# Report

Roland Berger

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# Charging Ahead 2: Location, Location, Location

WHERE AND HOW WILL ELECTRIC VEHICLES BE CHARGED?

Roland Berger

# MANAGEMENT SUMMARY

**In 1911, coincidentally the same year that a Baker Electric Roadster became the first production vehicle to drive 200 miles (albeit slowly) on a single charge, Austrian economist Joseph Schumpeter wrote the world's most thoughtful book on innovation. It describes the two phases of young industries: first a period of product innovation in which competing solutions proliferate, then, after the emergence of an evolutionary winner, a period of process innovation in which the most efficient producers win through. To our minds, this seminal work has not been bettered in the intervening century and it illustrates perfectly the development of today's market for EV charging systems (EVCS).**

**Through more than five hundred strategy projects related to EVs over the past decade, RB has developed a clear view that electric vehicles are going to win. They are going to win, because, in comparison to their ICE cousins, they are simpler, better to drive, quieter, easier to automate, overwhelmingly less polluting and, quite soon, cheaper. In winning, the 2020s will see a wave of creative destruction crash over petrol stations, and a more diffuse EVCS market emerge channelling GBP 6 billion of annual spend in the UK alone. It is this EV charging network, and not EVs themselves, which are the topic of this paper.**

**At this stage, the nature of this future market is far from clear; today's product innovation phase is throwing up all sorts of EV charging solutions and business models. Technically, there are wired and wireless solutions, fast and slow, public and private, of various formats. Almost as many business models are emerging to support these solutions, fragmented further by the regulatory and demographic characteristics of different countries, and of their various use cases.**

**This paper explores the nature of the future EVCS market, how it will segment, why "location" is a key consideration, and importantly, what externalities EVCS operators will seek to harness. Finally, more for fun than out of any great expectation of being exactly right, we will predict the evolutionary winners of the present product innovation phase.**

# FAST FACTS & CONTENTS

There are **5** broad location types for chargers

**c. 75%** of EV charging is expected to occur at home

# 1 / The emerging market for EVCS

With an associated future market measured in hundreds of billions, EVCS is attracting much attention.

The world is learning that, behaviourally, charging EVs is not like going to the petrol station. For one thing, it takes longer and so is a parallel, rather than a serial, pursuit. People are developing a habit of charging their vehicles, a little and often, while they are doing something else.

There is a broad consensus that the something-else in question will mostly be "sleeping". Charging a car at home over night is mostly convenient, and, until governments find a way to recoup their losses in petrol excise, very cheap indeed. The second most popular something-else will very likely be "working", as companies across the world currently wire up their employee car parks and fleet depots.

After Homes and Workplaces, however, there is a crowded field of other EVCS locations, unified only by the need for a vehicle to be present while its driver does something-else. These include restaurants and hardware stores, bus stops and taxi ranks, car parks and supermarkets, and even potentially — through wireless charging — the road itself. An old-fashioned highway filling station without retail will likely be one of the smallest such segments. All of these locations will balance cost with convenience; today's mature EV markets seem to be teaching us that, unlike the hydrocarbon world of many habitually driving past a petrol station which costs 1% more, EVCS customers can be comfortable with price differentials as high as seven times where the use case justifies it. → A

We have already seen paybacks for some charger locations of less than a year, but also many that will never recover their investment costs; optimising the power rating, real-time pricing, and precise location of these chargers in order to maximise their utilisation, and thus financial returns, will become a new discipline of our times. Through work with data analytics partners, this new discipline is becoming a key focus of the Roland Berger Centre for Smart Mobility.

