An Overview on Electric Vehicle Charging Infrastructure

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PREFACE

In recent years the problems of “Range anxiety" associated with electric vehicles (EVs) have been alleviated by the introduction of hybrids (HEVs) and plug-in hybrids (PHEVs) and the development of higher energy density batteries capable of storing more energy in the same space. With the increasing popularity of electric vehicles, “Range anxiety" is now being replaced by “Charging anxiety“.

Unlike conventional vehicles that cannot be refueled without dedicated fueling infrastructure at designated locations, one of the positive aspects of electric vehicles is that these can be charged at many places like homes, workplaces, malls, parking spots, etc. However, proper and suitable charging infrastructure will need to be in place at such locations. A widespread and easily accessible charging network will be most crucial for mass adoption of electric vehicles.

The development of a robust charging infrastructure network is widely considered a key requirement for a large-scale transition to electromobility. Such infrastructure would not only provide more charging options for drivers but would also promote awareness and range confidence for prospective electric vehicle owners.

IMPORTANCE OF CREATING CHARGING INFRASTRUCTURE

As a daily practice and use pattern, it is likely that most of the time, people will have their electric vehicle charged before they will start a day. In the absence of parking places at residence, people would prefer to charge their electric vehicles at their workplaces.

During the day, for the city commuting, people will want to top-up the EV battery at every reasonable opportunity and place, say for e.g. at shopping complex or a commercial complex. We may expect that unless people have a stop-over of 2~3 hours or more, they will not want to charge at such places. However, for taxi fleets for the want of running more kilometer per day, the need for public chargers (with preferences for fast charging to reduce downtime) will become significant. For inter-city commuting, more fast chargers will be needed at stop-overs on the highways to allow top-up. It may be noted that for fast charging in 30 minutes or less, electric vehicles will have to be capable of taking such high voltage or current (or both), which will increase the cost of the EV and have an impact on battery life.

As illustrated in Figure 1, the availability of public charging is generally linked with electric vehicle adoption. Places with higher electric vehicle uptake tend to have more publicly available charging infrastructure

Note: Data is for the year 2017. However, the underlying conclusion is valid.

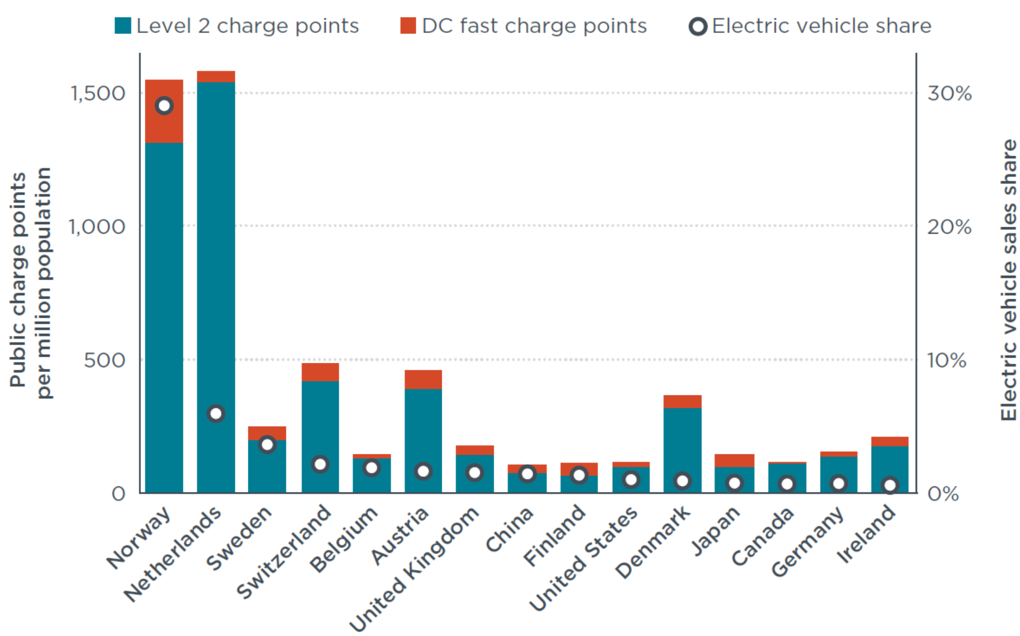


Figure 1: Electric vehicle sales share and public charge points per million population in selected leading markets

There are three main elements responsible for accelerating EV deployment and Creating Charging infrastructure is one of them. The below schematic explains the EV deployment roadmap.

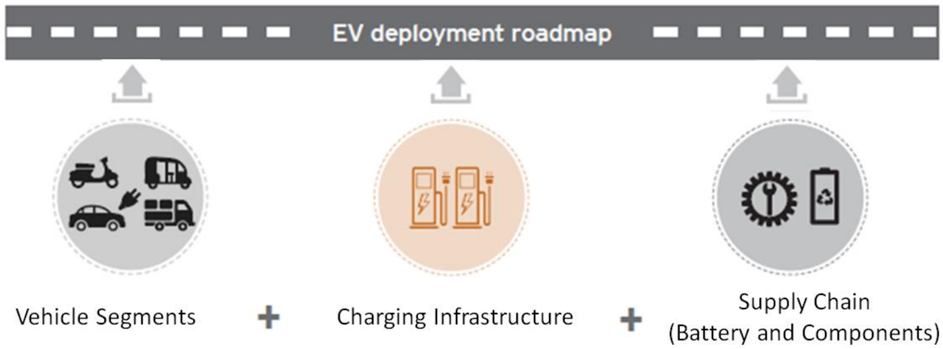


Figure 2: EV Development Roadmap

Another analysis of major metropolitan areas with the highest electric vehicle shares (Figure 2) shows that there is a wide variation of a number of electric vehicles per public charge point. Hence, at least for today, there is no universal benchmark for the number of electric vehicles per public charge point.

