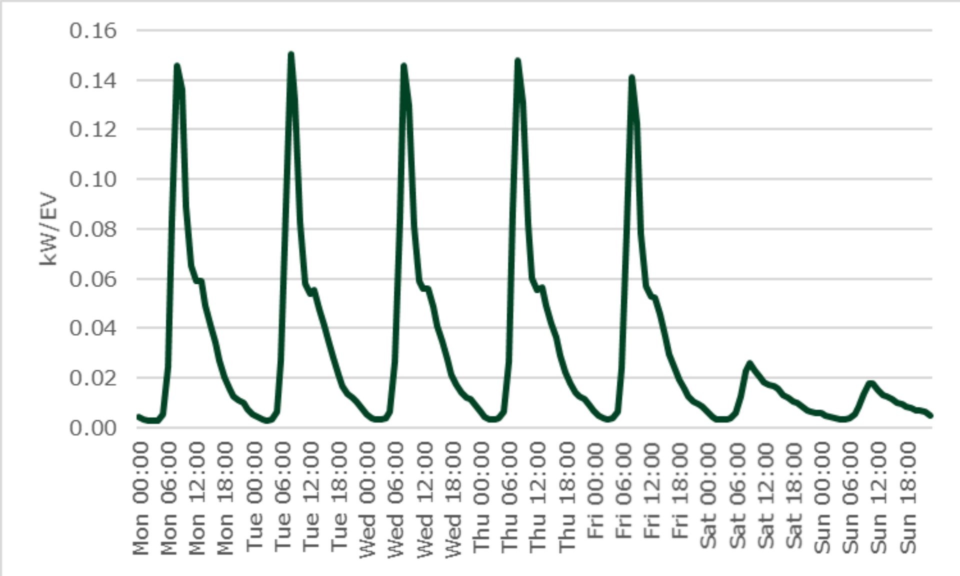
Overnight charging times



Source: National Grid FES 2019

Workplace charging will similarly mainly take place on weekdays with a peak as drivers arrive at work and a small secondary peak after lunch.

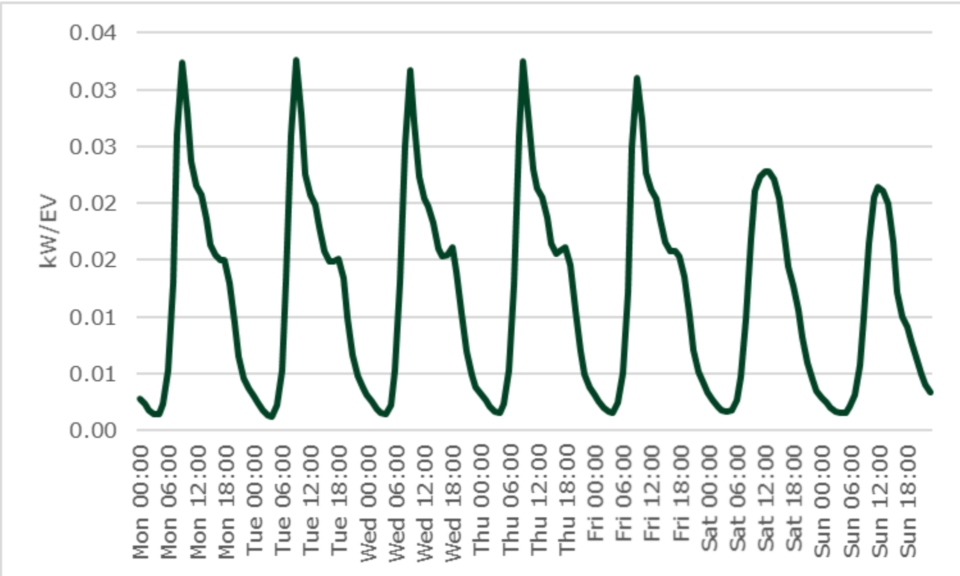
Workplace charging times



Source: National Grid FES 2019

Public charging is also likely to see a morning peak although slightly later than workplace charging and there again a second lunchtime peak but also a third early evening peak. Additionally, weekends see demand remaining strong.

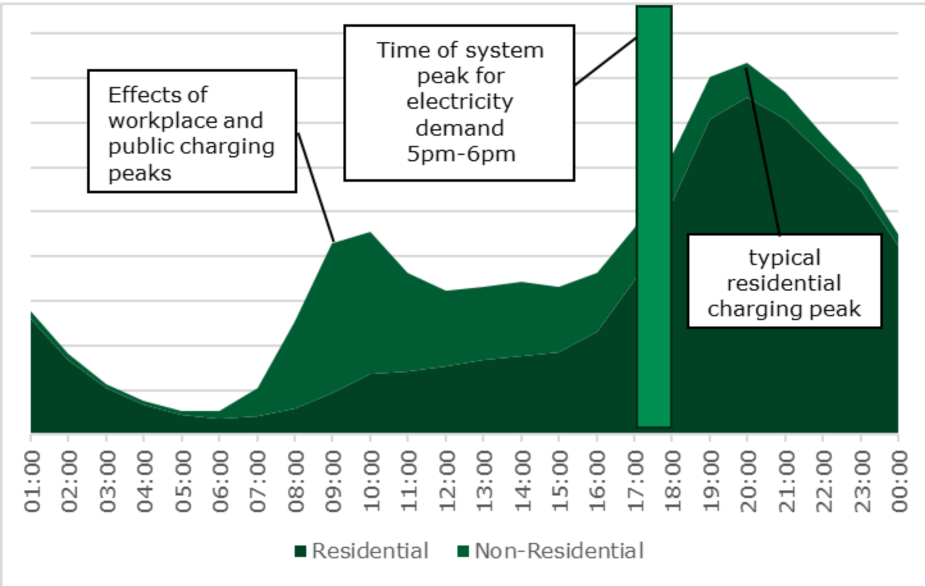
Public charging times



Source: National Grid FES 2019

The overall impact on demand across a typical day is to introduce a new morning peak and to extend the existing early evening peak. The evening charging peak is actually up to two hours after the existing system peak.