## A / Alternative pricing in Norway for a 30kWh charging session of a VW Golf [EUR]


Source: Company websites, Globalpetrolprices.com, US EPA, Fuelly, Secondary research, Roland Berger

# 2/ Lessons from the world's most mature EV markets

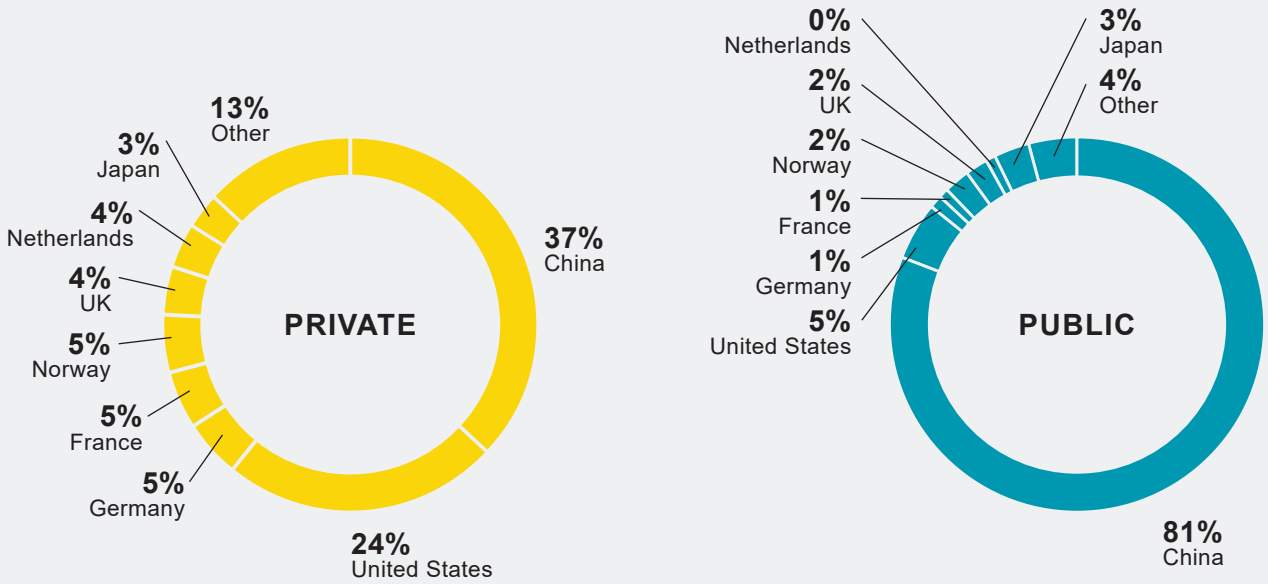
The majority of cars sold in Norway are now EVs, and as a result Oslo is the world's laboratory. Here, people are habitually buying EVs regardless of access to home charging; the convenience of the public and semi-public charging network is a key driver, and the power rating and market share of such chargers is higher than in the UK, and gradually rising.

Infracapital's Christophe Bordes sees this learning opportunity as a major driver in its recent investment in the Nordics: "the Fortum network secures a high-quality entry point into the market, providing a platform for growth in a sector benefiting from government policy support and ambitious decarbonisation targets".

The other increasingly mature market is China. Driven by its national industrial strategy, China has more EVs than any other country, and more fast public chargers than the rest of the world combined, many of them operated in surprisingly open-market conditions. RB Shanghai Partner Ron Zheng tells us that local start-ups "StarCharge and Tgood install their own equipment then charge a government-mandated electricity fee plus a service fee which is highly variant by CPO". → B

China, with its many high population density urban centres, has something in common with many other strongly emerging city-level markets. The world's city dwellers, pulled by their wealth and openness to modernity, and pushed by fiscal and air quality regulations, have a high propensity to use EVCS, often starkly at odds with their access to home charging. It is in cities, with their fractional ownership models, overloaded power distribution networks and parking constraints where many of the most innovative EVCS models are being born.

## B / Private and publicly accessible chargers by country, 2019 [%]




Source: IEA, Roland Berger

# 3/ Where will the world's vehicles be charged? Location, location, location

Some aspects of mass car ownership have changed little in 100 years. At USD 850, a Model T cost half that of a Cadillac (and a third that of a Baker Electric) making it around USD 25,000 in today's money.