Different segments of vehicles (2W, 3W, PVs, CVs) may require different types of charging standard (& connector), however, the charging infrastructure, at-least at public places, should be common to the extent possible to reduce the infra cost.

Based on the available duration for charging, locations like homes (residential and curb-side) and workplaces would be ideal for AC slow charging while places where vehicles halt for a shorter duration (less than 2 hours) like commercial complex, highways, etc., fast charging would be a more suitable candidate (within city commuting, taxi will have relatively more demand for top-up as compared to a private use). Buses will need captive charging at depots which will be mostly fast charging (both AC and DC).

Therefore, based on the use case, location and density of electric vehicles, a combination of slow and fast chargers will be required.

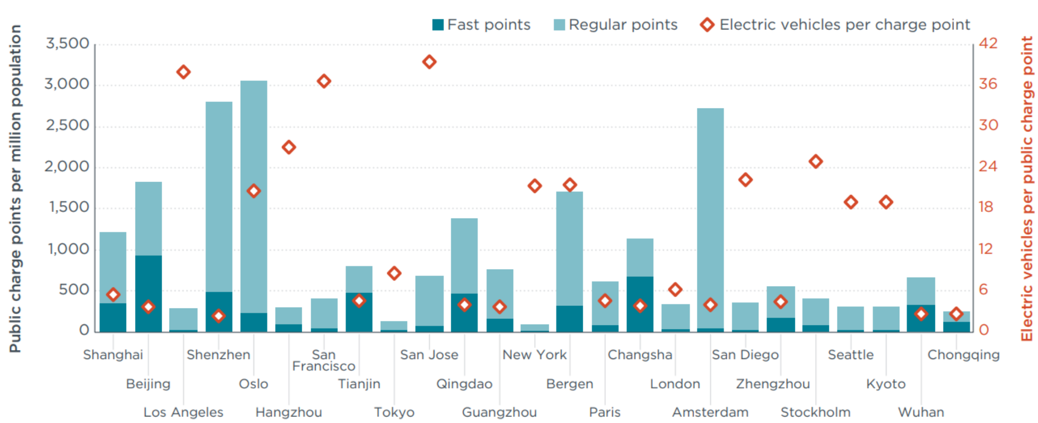


Figure 3: Public electric vehicle charge points per million population and electric vehicles per charge point in electric vehicle capitals

CHARGING STATIONS FOR ELECTRIC VEHICLES

More than just a power outlet, the charging terminal allows for charging electric vehicles safely with maximum efficiency. Unlike a household outlet, which does not include any specific function, the charging terminal is designed specifically for this operation and that any model of an electric vehicle is connected to the terminal.

The car is normally equipped with one or more electric motors with total capacity ranging from 15 to 100 kW depending on size, usage and desired performance. The battery pack provides power either from the charge provided by the cable from an external source or when driving during the deceleration of the vehicle, the engine operating as a generator. The battery capacity ranges from 5 to 40 kWh with a total voltage of 300 to 500 V.

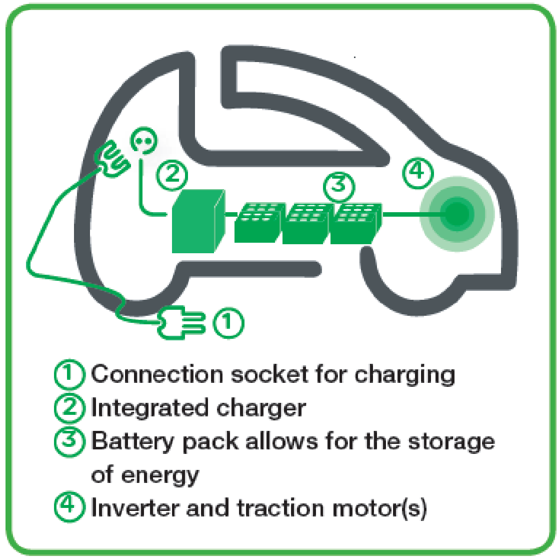


Figure 4: Charging Components (Source: Schneider Electric)

Charging stations merely deliver the energy to the vehicle, usually in the form of a high voltage AC or DC supply. They don't normally have the functions of the charger which must transform the electrical energy into a form that can be applied directly to the battery.

