ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

TABLE OF CONTENT

TABLE OF FIGURES

EXECUTIVE SUMMARY

Automobile industry is considered as one of the major industrial sector globally as well as in India. There has been rapid increase in motorization mainly because of urbanization, increase in per capita income, inadequate public transport services etc. This increase in automobiles has resulted in proportional increase in emission of pollutant gases as well, making automobile sector one of the major contributors of global warming. Road transport alone was responsible for three quarter of this emission. Electric vehicles are prominent solutions to this problem, which are not only environment friendly but also have better efficiency and economic operations. Therefore towards sustainability, use of electric vehicles in large scale is being explored by many nations including India.

India has taken an initiative through the National Electric Mobility Mission Plan 2020 (NEMMP 2020) to transform automotive and transportation industry in the country. It envisages a combination of policies aimed at gradually ensuring a vehicle population of about 6-7 million electric/hybrid vehicles in India by the year 2020. As part of NEMMP, a scheme namely FAME (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles) has been also launched to encourages buyers to purchase electric vehicles, where GoI reimburse the automakers the discount that the auto makers will pass on to the customers.

Electric Vehicles

Electric Vehicles use electric motor to drive the vehicle, where batteries in them serve as power source. The electric vehicles can be categorized into three categories based on their uses of batteries as source of power:

- **Battery Electric Vehicle**, which uses only battery as power source to operate
- **Plug-in Hybrid Electric Vehicle** comprises of both electric motor and Internal Combustion Engine (ICE), to drive the vehicle. Plugs are provided to charge the batteries.
- **Hybrid Electric Vehicle** which does not have plug-in feature to charge the batteries from electrical grid. Only regenerative braking is used to charge the batteries.

EV Charging Infrastructure

The electric vehicle charging infrastructure can be set up in two formats. In one format Electricity is provided to vehicle using EV supplying equipment, connectors, plugs etc. In second format battery swapping stations may be put into service where simultaneous charging of tens / hundreds of batteries is possible and swapping of charged batteries takes place with discharged batteries of EVs. Details of different types of charging infrastructures are described below:

- **Level-1 Charging Infrastructure**: These are generally installed at residential spaces and uses household supplies. They charge the vehicle in 7-10 hours of time.
- **Level-2 Charging Infrastructure**: These are generally installed at societies, offices, malls etc. They charge the vehicle in 3-4 hours of time.
- **Level-3 Charging Infrastructure**: Installed along the highways just like petrol pumps, charging equipment in these infrastructure charges vehicle batteries in 10-30 minutes of time.
- **Battery Swapping Stations**: In these stations batteries are charged simultaneously in tens or hundreds in number. Batteries of electric vehicles are swapped to provide service. Discharged batteries are taken back and charged batteries are provided to consumers in minimum possible time.

Electric Vehicle Plug Type

The plug type of EV refers to physical design of the plug(s) with which the vehicle is connected to the charging equipment. The plug type varies according to type of power supply & order of power. The plug types can broadly categorized into two AC plug and DC plug.

- **AC Plug:** At present, three types of AC plugs are available worldwide:
  - Type-1 (Yazaki Plug)
  - Type-2 (Mennekes Plug
  - Type-3 (Scame plug)
- **DC Plug:** DC plug permits fast charging by converting AC into DC in charging equipment itself and charging battery directly through DC power supply. DC plug has also different types as mentioned below:

  - CHAdeMO Plug
  - Combo Plug

Challenges in EV Charging Infrastructure

- **Technical Challenges**
  - Shorter travel range of EVs requires charging infrastructure at frequent intervals.
  - Energy transfer to vehicle battery requires physical connection between charging equipment and electric vehicle battery system. Therefore, there should be common standard of plug and accordingly suitable charging equipment. Presently many types of plug are in use across the world.
  - Due to a lot of innovations and developments in battery technology changing equipment technology and battery swapping stations shall have greater risk of becoming obsolete in coming years.
  - If battery swapping stations are installed, then there would be requirement for limiting battery types with respect to ratings otherwise multiple requirements would have to be created for each type of battery.
- **Financial Challenges**
  - Presently EVs are costly than the conventional fossil fuel vehicles which work as entry barrier and EV charging infrastructure viability is dependent upon higher penetration of EVs.
  - EV charging infrastructure on commercial model is still under development stage. With more EVs on roads, this model would shift from subscription basis to Pay-per-use basis.
  - EV charging infra requires a lot of investment, which would be possible only when returns would be attractive.