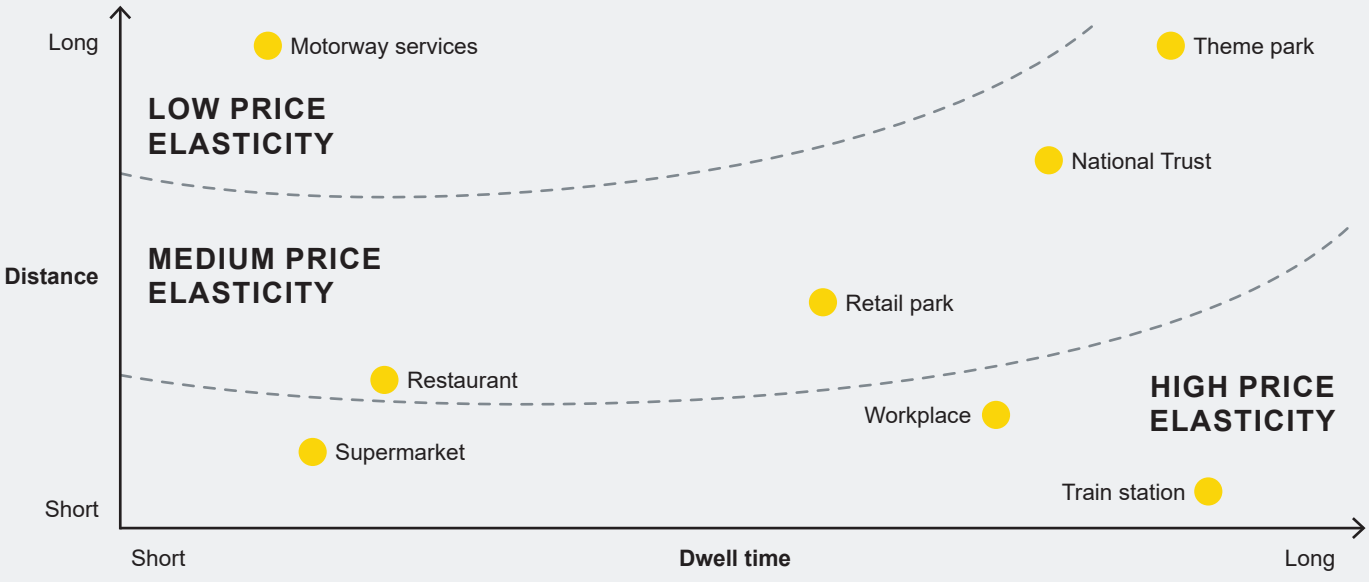
What is clearly different is that Henry Ford's customers were dependent upon location in a way that Elon Musk's aren't. 1908's car buyers had to wait for the now ubiquitous filling stations and paved roads, gradually paid for by gas tax over the next decades; the utility of a car was limited by its location and the infrastructure available to it.

In comparison, the marginal infrastructure cost of adding one EV today is trivially low. A USD 1,000 home charger, or even a simple plug, allows the new EV owner to freeload on the existing networks. It is the price of the car, and not infrastructure, which provides the obstacle to EV adoption, and it is the location of the charger which dictates its utilisation rate.

A helpful way to envision all of these competing locations is shown courtesy of EDF PodPoint. This model, building on the work of their founder Erik Fairbairn, segments locations in the eyes of a typical customer according to how far from their home charger they are, and how long they are planning to stay there. It can be helpful in thinking about the price sensitivity of customers in different use cases, and the type of chargers best suited for these locations. → C

An implicit assumption of this model is that there are often ulterior motives for providers of charging infrastructure in all environments. In the private arena, this could be as simple as wanting to be perceived as a good host or employer,