Broadly speaking, three different power levels have been defined but within these levels, a very wide range of options are available to accommodate the different existing power grid standards of the national electricity generating utilities.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

Electric Vehicle Supply Equipment (EVSE) or charging equipment is prerequisites for electric vehicle (EV) adoption and they can be broadly classified as

- AC charging devices
- DC charging devices

Charger Types and Sockets	Picture	Origin and Popular EV Models	Maximum Power Output and Communication Protocols
AC CHARGERS			
Type-1 with Yazaki Socket		Japan, USA (uses separate standard – JSAE 1772 due to 110 Voltage)	Up to 7.4 kW (32 Amps, Single Phase)
Type-2 with Mennekes Socket		Europe (Germany) – many European cars	Up to 44 kW (63 Amps, 3 Phase)
Type-3 with Legrand Socket		France and Italy – some European cars	Up to 22 kW (32 Amps, 3 Phase)

Table 1: Charger Types & sockets

In the case of AC charging, the charging speed depends on the DC output from the onboard AC-DC convertor. For example a single phase 220V AC, 15 Amps supply (AC output- 3.3 kW) connected to an EV with a 10 kWh battery and on-board AC-DC converter with an output of only 1 kW DC could take 10 hours to fully charge the battery. AC chargers with high power output are available which can fast charge the batteries depending on the battery chemistry and battery management system (BMS) in the EV.

DC Fast Chargers (DCFC) with high power output can supply DC power to the battery and can charge the EV battery much faster. A 50 kW DCFC can charge an EV with a 25 kWh battery in 30 minutes (theoretically). DCFCs are more economical as AC-DC conversion takes place in the EVSE itself rather than inside the vehicle. When an EV is connected to the EVSE a hand-shake is established between the EV and EVSE, and the BMS in the EV takes control over the charging process

There are different types of AC and DC Chargers with different communication protocols which are briefed in the table below

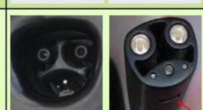
Charger Types and Sockets	Picture	Origin and Popular EV Models	Maximum Power Output and Communication Protocols
DC CHARGERS			
CHAdeMO		Origin from Japan; Most popular DC charger in the world; used in Japan, Korea and parts of USA and Europe; Nissan Leaf, Mitsubishi, Kia etc	Up to 400 kW DC charging (1000 Volts, 400 Amps); Control Area Network (CAN) For communication between EV and EVSE
GB/T		Used in China; as well as Bharat Chargers in India; Chinese Vehicles and Mahindra Electric in India	Up to 237.5 kW DC charging (950 Volts x 250 Amps); CAN for communication between EV and EVSE
Tesla Super Charger		Tesla has its own supercharger. Tesla also sells adapter for connecting to a CHAdeMO charger	Up to 135 kW DC charging (410 Volt x 330 Amp); CAN For communication between EV and EVSE
SAE Combined Charging System (CCS)		CCS-1 and CCS-2 versions available; same plug used for both AC and DC charging; Most European Cars -Audi, BMW, Daimler, Ford, GM, Porsche, VW etc	Up to 43 kW AC and up to 400 kW DC (1000 Volt x 400 Amp) Power Line Communication (PLC) for Communication between EV and EVSE.

Table 2: Types of AC and DC Chargers with different communication protocols

All batteries cannot be fast-charged. In the battery parlance, the C-rate is used to refer to the charging rate. 1C rate refers to full charging in one hour; 2C rate refers to full charging in 30 minutes; 10C refers to full charging in 6 minutes. And C/2 means two hours to fully charge.
The maximum rate at which various types of batteries can be charged is provided in the table below:

Battery Chemistry	Maximum C Rate	Max Temperature (Degree C)	Life (Maximum Cycles)	Power Density (Wh/kg for cell)	Average Module Price (US$/kWh in 2018)*
Lithium Ion Iron-Phosphate (LFP)	Up to 2C	40	1500-3000	100-130 Wh/kg	270
Lithium Ion- Nickel Manganese Cobalt (NMC)	C/2	40	1000-2000	230-250 Wh/kg (for NMC 811)	250
Lithium Ion- Nickel Manganese Cobalt (NMC)	3C	40	3000-4000	200 Wh/kg (for NMC 811)	400
Lithium Nickel Cobalt Aluminium (NCA)	2C	40	1000-1500	250-270 Wh/kg	230
Lithium ion Titanate Oxide (LTO)	6C	60	7500-10000	50-80 Wh/kg	700

Table 3: Charging capacity for different battery type

More importantly, no matter what voltage or current the charger can deliver, the charging time is ultimately controlled or limited by the battery and the cells from which it is made and how much current they are capable of accepting.

The table below shows the charging times and associated charging currents for a variety of chargers used to charge batteries in a variety of vehicles.