Public charging times



Source: National Grid FES 2019

For how long

The Zap-Map survey also showed typical dwell times at each charging point. From this we can get a view on the likely energy transferred at each charge.

Dwell times and energy transferred

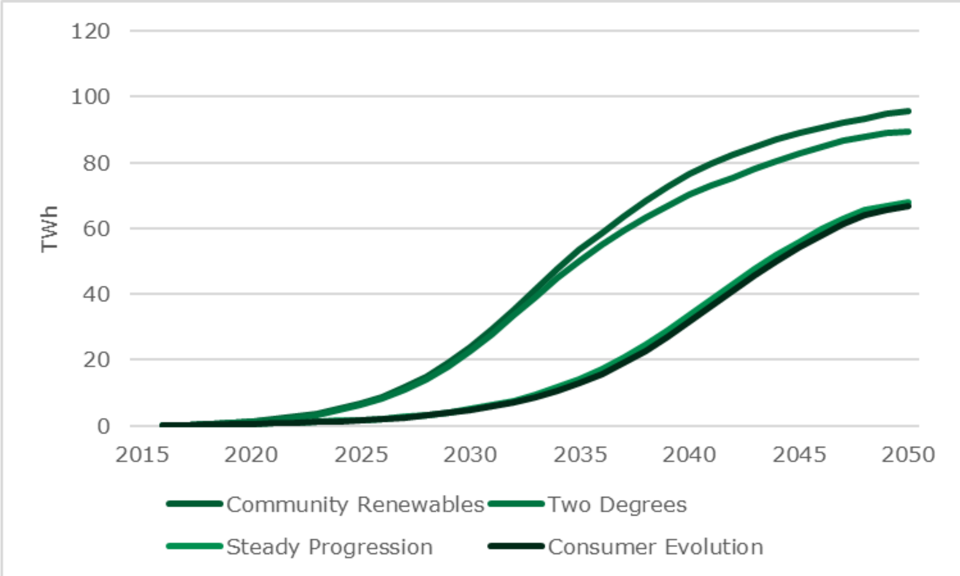
	Typical output (kW)	Typical dwell time (h)	Max energy transfer (kWh)
Home	7	10	70
Work	7	8	56
Motorway service area	50	0.5	25
Trunk road service station	50	0.5	25
Other location	50	0.5	25
Public car park	7	1	7
Retail car park	7	2	14
Local authority car park	7	1	7
Dealership forecourt	7	1	7
On-street	7	2	14
Park-and-ride	7	3	21
EV charging hub	7	2	14
Hotel / other accommodation	7	10	70
Leisure centre	7	1	7
Other	7	1	7

Source: RAC Foundation based on Zap Map July 2012

THE IMPACT ON ELECTRICITY DEMAND

In the UK the National Grid's scenario forecasting suggests that electricity demand from electric vehicle charging could rise to between 67TWh and 96TWh by 2050, equal to between 18% and 23% of total demand.

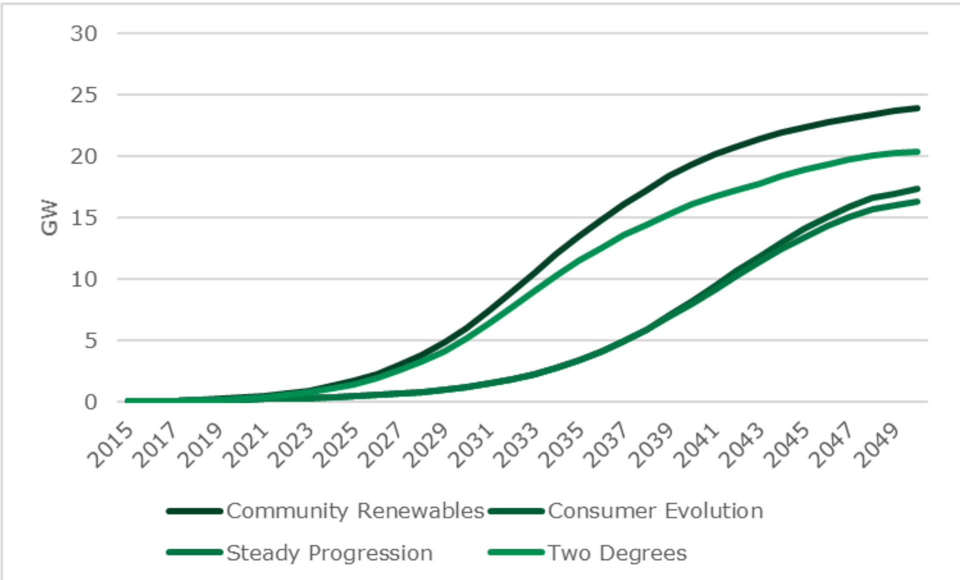
Impact of EV charging on UK electricity demand under four scenarios



Source: National Grid FES 2019

However, the bigger issue is the potential impact on peak demand. Data from National Grid's scenario work shows that before the impact of any smart charging solutions or V2G, the national peak demand to 2050 could increase by between 16GW and 24GW or 19% and 25% of total demand.