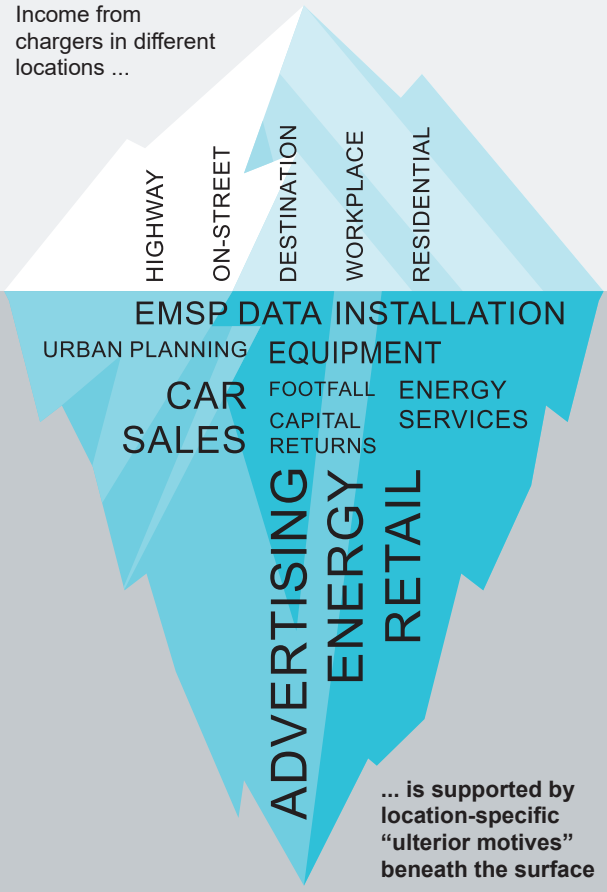
## C / Charging use case segmentation and price elasticity




Source: EDF PodPoint, Roland Berger

or as complex as seeking access to balancing payments through National Grid's fast reserve mechanism. Public and semi-public environments have even more numerous motivations. The task of weighing these various benefits and allocating them to the location owner, the location operator, and the infrastructure owner is thus part and parcel of the EVCS market. However complex these ulterior motives, EV charging revenue is the tip of an iceberg, and the profit pool has much beneath the surface. → D

**D / Direct revenues from EV charging is the tip of an iceberg**




Source: Roland Berger

We will now consider five broad types of location: highway charging stations, public car parking places, destinations, workplaces, and the home, starting with the most publicly accessible.

## HIGHWAYS

The highways charging model is the one most akin to petrol stations; long distance drivers, running out of range and far from home, stop with the primary intention of "filling up". Speed of charging is vital here to speed travellers on their way. And as with petrol, price elasticity is at its lowest.

The challenge for first movers in highway charging has been the low utilisation rates achieved. In young markets, EV uptake can be ponderous and often skewed towards the "bridging technology" of PHEVs, for which range anxiety is solved by petrol, not highway charging. Fast chargers can be expensive, perhaps fifty thousand pounds for the hardware alone, with installation and grid reinforcement on top. These capital costs can dominate charger economics, making the energy cost component of running a network relatively low, sometimes as low as 25%.

In combination, a pure highway charging infrastructure model is yet to make anyone rich; the outcome is a tiny 2-3% share of the charging market.

As in most countries, the UK's highway charging business models have shown mixed success. The two first movers, Ecotricity and Tesla, have very different business models: Ecotricity is an eco-focused energy retailer and has attempted to draw in its eco-minded clientele, for example, by cross selling discounted miles to domestic energy customers. Tesla in contrast has been all about selling BEVs and curing range anxiety to sell more of them. As such, its charger's branding has been hi-tech and futuristic, and its pricing designed to

draw in more Tesla owners. Neither of these first movers have made huge profits from their charging networks, though their host companies have both prospered.

More recent entrants to the UK's highway charging market are also in evidence. Petrol stations, fighting to maintain long-term relevance (and perhaps fighting to avoid the long-term cost of land remediation on closure), are part of this. In the foremost UK example, BP acquired Chargemaster in 2018 and went on to develop the country's largest network in its offering. Many smaller networks have also emerged, a dozen of which are presently establishing a unified roaming tariff to project a simpler national coverage.