EV Battery Charging Times Using the Maximum Available Power from Different Chargers												
Representative Vehicles and Chargers (Many variants are possible)				Charging Times and Rates (Hours and Equivalent Battery C Rates Supplied by Charger)								
				Charger	Level 1				Level 2		Level 3	
				Available Power	2 kW US Domestic		3kW Euro Domestic		20 kW 3 Phase Public		50kW DC Public Fast Charge	
	Charge Level and Equivalent C Rate	Battery Capacity (kWh)	Battery C Rate (Amps)	Charger Efficiency (%)	Hours to 80%	Charger Equiv C Rate (C)	Hours to 80%	Charger Equiv C Rate (C)	Hours to 80%	Charger Equiv C Rate (C)	Hours to 80%	Charger Equiv C Rate (C)
Vehicle	Electric Bike	0.5	20	85	0.2	4.3	0.2	6.4	0.02	42.5	0	425
	Plug In Hybrid PHEV	10	41	85	4.7	0.2	3.1	0.3	0.5	2.1	0.05	21.3
	EV Passenger Car	24	66.2	85	11.8	0.1	7.8	0.1	1.2	0.9	0.1	8.5
	Heavy Delivery Van	50	200	90	22.2	0.05	14.8	0.1	2.2	0.5	0.2	4.5

Table 4: Battery Charging time under different chargers

The table assumes charging from empty. In practice, most drivers will recharge before the battery is completely empty so that average charging times will be less than those indicated

The table also assumes fast charging. Thus the charger only supplies current during the "constant current" (CC) phase of charging so that the battery is charged to about 80% of its capacity

To fully charge the battery to 100% of its capacity, the "constant voltage" (CV) charging phase would require the current to be reduced to an average of about 10% of its "constant current" value to complete the final 20% of the charge. This would, in the worst case, increase the total charging time of all batteries using CC/CV charging to 3.5 times the fast charging time

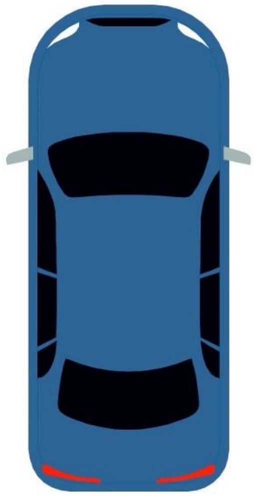
The table shows the minimum theoretical charging time for each application with different chargers assuming the full power of the charger is applied to the battery, in other words, the charger capability is fully utilized. Smaller batteries may not be able to use all of that capability however since the higher capacity chargers can deliver much more current than the smaller batteries can accept and so the current must be limited by the Battery Management System in the battery.

CHARGING INFRASTRUCTURE BUSINESS MODEL

Different countries have adopted different approaches in the creation of EVSE ecosystem with mixed results. There are two main approaches as described below:

Integrated Model

- The electric utility owns the EVSE and operate it either directly or through their franchisees (or contractors).
- The EVSE assets forms part of the regulated assets of the utility who are responsible for distribution of electricity as well as operation and maintenance of the EVSE.
- Most popular example of this model is Ireland and British Columbia in Canada.
- The main advantage of this model is that the utility need not worry about low volume of business in the initial years as the assets are created under regulated capex route.



Independent Model

- In this case independent private (or public-private partnerships) players set up EVSE under licenses from local governments or municipalities.
- They may appoint EV Service Providers (EVSP) for charging operations and payment settlements who ensures certain level of interoperability amongst different EVSE network owners.
- UK and Netherlands are examples of the Independent Model.

Figure 5: Charging Infrastructure business models

A comparative table of EVSE ecosystem in select countries is given below:

	United Kingdom	China	United States	Germany
Total EV Stock	160,000	2,600,000	1,100,000	200,000
Total Charge Points	14,000	808,000	500,000	25000
Charging Market Model	Independent	Independent	Independent	Independent
Public Charging Organization	By local authorities, over discrete platforms	By local authorities, over open access platforms	By charging network operators and property owners on Discrete platforms	Over three quarters of charging points are operated by electricity companies
Private Operators of Public Charging	5-10	5-10	10 networks ,many property owners	
EVSE Owner	Infrastructure is tendered by lower Governments like cities, regions or municipalities	Cities and provinces tender public charging infrastructure	Third party charging Service provider, Individual residents, Homeowner associations etc.	Municipal governments & private investors
EV Service Providers (EVSP)	Operation is done by private parties that Subcontract their energy supplier	Private companies, Energy companies and contractors operate as EVSPs	Private EVSPs	Private EVSPs
Entity Responsible for Grid Upgradation	Grid operator	Grid operator	Grid operator	Private investor but the Govt funding will cover Network connection cost
Interoperability	No national interoperability between EVSEs in different UK regions, however, interoperability within regions is organized by EVSPs	No national interoperability between EVSEs in China	No national interoperability between EVSEs in USA.	Ladenetz, a government sponsored consortium of utilities, universities, and private EVSPs in Germany and the Netherlands, is creating a Europe-wide network of Interoperable charging stations.

Table 5: EVSE Business Models in select Countries

GLOBAL POLICIES ON CHARGING INFRASTRUCTURE

Multifaceted and collaborative efforts would be required in promoting the establishment of a charging infrastructure. Early charging infrastructure will be crucial, and Govt. will surely need to play a leadership role. Eventually, with growth in the number of EVs and viable business models, businesses will be willing to set-up and operate charging infrastructure.

Various governments around the world have earmarked funds for setting up charging infrastructure.