UK EV peak demand forecasts under four scenarios



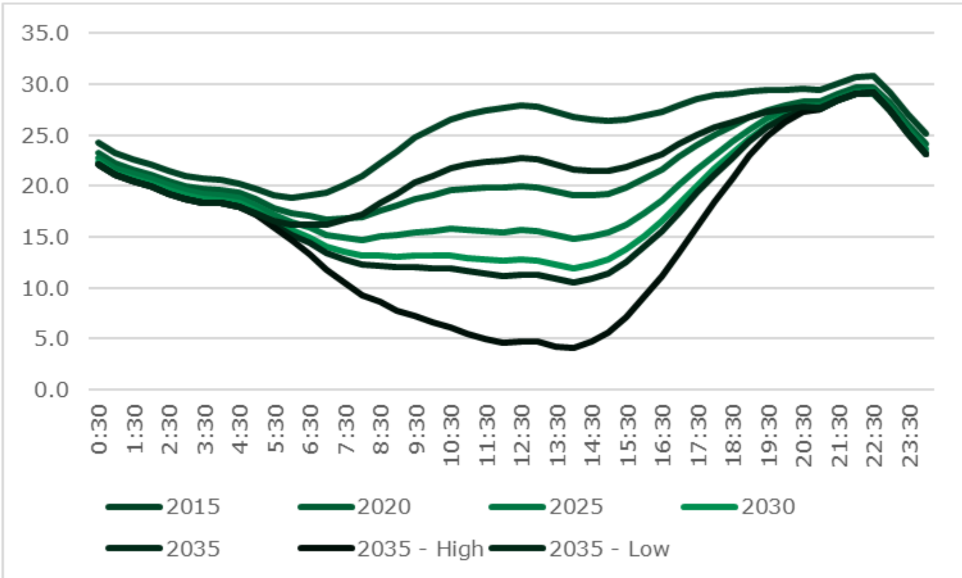
Source: Longspur Research based on National Grid FES 2019

These new peaks are likely to exacerbate the growing issue of rapid changes in demand at certain times of the day. Renewable electrical supply is generally mismatched with the additional demand for EV charging. For example, residential charging mainly happens overnight whereas solar cells only generate during the day. This puts more pressure on the grid, worsened by the intermittent nature of most renewables.

Could the duck curve become the giraffe curve?

These timing issues can be further examined by looking at the "Duck Curve" in the daily demand profile. The potential impact of significant solar capacity on demand was first raised by the California Independent System Operator ("CAISO"). California used to see energy demand on the grid rise in the middle of the day and be fairly flat across the afternoon before rising to a peak in the early evening. Solar is recognised as negative demand because of its distributed nature. With considerable solar on the Californian system, demand now begins to fall from 11am as this capacity kicks in. Then in the late afternoon as the sun wanes and solar starts to come off, demand rises very steeply into the early evening peak. This can be represented on a demand graph showing how demand is expected to behave as even more planned solar capacity is added out to 2035. The shape is said to resemble something that quacks.

Duck Curve (UK data)



Source: National Grid FES 2018

It can be readily seen that the new peaks created by EV charging are likely to occur either side of the PV created demand dip and in particular could exacerbate the impact coming out of the dip in the evening. If smart charging sees lower usage than the grid expects, then the early evening ramp up could become quite exagerated and prolonged giving the "duck" a particularly long "neck".

The key message of the duck curve is that the grid used to have to deal with a small ramp up in demand in the later afternoon or early evening but might now have to deal with a much more marked ramp up lasting later into the evening. This puts pressure on the system and increases demand for flexible and responsive capacity, potentially increasing demand for grid-based energy storage solutions.

Higher demand will vary across the transmission and distribution networks and its impact will vary considerably by location depending on the exsting availability of spare grid capacity.

GRID OPERATOR RESPONSES

While the impact of higher demand might seem dramatic, the transmission and distribution network operators are so far relaxed and believe that the larger components of the grid at the transmission level will be able to cope. Even at the higher voltage end of the distribution networks there is said to be capacity on the whole.

"We predict that the majority of our larger local transformers will be able to accommodate one 35kWh charge every five days for each of the customers connected to it. This provides a charged range of around 150 miles in many EVs and it is likely that this will support the demands of home connected EV charging. We also expect that our backbone 33kV network and transformers will be able to accommodate this level of charge point activity." (Western Power Distribution, Electric Vehicle Strategy March 2019).

This suggests that it is at the level of the local grid and the connection point where difficulties are likely to occur. But also note that any fast or rapid charging would be over and above this level and would start to put pressure on the network. With fast and rapid charging becoming more prevalent, we expect that pressure will build at the local distribution network level.

The typical UK distribution system is designed to deliver 2kW to 3kW per home. Adding a 3.6kW standard charger or a 7kW charger might work when only a few cars per street are EVs but once penetration increases operational limits will start to get breached.

Cost of local network reinforcement

Local connection costs have been published by Western Power Distribution with a typical 20kW charger needing a minimum spend of £1,000.