Finally, a notable international entrant to the UK is IONITY. A joint venture founded by car OEMs, IONITY has proprietary fast charging technology, developed in-house and made available preferentially for selected EV owners (e.g. free to drivers of new Porsche Taycans). Its international network across Europe supports a new breed of high-end international drivers, with the apparently high cost of subsidy being manageable because, for example, even Porsche Taycan owners are still observed to charge at home. Like Tesla, this network seeks to allay range anxiety in order to sell more cars, but unlike Tesla it has a more open architecture; all other users can then access these chargers too, only at a premium price typically more expensive than petrol.

Highway charging business models have been difficult to date; home and work charging segments have beaten them for market share, and some chargers have rusted from underutilisation before they have even paid back their investment. But mature markets like Norway are seeing highway market shares creeping up as BEVs become more popular than PHEVs, and as long distance EV driving (even before COVID-induced public transport anxiety) becomes more common. Time will tell how high the sector will rise.

## ON-STREET

Does a lack of off-street parking facilities preclude one from owning an EV? The short answer: absolutely not. Does that mean I won't be able to charge my car "in the normal way"? Again, the short answer: absolutely not.

Fortunately, many different stakeholders have already begun addressing this potential conundrum through a variety of different "on-street" solutions. First of all, there are the more "traditional" charging players such as Source London, very often tied to a specific, typically urban, locale. They have been described as traditional here as they were some of the first publicly available chargers and the hardware is the most prototypical bollard-style charging station. Although initially targeted towards short-term parking usage, the increasing frequency with which they are located in highly residential areas has somewhat changed the use case to one where overnight charging is closer to the norm.

A challenge here is that the resultant increase in street furniture and required installation works put a cap on the scalability of this type of charger as the silver bullet for EV owners without off-street parking. In the last few years, a new style of charger has emerged: one that leverages existing street furniture. Several providers, including Virgin Media, are pursuing solutions like this, but one of the first examples to market is Ubitricity. Their small, discreet chargers are

installed onto existing street lamps with EV drivers charging using a proprietary cable that is able to record the amount of energy charged and act as a "meter". The power rating of such devices currently sits around 5 kW for a number of charge points, still noticeably slower than the 7 kW home charger installations, but better than that offered by a standard 3-pin plug, and "fast enough" in an environment where cars will typically be left for a long time.

It is not only large-scale megacity initiatives that will thrive here: Dundee city in Scotland has been able to get its residents to successfully utilise "charging hubs" located at the top of a multi-storey car park. These hubs are partly powered by solar panels and have allowed the city to become the soi-disant "most EV friendly city in the UK". With tight control over its assets, the city council has been able to position the city in a way that allows for more e-mobility infrastructure development, saving a commendable 854 tonnes of $CO_2$ emissions (equivalent to 5,452,000 miles of driving) along the way.

Ambitious city mayors, driving air quality ambitions, will likely continue to be the catalyst for the on-street sector. Many variants of this will emerge, sometimes straying into public car parks, some of it (e.g. induction charging pads under taxi ranks) prescribing car technology types, and often drawing on infrastructure funds to relieve pressure on the public purse.

## DESTINATIONS

A surprise early leader in the battle for charging customers is a brand-new category: "destinations". Destinations can include a wide range of venues, the primary purpose of which is neither parking nor charging, but at which cars are typically left for half an hour or more. The single most highly utilised EV charging location we have seen evidence for is a fast food outlet near Oslo's international airport, where drivers are known to congregate to avoid the high parking costs of the meet-and-greet.

Like all new categories, particularly those with such strong and varied ulterior motives, there are no clear rules as to what the price or the offer of destination charging should be.