Country	Program	Budget	Mechanism of Support
Germany	• €300 million for 10,000 Level-2 and 5,000 DC fast charging stations	€300 million ($285 million)	Subsidies for 60% of costs for all eligible businesses
Japan	• Next Generation Vehicle Charging Infrastructure Deployment Promotion Project • Nippon Charge Service government-automaker partnership	Upto Yen 100 billion ($1 billion)	> Grants to local governments & highway operators > Public-private partnership
Netherlands	• "Green Deal:(curbside chargers on request)	€33 million ($31 million)	Contracts tendered to businesses on case-by-case basis
Norway	• Enova grant scheme from 2009 onwards		Quarterly call for proposal for targeted projects
United Kingdom	• Curbside stations for residential use • Highways England building DC fast charging stations along major roads in England	BP 2.5 million ($ 2 million) BP 15 million ($12 million)	> Municipalities apply for grants. Installers reimbursed > Grants and tenders administered by public body
China	• New Energy Vehicle Infrastructure Incentive Policy		> Grants to provincial & local governments > Local Government subsidies for home and public EV Charging
United States	• Grants for funding public charging stations through American Recovery & Reinvestment Act	$15 million	Matching grants for local governments

Table 6: Summary of major national-level charging infrastructure programs in selected markets

The scale of such support indicates a substantial commitment of the government towards electric mobility. There are examples from various metropolitan cities around the world where municipal governments in these cities have funded many charging stations in collaboration with utility bodies.

National government bodies in countries like the Netherlands, China, Germany, France, etc. have funded municipalities to install charging infrastructure.

Private charging, both at home and at the workplace, will represent the majority of electric vehicle charging. Therefore, a higher priority may be accorded to have policy measures and regulations around building a private charging network.

The Table provides a snap-shot of what is going on in various countries to enable home charging infrastructure:

Country/City	Program	Mechanism of Support
UK	Level 2 Charging at Homes	Incentive of up to 75% of hardware & installation cost (up to 500 Pounds)
Quebec (Canada)	Level 2 Charging at Homes	Incentive of up to 600 CAD on hardware & installation cost for 240 V Station
California	Green Building Standards Code	Regulation to have 3% of all parking spaces in commercial buildings include "make-ready" infrastructure for charging stations.
Europe	EU Directive	Directive that will require a charging point in every new or refurbished home beginning in 2019.
London	Regulation	Requires charge points at 20% of parking spaces in all new housing project as well as make-ready infrastructure for an additional 20% of spaces.
Germany	Mandate	Considering new policies to mandate charge points or make-ready infrastructure in all new building, as well as policies to streamline construction of charging stations in existing building

Table 7: Summary of schemes in various countries to enable home charging infrastructure

Charging infrastructure requires substantial installation, operation, and maintenance costs and can also incur significant costs for land procurement. Demand aggregation of home and workplace chargers (AC charging) can be a great lever to reduce prices as well as to have such charges installed at a mass level.

Governments can also support various other strategies like providing land for setting up charging stations, subsidized electricity tariffs, collaborate with residents and property owners to install AC slow charging infrastructure in shared parking facilities and promote consumer awareness in multi-unit dwellings.

The automobile industry can also collaborate with banks and power companies to form a joint venture and form a nationwide network of charging stations (including fast-charging stations).

EMERGING TRENDS

Induction Charging / Wireless Charging

Many manufacturers are currently working to propose that local communities and businesses end charging by cable and sockets for a non-contact system of electrical charging for electric vehicles.

The system designed to be installed on the ground can be integrated on a large scale in the asphalt of a road or attached to off-street parking places. The charging of the battery of a vehicle parked above the system will be done wirelessly by induction.

The technology is based on inductive charging, which involves electricity being transferred via an air gap between two magnetic coils.

It allows electrical energy to be transferred from the grid to a vehicle without the aid of wires. Energy transfer takes place by magnetic resonance coupling between two copper coils tuned to the same frequency, one embedded in the ground and the other mounted under the vehicle. The arrangement is essentially a transformer with the primary in the ground and the secondary in the vehicle. This is not a charger in itself. It simply replaces the direct connection to the grid. The AC power picked up by the secondary coil is applied to a normal charger such as the Level 1 and Level 2 chargers.

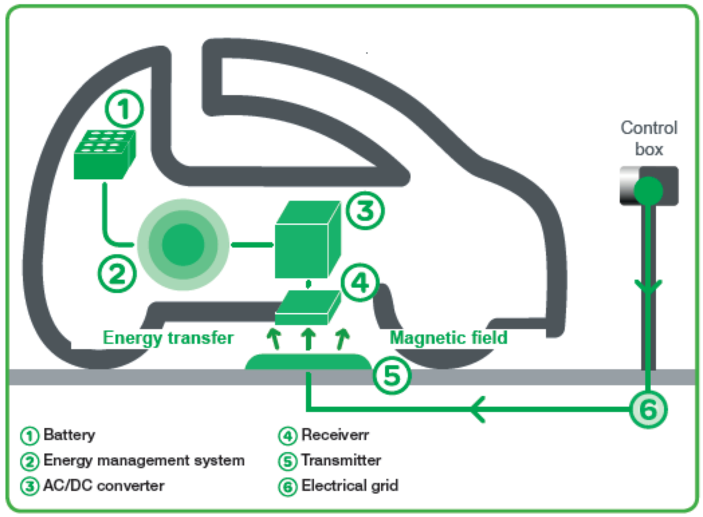


Figure 6: Schematic of Induction Charging

Benefits of wireless charging

- Full autonomy: The application of autonomous vehicles is yet to be fully realized because they are still being developed. However, if there is no need to stop in order to charge autonomous vehicles, they can move indefinitely – or at least until repairs are needed. This may increase the scope and efficiency with which they can be utilized
- Charging station not required: There is no need to insert a cable with wireless charging, which means it's a more user-friendly approach. You can go about your day without even thinking about charging the car and it will automatically take care of itself
- Smaller battery units: The increase in charging points means the size of the battery pack can be reduced. This reduces the cost and weight of the vehicle