Charger impacts on local distribution

Small	Medium	Large
(up to 70kVA)	(200kVA – 1,000kVA)	(above 1,000kVA)
	Number of charge points	
1-3 fast or 1 rapid charge	More than 3 fast or more than 1 rapid charge	Multiple fast/rapid charge points
	Approximate connection time	
8-12 weeks	8-12 weeks	6 months +
	Approximate connection cost	
£1,000 - £3,000	£4,500 - £75,000	£60,000 - £2 million
	Other considerations that may affect the cost	
Street work costs	Street work costs Legal costs for easement and wayleaves	Street work costs Legal costs for easement and wayleaves Planning permission and space for a substation

Source: Western Power Distribution March 2019

Charger impacts

The My Electric Avenue project identified voltage issues when five 3.5 kW chargers were connected to a network cluster (with 134 dwellings) and were simultaneously charging. This project involved a number of key UK industry players including SSE and Northern Powergrid and the project concluded that across Britain 32% of low voltage circuits will require reinforcing when 40% – 70% of customers have EV's based with the most basic 3.5 kW chargers.

Therefore, as more chargers appear, the network will become increasingly strained. We expect that related reinforcement costs will rise. For example, a 350kW charger site was recently connected at a cost of over £1m which would equal c.£60k for a 20kW site. The recent prospectus for the listing of Fastned quotes connection fees of up to €150,000 for 50kW chargers, again equal to almost £60k for a 20kW site.

UK regulator OFGEM has published the results of a low voltage network study showing how many vehicles could be charged before major reinforcement is required. This is done for slow and rapid charging and with and without flexible (smart) charging. We are slightly sceptical about the degree to which smart charging will be adopted and also note that the OFGEM definition of rapid charging is just 11kW. If we assume normal inflexible charging and a 22kW rapid charger, significant reinforcement would start to be required with just 5 cars connected.

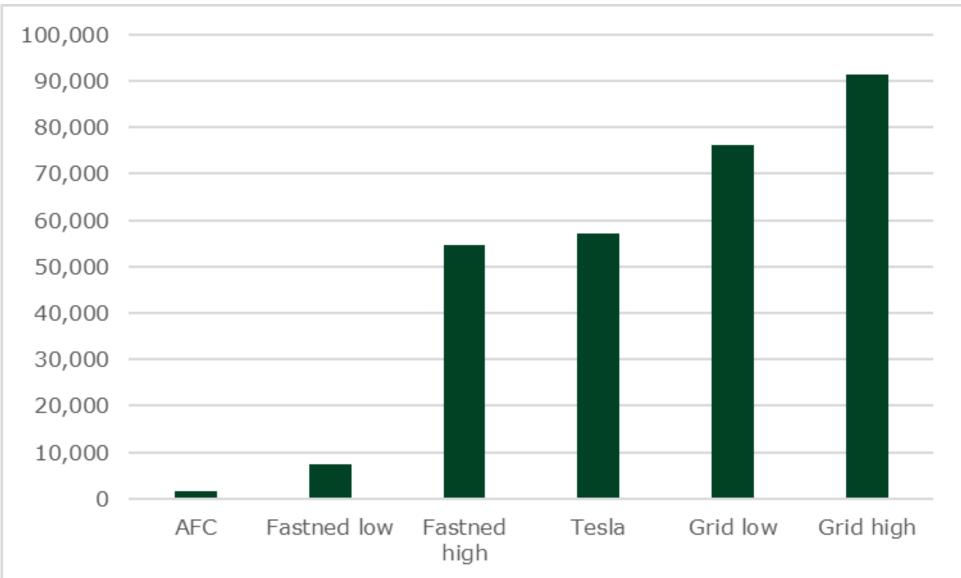
Number of EV's connected to breach capacity limits

Description	Transformer Capacity Limit Reached	Feeder Capacity Limit Reached	Feeder Minimum Voltage Limit Reached
Case 1 Inflexible Slow Charging (Peak)	33	36	72
Case 2 Inflexible Fast Charging (Peak)	9	12	18
Case 3 Flexible Slow Charging	102	54	84
Case 4 Flexible Fast Charging	108	60	96
Case 5 Heat Pump Operation with Flexible Fast Charging	60	30	72
Case 2 revised for 22kW rapid charging	5	6	9

Source: OFGEM Future Insights Paper 5 23 July 2018, Longspur Research

As even more rapid chargers are connected, pressure builds further up the system. A National Grid spokesperson has suggested that existing connections have been low hanging fruit and the cost of a future proofed grid connection for 5-15 rapid chargers is likely to cost between £8m and £20m equal to a range of £76k to £91k for a 20kW charger.

Implied marginal reinforcement costs for a 20kW charger



Source: AFC, Fastned, Tesla, National Grid, BNEF, Longspur Research

So while sites are available now without significant reinforcement requirements, it is likely that the marginal, nth of a kind, site will see reinforcement requirements becoming quite significant.

Additionally, there are many sites where a grid connection cannot simply be provided in a suitable time frame such as where significant undergrounding is required or where there is limited space for additional transformers.

A number of commentators have described the current market as a land grab with participants trying to secure sites with good grid access. Once the good sites are gone the costs of connection could rise dramatically, potentially limiting options despite demand being unfulfilled.

SOLUTIONS TO OVERCOME CONSTRAINTS

There are ways in which the pressure on grid capacity can be mitigated. Smart and V2G are the leading contenders and the solutions most talked about by National Grid and DNOs.