The owners of a restaurant or a shop are unlikely to view themselves to be experts in operating electrical infrastructure, but will have a clear focus on the value of an additional customer, particularly where that customer is likely to be a big spender. Some British supermarkets are now offering free charging to entice target customers from competitors.

We are living through a period in which the value of chargers in these destinations is unclear. While it is undoubtedly true that some speculatively installed chargers will never achieve a meaningful investment return for either the EVCS owner or its associated site operator, there will be others which become very valuable highly utilised assets. The contracts offered between the EVCS supply chain and the venues themselves reflect this wide range of outcomes, ranging from one-off sale contracts, to 10-year concessions, and with evidence of cashflows in each direction. What is clear is that there is a kind of land grab underway, and that the ultimate owners of locations that become the gas stations of the future stand to make material gains.

## WORKPLACES AND FLEET DEPOTS

The UK's transport statistics reveals that two thirds of the labour force commute to work by car or van; after "parked at home", the second longest amount of time that EV drivers spend doing "something-else" is very likely to be in the workplace. As such, the workplace represents a good place, at least from an owner's perspective, to charge their car.

From many employers' perspectives, there aren't a huge number of immediately beneficial reasons as to why you would install workplace chargers for your employees. Many employers haven't enough car parking space anyway, it will be hard to charge employees for the electricity, and the installation disruption, investment cost and maintenance costs of the equipment itself will also militate against. However, the goodwill that can be obtained from certain employees and the external pressure for large companies to behave more sustainably have already resulted in some modest uptake. And of course, this is also helped by the Government's Workplace Charging Scheme, which has supported 6,500 chargers being installed at workplaces in the UK, and to which the strong personal tax incentives for company car drivers from April 2020 will only add.

In the UK, Enterprise Fleets and Company Cars are likely to be the main drivers for EV and EVCS adoption. Around 50% of new passenger vehicle sales in the UK are in this category, and just as corporate taxation rules drove the early adoption of PHEVs back in 2015, the new zero rate BiK taxes are likely to drive BEV adoption going forward.

Yet more in the vanguard than company cars, enterprise fleets are already seeing considerable electrification, with depots for fleets as varied as estate agents' city cars, parcel deliverers' vans and even buses starting to pop up across the country, particularly alongside ULEV zones. There is strong evidence that, for residual cost reasons, hire car companies may be amongst the first to abandon the internal combustion engine. Depots for such players, for which higher charging power rates mean saved time and money, are already driving technological advances in the sector, and raise the spectre of such depot locations becoming obsolete if their electrical distribution networks are insufficiently strong.

Post-COVID work and travel patterns will remain an area of uncertainty in months to come. What we have seen, however, is increasing interest from all quarters, including from employers' landlords, facilities management players, warehousing companies, and even infrastructure players like IDNOs, all seeking to invest.

## HOME CHARGING

Some estimate that 80% of EV charging will occur at home, a seemingly ambitious forecast given government estimates that suggest only two thirds of the UK's domestic building stock has access to off-street parking. Upon closer examination however, this figure could be credible: current car ownership statistics show that 75% of privately-owned cars are parked in a garage or other form of off-street parking, and that of the time the average UK car spends parked, 83% of this parking is at home. For those with access to off-street parking, the simple act of plugging in your car is little toil compared to the convenience of

being able to start every journey with "a full tank", especially when home charging is typically so much cheaper.

At first glance, the industrial attractiveness of this largest segment may be relatively modest, except to equipment manufacturers and to contractors in the notoriously tough domestic installation market. The pricing potential for this equipment has a glass ceiling, the technology in it being relatively simple with little demand for innovation.

However, we believe that to overlook this market would be a mistake. Specifically, we believe there is a significant adjacent profit pool accessible through aggregating domestic EV chargers to assist with grid stability via demand side management (DSM).