Drawbacks of wireless charging

- It's important to have a balanced overview of any technology, and wireless electric vehicle charging is going to have teething problems just like the majority of new technologies – here are a few potential drawbacks
- Energy loss: There is the potential for 90-93% energy efficiency, but there will still be energy loss during the transfer. Over a larger scale, this leads to a lot of wasted energy that increases the total amount of electricity required to run the vehicles
- Building the infrastructure: When considering adding wireless charging to roadways, implementing the infrastructure may not make economic sense. To start, it might be restricted to densely populated urban areas, which will limit the user to predefined locations
- Health effects: The magnetic fields created may be harmful or they may not – more investigation is required to ensure that long-term exposure to weak magnetic fields isn't going to be a problem

Currently, there are a limited number of companies offering wireless charging technology. Since 2012 Qualcomm Halo has been developing its charging system that's currently used by the Formula E electric race series. They can transfer up to 22kW of power, which is in line with what rapid public chargers are offering.

BMW plans to sell a wireless charging pad for the 530e iPerformance hybrid. It will take 3.5 hours to fully charge the car and works by connecting your home's power outlet.

Figure 7: Wireless Charging Systems

Battery Swapping

Significant consideration has been given by the government on battery swapping as a mechanism to mitigate the issues of (a) cost of ownership and (b) range anxiety faced with electric vehicles.

A Battery Swapping Infrastructure essentially supports swapping of discharged batteries in a vehicle with fully charged batteries from a shelf. A key advantage of battery swapping is the reduced time for energy replenishment in EVs as battery swap can be possible within 5-15 minutes compared to up to eight hours required for charging a battery.

This strategy of providing widespread battery swapping model is also expected to contribute to reducing the upfront cost of EVs as vehicles can be sold with a battery available on lease.

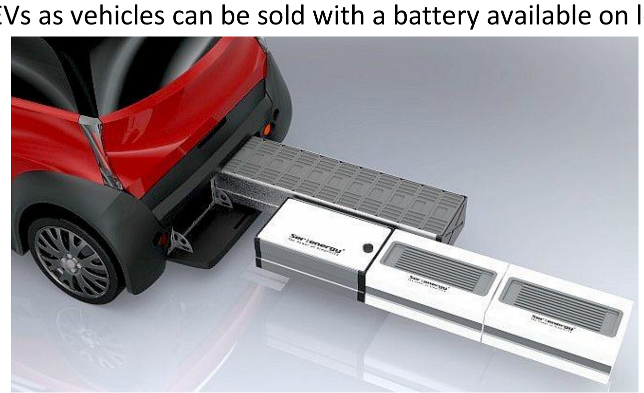


Figure 8: Typical Schematic of Battery Swapping System

To fully utilize the potential of BSS, the EV batteries should be easily replaceable and accessible to one and all.

For this, there would be one most important requirement: Consistent Standardization of Batteries of various EV's. Therefore, the best model for EV will be one where batteries will be leased by the vehicle owner from the company. The most prominent feature of this approach would be that the price of EV will drastically reduce as the cost of the battery is deducted from the total vehicle cost

Battery swapping station is a place that an electric car can drive over and an automatic or a manual system can open up the bottom of the electric car, remove the exhausted battery, and insert a new fully charged battery in its place. You can in fact picture it as robot mechanics giving an electric car a fresh battery

The adoption of EVs is hindered due to high cost of ownership. By taking out of the battery from the equation the cost can be reduced. A third party will have ownership of the battery and will be liable for replacing the drained batteries with fresh, charged and standard ones.

Battery Swapping Stations acts as a battery aggregator and has enough clout to participate in markets for electrical energy and reserve. The BSS can maximize its profits by providing services to the system, such as voltage support, regulation reserves, or energy arbitrage

However, the battery swapping model has not fully succeeded globally due to techno-commercial dynamics. As is known, the main issues are around standardization, commercial viability, and reliability. This system has its own advantages and disadvantages.