SMART CHARGING

The problem could be overcome by changing behaviour so that, for example, home charging does not start until later in the evening. Smart charging systems that defer the initiation of charging until after the evening peak are the obvious solution. Coupled with time of use ("ToU") tariffs behaviour might be changed to avoid the inflated demand peak. Charging devices themselves are already being designed to work with control systems that will facilitate smart charging, making use of customer friendly programming through mobile phone apps. The UK government is framing secondary legislation under the Automatic and Electric Vehicles Act 2018 that will make smart charging mandatory although importantly is also likely to allow manual override of smart charging systems.

However, consumer behaviour is uncertain and it would only take a few well publicised charging failures to create hostility. Very preliminary and unpublished work by Cardiff University was reported in an answer to a conference question suggesting that focus groups strongly favoured activating overrides in order to increase the optionality of their EV.

In addition, existing driver behaviour does not conform to the apparent economic rationale. The average car in the UK spends 80% of its time parked at home not being used, whilst 16% is spent parked at a destination and the car is only in use for 3%-4% of the time. This suggests that the optionality value placed on a car by the average driver is extremely high, perhaps as high as 80% of the vehicle's value. This suggests that economic incentives to adopt smart charing would need to be significant.

V2G

The pressure placed on networks by EV charging demand could also be mitigated by vehicle to grid charging ("V2G") where surplus power stored in a vehicle battery can be used by the grid. Recent research from the University of Warwick suggests that by managing the discharge and charging more efficiently, V2G could actually prolong battery life. However other research including work at the University of Hawaii suggests that V2G could have a detrimental impact on battery condition and life and even if merely suspected this could make it a difficult concept to sell to EV owners with battery warranty providers likely to be particualry resistant. Fleet owners might be an exception to this as is Nissan who perhaps stand out among vehcile OEMs in researching this solution.

V2G also represents an unpredictable source of supply as the behaviour of individual vehicle owners cannot be perfectly predicted although adequate forecasting is likely to be feasible. The process must also result in a fully charged vehicle when the driver wants it. Again it would only need a few well publicised cases of owners finding their vehicles with flat batteries to make such schemes unworkable. For these reasons we think V2G cannot be assumed at least until it is developed further. Even National Grid has been cautious on the number of EV owners who will participate in V2G.

Percent of EV Owners Who Participate in Smart and V2G

Scenario	Smart take up		V2G take up	
	2030	2050	2030	2050
Consumer Evolution	45%	73%	2%	13%
Community Renewables	71%	78%	2%	14%
Steady Progression	26%	61%	2%	10%
Two Degrees	30%	65%	2%	11%

Source: National Grid FES 2019

LIKELY IMPACT

Even with smart charging and V2G, peak demand still increases in every case apart from the Community Renewables scenario.

EV peak demand as a percentage of sytem peak demand

Scenario	No smart or V2G		With smart		With smart and V2G	
	2030	2050	2030	2050	2030	2050
Consumer Evolution	10%	25%	6%	15%	4%	3%
Community Renewables	2%	20%	1%	10%	1%	-2%
Steady Progression	2%	19%	2%	13%	2%	4%
Two Degrees	8%	21%	7%	17%	7%	8%

Source: National Grid FES 2019

We remain sceptical about how far smart charging and V2G will be adopted given driver behaviour. Even if these solutions are adopted in line with National Grid's forecasts, demand still increases in all but one scenario. Even a small increase in demand could be significant at locations where grid capacity is already weak. So even with these measures there remains a potential for very high connection costs at marginal locations as grid capacity comes under strain.

There are however other immediate solutions available now:

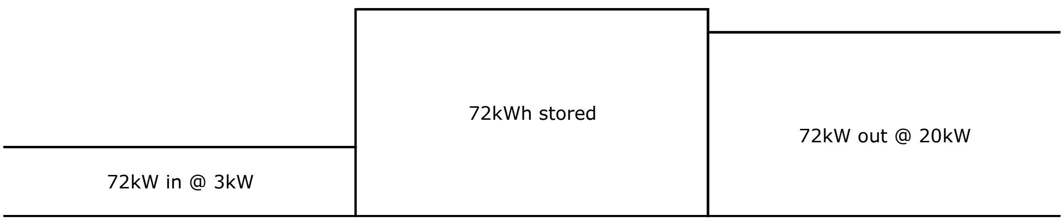
- Charger located storage
- Charger located generation

HOW STORAGE CAN SOLVE THE CAPACITY PROBLEM

Even if a 3kW supply can be guaranteed to a charger, there remains an issue especially with rapid chargers which we expect to make up the majority of public destination charging sites. If you want 20kW out from a 3kW supply some form of storage is necessary.

A 3kW supply can deliver 72kWh of energy in a 24 hour period (3x24). It will take just 3.6 hours to put this energy into a car battery using a 20kW charger. To make this possible a battery or other storage device is required to retain the energy during the 24 hour period so that it can then be released over the shorter 3.6 hour charge.

Storage and charging



Source: Longspur Research

Long duration storage

Lithium ion battery solutions are coming down in price so that even at 3 hours they may be the most economic option. However, where storage is required for longer durations, other solutions may become more economic. At the relatively small and compact level required for EV charging, flow batteries and hydrogen storage solutions may see opportunities. Much will depend on the exact specification of the charger and the site. Storage solutions with between one and eight hours of duration are likely to find demand in this market.