Two different technologies may be in play here: in the first ("V2G"), engineers imagine that car batteries will feed in to the grid through inverters, and in the second, simpler approach, the charging of cars at home will simply be manipulated to reduce or increase demand. Simply shifting the load that EV charging represents (and incentivising EV owners to do so, through EV-specific tariffs) to an off-peak period has the potential to be of great service to the TSO, National Grid in the case of the UK.

The 2020 May bank holiday was a historic weekend in terms of DSM; COVID's impact in reducing demand to its lowest level in 20 years coupled with a period of plentiful sun and wind to mean that National Grid was reported to spend GBP 50 million simply getting rid of excess electricity. As part of this, certain domestic customers with smart meters were invited to take part in a trial whereby they were paid up to 5p for each kWh that they used between the hours of 2-3pm due to the expected mismatch in electricity supply and demand. Many participants, most of whom will already be more engaged with UK $CO_2$ emissions/ grid management requirements than the average citizen, delayed running their dishwashers/tumble dryers etc. to maximise their electricity usage as much as possible during those hours.

Whilst the level of engagement in the trial is very encouraging, the novelty of this trial is unlikely to be sustainable at scale in the long run. Will the average UK citizen time their washing such that they save a few pence on their electricity bill? Much more credible would be a fleet of thousands, even millions of domestic EVs, the chargers for which can be turned on and off by the DSO. As such, a connected EVCS with smart charging capabilities represents a perfect automation of this process, one that requires no more effort than you would already go to just to charge your EV.

A country like the UK presently spends over GBP 1 billion/year on grid stability, a number which is growing as intermittent renewables grow, and a large part of which we believe will soon be served by aggregated home EV chargers.

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# 4/ An iceberg lies mostly below the surface: "below the water line" business models

The above example of grid stability payments, with an EVCS customer benefitting in part from a broader energy services offer, illustrates that the "tip of the iceberg" model of charging for charger utilisation may ultimately be no more interesting than EVCS adjacencies.

The wide range of players presently exploring EVCS illustrate this point. Manufacturers, facility managers and installers are mobilising to supplement their existing product range. Energy retailers and smart meter asset providers are appending EVCS offerings to make their offer more attractive or "sticky". In public environments like highway and destination charging, particularly those with chargers frequented by the most affluent socio-economic groups, advertisers are also getting in on the act: digital advertising screens on chargers are a much more compelling proposition than the ads on petrol nozzles, and the revenues attracted through advertising can be a very attractive fillip to the EVCS business model, or, as in the case of the US-based Volta, even its mainstay.

Pure finance models in support of this infrastructure, regardless of its location, are another observable trend. Where the first chargers have been bought outright by end users or equity players, alternative asset providers are now emerging. Charge Point Operators with the lowest possible cost of capital seeking rent on the basis of utilisation can now be seen in some markets, with infrastructure funds as the likely protagonists. Certain semi-public locations (workplaces, multi-occupant dwellings, car parks, destinations) are attracting wider long-term network investment from businesses like the UK's IDNOs. We are even seeing exploratory forays into debt-financed networks, with some equity players seeking to offer their charger networks as collateral for increased leverage.

Perhaps the biggest indirect play in the EVCS market however comes not from the physics of the chargers, but from the information that their use contains. A player able to understand the entire use case of the EV charging network by consumers both individually and in aggregate will have an asset of value to transport operators, car OEMs, power utilities, governments, highway agencies, tourism operators, and even restaurateurs. E-mobility service providers ("EMSPs") are thus emerging that deploy apps to simplify or reduce the cost of EV charging to the consumer, while simultaneously hoovering up a huge data set on the future of transport.

Most EMSPs leverage the Open Charge Point Protocol embedded in new chargers to provide a cloud-based software solution able to provide B2B back-office/operational services and to point consumers to available public chargers, regardless of their hardware type or charge point operator. The holy grail is to become the natural monopoly app provider for EV drivers across an entire country, and then to use this consumer power to extract (and share) cost advantages from the EVCS supply chain, while simultaneously monetising the growing dataset.