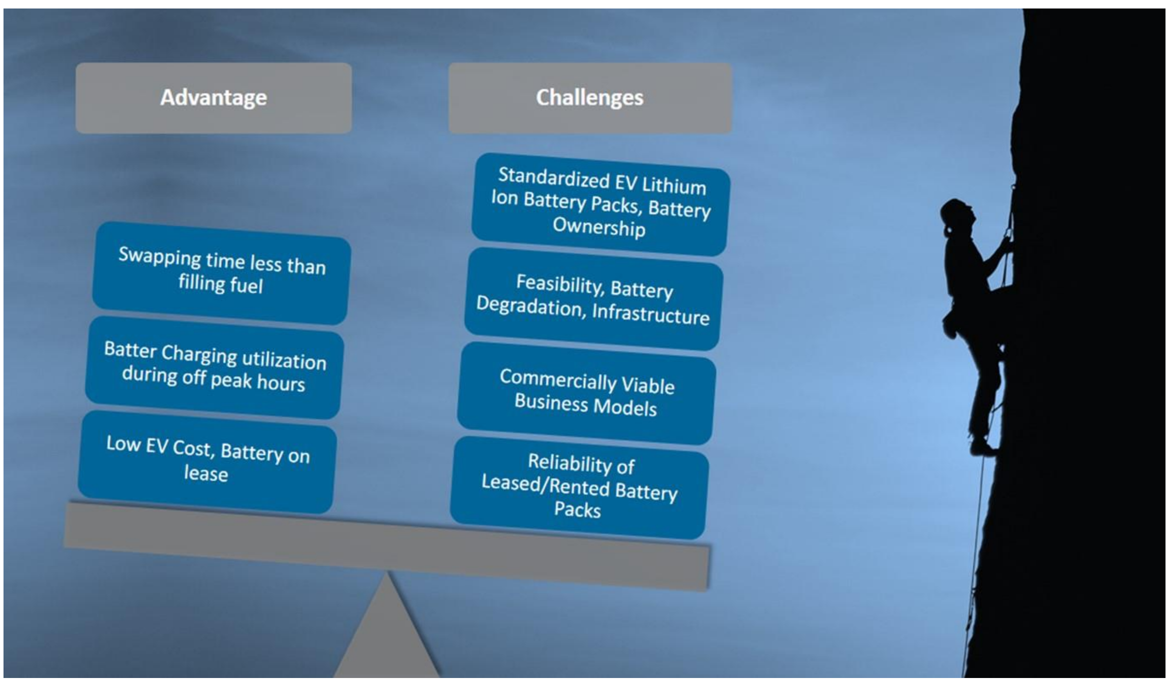


Figure 9: Battery Swapping Model Advantage & challenges

Vehicle to Grid (V2G) Energy Transfer

Proposed by electric utilities and academics, the V2G facility of the Smart Grid envisages the ability of electricity-generating utilities to level the demand on their generating capacity by drawing energy from the batteries of EVs connected to the grid during the daylight hours of peak demand and returning it to the vehicles during periods of low demand during the night.

It would require charging stations to be capable of bi-directional power transfer incorporating inverters with precisely controlled voltage and frequency output to feed the energy back into the grid.

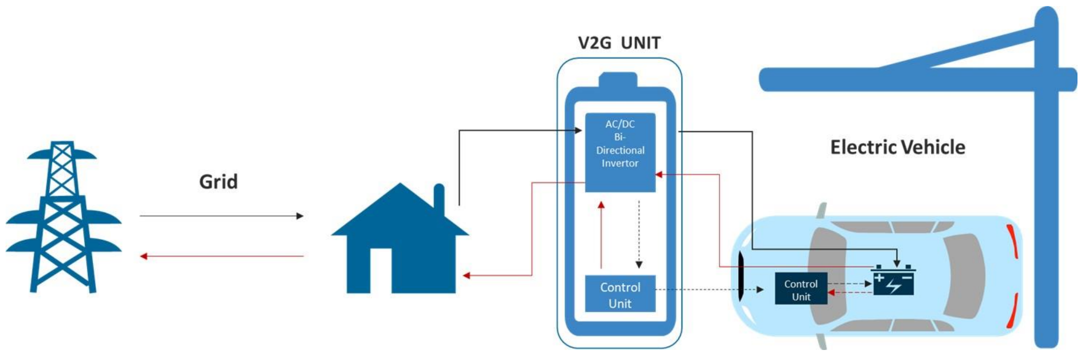


Figure 10: Vehicle to Grid Energy Transfer

Vehicle-to-grid (V2G) describes a system in which there is reciprocal, bi-directional electrical energy flow between plug-in electric vehicles, such as electric cars (BEV) and plug-in hybrids (PHEV), and the power grid. This is done through selling demand response services by throttling the charge rate or returning electricity to the grid.

Other types of V2G technology consists of load-sharing sources with the power grid. This can include subsets of V2G like vehicle-to-home (V2H) and vehicle-to-building (V2B), both of which draw power directly from the EV rather than through the power grid.

Benefits of V2G

Owning an electric vehicle already has a variety of benefits from tax breaks to rebates and grants, but now, with V2G technology, it can also be used to power your house. The following are some of the biggest advantages to V2G technology:

- Financial Rewards: Energy stored in the vehicle can be used to avoid peak tariffs at times of demand and an extra strain on the power grid. V2G can also optimize the value of energy generated from home renewables (like solar panels) to reduce monthly bills. All of these cost savings are in addition to the savings bundled into owning an EV in the first place.
- Home Energy Storage: A 4kWh electric battery has the power to provide a third of the energy needs for a typical home. Products for home battery energy storage are currently being developed to offer the opportunity to scale-up dispersed energy storage capacity. Maximizing resource use through a fully connected home energy network can help homeowners save thousands each year. Additionally, the energy can be saved from the power grid by using EVs when people are at work and running errands to power other buildings as part of the new grid infrastructure.