Existing and known pipeline of co-located storage and fast charging

Project / Owners	Location	Completed or announced battery deployments	Year deployed
PivotPower*	UK	50,000kWh	2019
Leclanché / Fastned	Netherlands	6,000kWh	2017
Trans - Canada / eCamion / Leclanché	Canada	4,000kWh	2020
Tesla	Global	~13,000 kWh**	2020
Alfen/BMW	Germany	1,100kW/1,100kWh	2018
NYSEG	U.S.	150kW/600kWh	2015
Green Charge Networks / ChargePoint	U.S.	250kW/250kWh	2015
Greenway	Slovakia	50kW/52kWh	2018
EVGo	U.S.	30kW/44kWh	2018

Source: BNEF 15 October 2018

THE UTILISATION PROBLEM

Even with cost effective storage it will be noted that in our example, charger utilisation is limited to just 15% (3.6/24.0).

Charger utilisation with storage

Capacity in	3	kW
Hours in day	24	hours
Electricity in	72	kWh
Capacity out	20	kW
Hours available	3.6	hours
Max utilisation	15%	

Source: Longspur Research

By providing an alternative source of power to the grid, distributed generation such as a fuel cell can deliver sufficient power to increase utilisation. In our example above if we add a 17kW genset we can deliver 100% utilisation of a 20kW charger without grid reinforcement.

Charger utilisation with distributed generation

	kW
Grid in	3
Distributed generation in	17
Charge out to EV	20
Utilisation without distributed generation	15%
Utilisation with distributed generation	100%

Source: Longspur Research

This distributed generation could be from solar PV cells co-located at the charger site. This can be a very valid solution in many cases. However the timing issues mean that some form of storage will also be required. Other more dispatchable forms of distributed generation could also have their part to play.

FUEL CELL SOLUTIONS FOR DISTRIBUTED GENERATION

Distributed generation, normally diesel, has in fact been a solution to many similar issues where grid reinforcement cannot be provided efficiently or fast enough. While still an option, diesel generators can be loud, vibrate, and emit harmful fumes. By comparison, fuel cells are near silent in operation, almost vibration free and only emit water. Even some of the silenced diesel genset options on the market are much louder than fuel cells.

We estimate that a fuel cell power by readily available ammonia could have running costs slightly below a diesel genset using red (low tax) diesel. The higher capital costs of a fuel cell mean that the levelized cost is about 20% higher than diesel. We think that is well within the premium that the market will pay for the soft benefits described above. Diesel may simply not be an option in areas where policy concerns make planning unlikely. There is also little point fuelling EVs with such an obviously polluting power source as diesel. Of course ammonia itself is not necessarily green, although it can be and we expect this to become more available over time.

Fuel cell and diesel levelized costs of electricity compared

	Diesel off-grid	AFC fuel cell (NOAK)
WACC	10.00%	10.00%
Capacity factor	90.00%	90.00%
BoP capital cost		
Life (years)	20	20
Capital Recovery Factor	0.1175	0.1175
Capital cost (US$/MW)	250,000	1,325,000
Capital cost (US$/MWh)	3.7	19.7
Cell capital cost		
Life (years)	20	4
Capital Recovery Factor	0.1	0.3
Capital cost (US$/MW)	0	600,000
Capital cost (US$/MWh)	0.0	24.0
Fixed O&M cost (US$/MW)	20,000	0
Fixed O&M cost (US$/MWh)	2.5	0.0
Variable O&M cost (US$/MWh)	0.1	0
Fuel unit cost (US$/MMbtu) (US$/l for diesel)	0.53	450
Fuel unit cost (US$/MWh)	53.1	75.8
Efficiency (%)	33%	48%
Fuel cost (US$/MWh)	160.9	158.0
LCoE at grid (US$/MWh)	**167**	**202**

Source: Longspur Research

CHARGER ECONOMICS

Charger point operators normally work on the basis of buying power and selling it on at a premium which allows a return to be made on the cost and installation of the charger. Typical charger pricing is around £1.9k for a 20kW charger.

Charger installation costs

	3.3kW charge point			20kW dual outlet charge point		
Cost type (£ k)	**Low case**	**Mid case**	**High case**	**Low case**	**Mid case**	**High case**
Equipment	0.4	0.6	0.8	1.4	1.9	4
Installation	0.6	1.2	1.8	1.6	2.4	3.2
Network upgrade	0.3	0.5	0.8	6.5	13	19.5
Running costs (annual)	0.3	0.3	0.9	0.3	0.6	0.9
Running costs (12-year NPV)	2.1	2.4	7.1	2.1	4.5	7.1
Total (12-year NPV)	3.3	4.7	10.5	11.6	21.9	33.8

Source: Aurora Energy Research 18 October 2018

Charging prices

While the market is new, charging prices are consolidating with current European pricing averaging US$0.41/kWh or 33p/kWh. Rapid chargers are generally seeing a premium.

CAAS

Not all chargers will ask drivers to pay for every kWh of energy consumed. Charging as a service ("CAAS") options are likely and we also expect a large number of organisations to offer charging free to the driver. Many organisations may seek to contract with CPO and pay a regular "service fee" for charging service to residents, employees, customers or other users. In many ways this will make for a more bankable charging point rather akin to the growth in the private PPA market seen in renewable energy.