The early pace for EMSPs has been set by ChargePoint of the US, but there are many notable new entrants, including several interesting UK players;

ZapMap is now extending its offer from public to home charging, and Centrica has entered through its acquisition of the Israeli software company Driivz.

All of these "below the water line" models can now be observed beneath the EVCS "iceberg", either alone or in combination; they are not mutually exclusive, and are almost always additive.

## 5/ Predicting winners: a mug's game

The only thing we are relatively confident of is that, as the product innovation phase plays out, the winning companies will experiment with multiples of the locations and additive business models described above. As such the winning management teams' styles will be flexible and entrepreneurial.

You have read this thought-piece this far, and we are not offering you a Reliance Letter, so it seems only fair to stick our necks out a little: we expect wireless and V2G to be losers. The engineers in our group hope this is wrong, because these are neat technical solutions, but "the perfect can be the enemy of the good". One of the great advantages that BEVs have over other technological solutions, not least Fuel Cell vehicles, is that they require minimal centralised decision taking. The marginal cost of addition is low; you can buy one and just plug it in. Every vehicle so bought is another vehicle unable to use a wireless induction charging system without a costly upgrade, and with a cathode chemistry better tuned to driving performance than to power grid stability. OEMs could build higher cycle-life batteries with induction chargers in for additional cost at the factory, but most people don't want these functions, preferring a cheaper car that drives better. We thus think that the central decision taking that would be needed to make induction charging or V2G standards win through are an unlikely fit, except in fleet niches.

Warming to our theme, we also expect OEM-specific charging stations to gradually fade away, though calling these losers seems too strong, as they will serve their intended purpose of securing EV market share in the interim.

From a finance perspective, in the public charging arena, we see a moral hazard challenge for debt financed assets. An installer of charge points will be minded to take a punt on a new charger, even where the location is unlikely to lead to utilisation rates with workable IRRs, and we can see this creating tensions between lenders and operators.

But not all investors in EVCS will be losers, indeed we think quite the opposite. We expect high-capacity BEVs and wired chargers to be the evolutionary winner, with the comfortable co-existence of chargers in all of the locations described. In the subsequent process innovation phase, efficient operators with low cost of capital and cost-efficient manufacture to open-architecture standards such as ChaDeMo will win through. Finally we would not be surprised if a single winner were to emerge, at least on a national basis, in the potentially very valuable natural-monopoly worlds of EMSPs and grid stability aggregators.

## CONCLUSION

*We believe that Climate Change concerns are going to propel the continued transition of personal transport from ICE cars to BEVs. Underpinning this, the market for EV charging systems is going to be huge, and very unlike the petrol stations that preceded it. In the first instance the home will dominate as a charging location, but this will partly evolve towards public chargers, driven by network infrastructure and behavioural demands, already observable in Norway. By our analysis, this transition will take place continuously between now and the 2040s, with near double digit CAGRs. The best charger locations, those with strong low-cost electrical distribution systems and distractions attractive to EV drivers, will become valuable assets. The sector will continue to evolve, for example as autonomous vehicles dock themselves to public chargers later in this period, but the course is now being set.*

# AUTHORS


**Tim Longstaff**
Partner +44 7880 202910 tim.longstaff@rolandberger.com

**Philip Dunne**
Partner +44 20 3075-1100 philip.dunne@rolandberger.com

**Deniz Karadadas**
Project Manager +44 20 3075-1100 deniz.karadadas@rolandberger.com

**Robbie Zhao**
Consultant +44 20 3075-1100 robbie.zhao@rolandberger.com


# EXPERTISE

Roland Berger has been involved with over 500 EV-related projects over the past decade across all aspects of the value chain. Roland Berger‘s London team published its first “Charging Ahead“ document in 2017, and most recently it has supported both business strategies and landmark transactions in some of the world‘s most advanced EVCS markets.

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ROLAND BERGER LTD
55 Baker Street
London W1U 8EW
United Kingdom
+44 (0) 203 075 1100

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