- Green Impact: V2G is intended to put more electric vehicles on the road in an attempt to give back to the power grid and save from any lapses in the power supply. Inevitably, this has an incredibly positive impact on the environment and the air. Not all vehicle owners have to invest in expensive technology, either.

Drawbacks of V2G

- Major obstacle V2G faces is the fact that when batteries are overused, they become less effective at storing energy. However, as the stronger lithium-ion batteries are getting cheaper to manufacture (and more disposable), this issue is quickly becoming less of a problem.
- Business cases for V2G still need to be made in a variety of local economies and governments.

V2G is fairly new but each year more car companies are jumping on board to harness the potential of the technology. This type of hardware helps to balance supply and demand when used in addition to smart chargers.

Nissan and Mitsubishi are currently the leaders in manufacturing EVs with V2G capabilities

Figure 11: Vehicle-grid-v2g-charging

CONCLUSION

- The problem of charging infrastructure availability is complex and large, and constructing a comprehensive charging network would be prohibitively expensive. Furthermore, because the industry is evolving quickly, current assumptions about technology and driver preferences may not hold in the future.
- Interoperability between the EVSEs is a challenge. While Japan and Korea have adopted CHAdeMO, Europe has gone for CCS; and the USA has all four types of EVSEs. China has developed fast-chargers based on the Chinese GB/T standards
- Different segment of vehicles (2W, 3W, PVs, CVs) may require a different type of charging standard (& connector), however, the charging infrastructure, at-least at public places, should be common to the extent possible to reduce the infra cost
- Standardization of Batteries is a challenge in the current scenario. With new battery technologies, like solid-state lithium-ion batteries, sodium-ion batteries and silicon-based batteries under development, charging ecosystem is expected to be disrupted
- Battery swapping infrastructure for 2/3-wheelers and buses may be considered feasible. Hence Standard for battery swapping should be formulated to ensure safety and functional requirements
- Regulations need to be put in place to ensure the availability of stable and good quality power for EV charging
- It is generally accepted that the charging infrastructure industry will eventually shift to the private sector as electric vehicle sales increase the demand for charge points and the profitability of their operation.

ABOUT TATA ELXSI

Tata Elxsi is a leading provider of design and technology services for product engineering and solutions across industries. Our ability to provide complete product development support to OEMs and Tier 1 suppliers enables us to offer exclusive software and engineering services for the automotive sector. We run Centers of Excellence (CoE) in the areas of styling/ aesthetic design, Mechanical Design Engineering, embedded electronics, cloud software Engineering, and mobile-based applications. Looking at the global electrification trend in Automotive Industry, we have been able to set up a dedicated core team in the area of Electric mobility including the domain of EV charging infrastructure. The capability of the core EV Charging infrastructure team, in a nutshell, is depicted below:

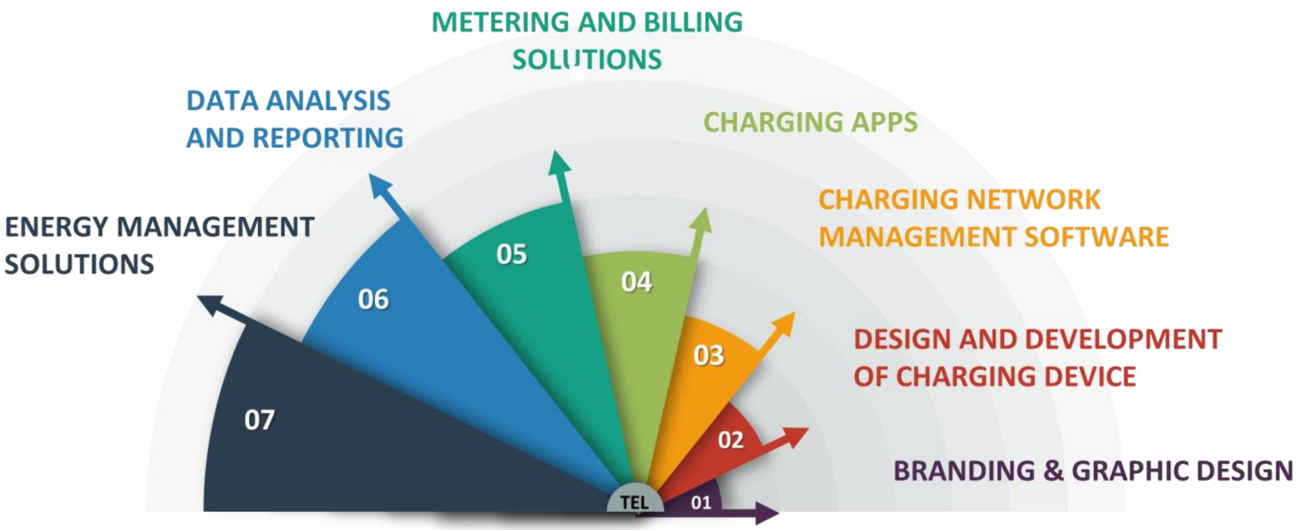


Figure 12: Snapshot of Tata Elxsi Competency

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