Charger costs

In terms of input electricity costs, current UK final user business tariffs are around 14p/kWh with an additional standing charge of about 27p per day. Charge point operators may be able to source power more cheaply and those using batteries will be able to take advantage of off peak rates which could be up to half as much as the full rate.

Utilisation

While we have discussed utilisation limits in our section on storage, achieved utilisation levels are as important to assessing charging economics. The industry clearly faces a chicken and egg dilemma in that chargers are needed to encourage the uptake of EVs but more EVs will improve charger utilisation and thus economics. Fastned has reported utilisation of just 10% in December 2018. This is low but reflects the immature state of the market and we expect average utilisation to grow. Indeed Fastned also suggest a "real world capacity" of 40% which can be compared to utilisation. The company has told us that utilisation at some chargers is already at 40% and we think a slightly higher level is possible for well placed public chargers. In our modelling we think 45% is possible in time but suspect it will take a number of years to reach these sorts of levels.

Support to bridge the utilisation gap

The UK government has recognised that there is a dilemma driven but the fact that people will be reluctant to buy EVs without adequate charging infrastructure and that investment in this infrastructure needs enough EVs for utilisation of the chargers to be high enough. In 2017 it announced a £400m Charging Infrastructure Investment Fund ("CIIF"). Masdar has just announced a £70m investment into the matched funding vehicle. We think this will help bridge the "utilisation gap".

Actual charging prices

Network / plan name	Registration fee	Monthly fee	Connection fee	Cost per hour	Cost per kWh	Total cost	Total cost p/kWh
Home – night rate (3kWh)	£0	£0	£0	n/a	£0.07	£2.18	6.99
Home – day rate (3kWh)	£0	£0	£0	n/a	£0.14	£4.37	14.01
Charge Your Car (7kWh)	£20.00	£0	£2.50	n/a	£0.20	£8.74	28.01
Charge Your Car (50kWh)	£20.00	£0	£3.50	n/a	£0.25	£9.22	29.55
Charge Your Car (50kWh)	£20.00	£0	£0	n/a	£0.36	£11.23	35.99
Ecotricity (43kWh)	£0	£0	£0	n/a	£0.30	£9.36	30.00
Geniepoint London (22kWh)	£0	£0	£0.50	n/a	£0.30	£9.86	31.60
Geniepoint London (43kWh)	£0	£0	£1.80	n/a	£0.30	£11.16	35.77
Geniepoint UK (22kWh)	£0	£0	£0.50	n/a	£0.30	£9.86	31.60
Geniepoint UK (43kWh)	£0	£0	£1.00	n/a	£0.30	£10.36	33.21
Instavolt (50kWh)	£0	£0	£0	n/a	£0.35	£10.92	35.00
Pod Point (50kWh)	£0	£0	£0	n/a	£0.24	£7.49	24.01
Polar Instant (3kWh)	£0	£0	£1.20	£1.20	£0.40	£13.68	43.85
Polar Instant (7.2kWh)	£0	£0	£1.20	£1.50	£0.21	£7.70	24.68
Polar Instant (50kWh)	£0	£0	£1.20	£12.00	£0.24	£8.69	27.85
Polar Plus (3-50kWh)	£0	£7.85	£0	n/a	£0.09	£10.66	34.17
Shell Recharge (43-50kWh)	£0	£0	£0	n/a	£0.25	£7.64	24.49
Source London Full (7.4kWh)	£0	£4	£0	£2.76*	n/a	£15.64	50.13
Source London Flexi (7.4kWh)	£10.00	£0	£0	£4.14*	n/a	£17.46	55.96
Source London Full (22kWh)	£0	£4.00	£0	£6.30*	n/a	£12.93	41.44
Source London Flexi (3-50kWh)	£10.00	£0	£0	£7.74*	n/a	£10.98	35.19

Source: What Car 22 February 2019

HOW DIFFERENT SOLUTIONS STACK UP

If we look at the charging options available, it can be seen that at current pricing a 20kW charger on its own makes a very good return if a site can be found that needs minimal grid reinforcement. We have referred to this as a first of a kind ("FOAK") reinforcement solution. However, as the best connected sites are used up (the low hanging fruit), reinforcement charges rise to the point where the marginal site or nth of a kind ("NOAK") site sees significant grid costs. Even then a reasonable return can still be made but storage becomes a competing option at this point. However, storage is limited by low utilisation and a fuel cell option becomes even better. The table below shows the economics of four charger options.

Charger economics under different scenarios

	With reinforcement FOAK	With reinforcement NOAK	With battery	With fuel cell
Grid capacity (kW)	3	3	3	3
Charger capacity (kW)	20	20	20	20
Charger cost	12,000	12,000	12,000	12,000
Reinforcement cost	19,500	91,500	0	0
Battery cost	0	0	19,584	0
Fuel cell cost	0	0	0	75,000
Total capex	31,500	103,500	31,584	87,000
Life	20	20	20	20
Availability (max)	98%	98%	98%	98%
Utilisation	45%	45%	15%	45%
Annual output (MWh)	77.2632	77.2632	25.7544	77.2632
Charging fee (p/kWh)	38	38	34	38
Revenue	29,236	29,236	8,860	29,236
Electricity tariff (p/kWh)	14	14	7	14
Electricity standing charge (p/day)	27	27	27	27
Electricity cost	10,915	10,915	1,901	10,915
O&M, rent etc	605	605	605	605
EBITDA	17,716	17,716	6,353	17,716
Depreciation	788	2,588	790	2,175
EBIT	16,928	15,128	5,564	15,541
Tax @ 17%	2,878	2,572	946	2,642
NOPAT	14,051	12,557	4,618	12,899
IRR	45%	12%	13%	14%

Source: Longspur Research

This suggests that early movers who can find grid connections at low costs will do best. However, for those coming behind, storage and distributed generation offer routes to attractive returns.

CHARGER DEMAND FORECAST

Forecasts for commercial and industrial chargers for workplace charging, fleet charging for vans, public car parks and motorway service stations have been made by consultants Aurora Energy Research (in a report supported by Eaton, NatWest, Lombard and the Renewable Energy Association).

UK charger demand forecast

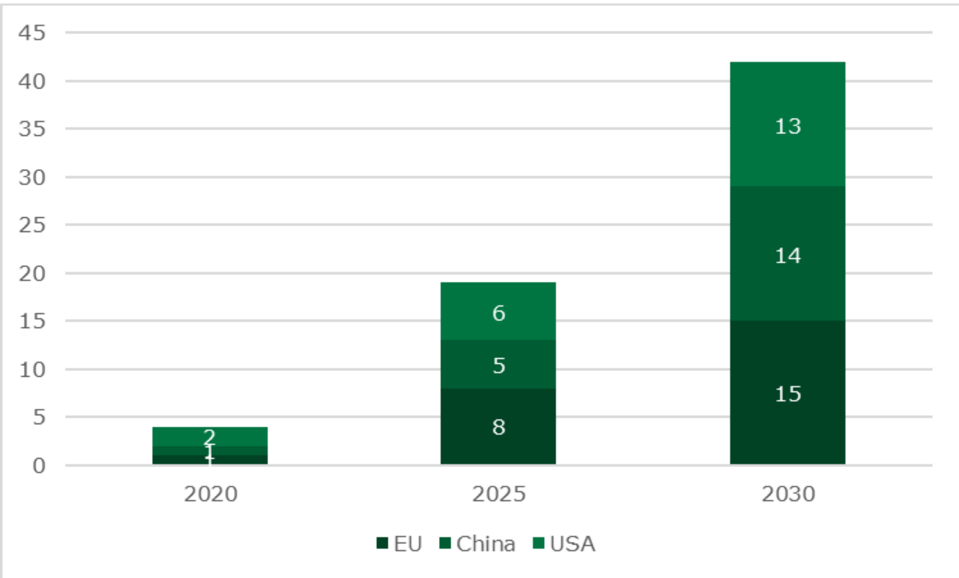
	Employees		Customers	
Application	**Workplace commuters**	**Fleet vans**	**Public car parks**	**Motorway service stations**
Usage of application	12m cars	0.6m vans	33m cars	99bn car & van
	182 visits/year	254 visits/year	164 visits/year	miles/year
	7.6h visit	12h visit	2.3h visit	
Annual energy (TWh)	5.9-8.3	2.6-3.4	1.8-2.4	0.7-0.9
Number of outlets	0.9m-2.4m	0.3m-0.6m	0.04m-0.11m	2k-8k
Cost of equipment and installation per outlet	£1.8k, based on	£2.2k, based on	£2.2k, based on	£25.6k, based on
	3.3kW charge points	7-20kW charge points	7-20kW charge points	150kW charge points
Total cost of equipment and installation	£1.6bn-£4.4bn	£0.7bn-£1.3bn	£0.1bn-£0.2bn	£0.1bn-£0.2bn

Source: Aurora Energy Research 18 October 2018

This shows an expected public charger market of between 1.3m and 3.2m outlets. The top end of this range is consistent with the European Commission's target of a ratio of 1 charger for every 10 EVs given a UK forecast of 3.6m to 3.9m EVs.

McKinsey has published forecasts for the EU, China and the USA showing 42m chargers by 2030 with a total investment of US$50bn.

Estimated number of chargers (million chargers)

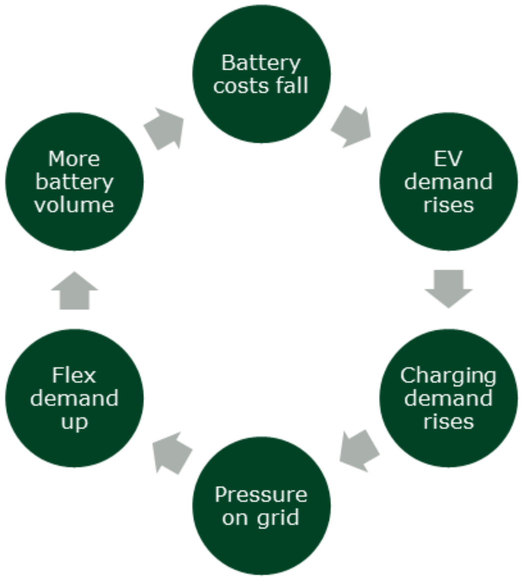


Source: McKinsey October 2018

EV CHARGING DEMAND CREATES MORE DEMAND FOR GRID STORAGE

We have already highlighted the cost of additional grid reinforcement at the chargepoint. But higher demand as a result of EV charging is likley to create pressure across the system leaving grids to solve this pressure. That is likely to see them adopt more flexible solutions such as grid connected storage resulting in battery demand growing further, leading to more cost reductions. This in turn allows more renewables and the process is driven further forward.

A Virtuous Circle in Energy Storage



Source: Longspur Research

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