- **Policy & Regulatory Challenges**
  - Finalisation of EV charging plug and infrastructure standards are required. Once the plug standardization is completed, it would be easier for deployment of more vehicles and their charging stations.

- In many countries including India for automobiles and power have separate ministry / institutions and accordingly policies. For EVs they need to come on common platform.
- Sale of electricity through EV charging infrastructure has not been considered in regulations. Necessary amendments are required to enable it.
- Policies need to be made for EV charging equipment installation within home or society

Business Potential in India

It is estimated that cost of setting up EV charging infrastructure shall be as below:

S. No.	Type of EV Charging Infrastructure	Estimated Cost (in Rs. Cr.)
1.	Slow Charging Station with 10 Nos. charging equipment	1.20
2.	Fast Charging Station with 6 Nos. charging equipment	3.69
3.	Battery swapping station with 100 Nos. Batteries	5.77

As per NEMMP 2020, Govt. of India is planning to set up 175,000 – 227,000 EV charging points for 6-7 million vehicle penetration. Out of these about 10% would be fast charging points. Therefore to meet the target it is estimated that following investment would be required:

S. No.	Item	Nos.	Cost of Each Station (Rs. Cr.)	Total Cost (Rs. Cr.)	Remarks
1.	Slow Charging Stations with 10 charging equipment	20430	1.20	24516.00	For world average penetration investment required would be Rs. 103,620 Cr.
2.	Fast AC/DC Charging Station with 6 Nos. charging equipment	1892	3.69	6981.48	For world average penetration investment required would be Rs.
3.	Battery swapping	114	5.77	657.78	

S. No.	Item	Nos.	Cost of Each Station (Rs. Cr.)	Total Cost (Rs. Cr.)	Remarks
	stations with simultaneous charging facility for 100 batteries				56,530 Cr.
4.	Central Management Centre	1	50.00	50.00	
Total Business Potential (In Rs. Cr.)				32205.26 **Say 32205**	

However, EGV charging points envisaged in NEMMP 2020 are very less compared to global standards. As per Global EV Outlook 2016, density of fast charging station for EV worldwide is 2.22% and that for slow charging station is 12.68%. Therefore, in subsequent years upgradation would be required with investment upto Rs. 160000 Cr.

Business Models

Following business models may be implemented to establish EV charging infrastructure:

- BUILD-OWN-OPERATE (B-O-O): In this business model, a company / SPV say “PowerCharge” will build, own and operate publicly accessible charging stations. In EV charging stations having EV Supply Equipment, charges shall be based on energy used to charge the vehicle, whereas in Battery Swapping type, it would be based on number of batteries and their State-of–Charge (SOC).
- BUILD-MAINTAIN: In this business model, EV charging stations shall be owned by public just like petrol pump owners presently, who will be operator as well. “PowerCharge” will build infra and would provide maintenance services. Electricity may or may not be provided by “PowerCharge”.

Way Forward

To make EV charging infrastructure a reality following policy and regulatory innervations are required, which may be taken up in consultations with representatives from concerned ministries, electrical utilities, electric vehicle manufacturers, battery manufacturers, electrical equipment manufacturers, urban bodies & other stakeholders etc.:

1. Finalization of technical standards for electrical vehicle supplying equipment, plugs etc.
2. Guidelines for setting up different levels of charging infrastructure
3. Regulation on category of energy sales from charging infrastructure
4. Regulation allowing EV charging Infra company to have open access for sourcing renewable power from grid
5. Identification of implementing agency and business model
6. Establishment of Central Management Centre
7. Change in Zone and building codes to accommodate charging stations
8. Identification of implementation agency for EV charging station and central management centre

part from this other initiatives like R&D, pilot projects, indigenization of technologies, Make in India etc. need to be continuously explored to make the electric transportation viable. Above infrastructure is very important for transforming transportation in India, which will be a game changer for our fight towards global warming & climate change.

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CHAPTER-1

INTRODUCTION

Automobile industry is considered as one of the major industrial sector globally. In India, this industry accounts for 7.1% of the GDP. Many companies have hub for design and development of automobiles and its components in India. India has also seen a tremendous growth in number of vehicles on roads, which has increased multifold from 55 million in 2001 to 182 million in 2013. This rapid increase in motorization is mainly because of urbanization, increase in per capita income, inadequate public transport services etc.

This is well established that automobile sector across the world is a major consumer of fossil fuels and is one of the major reasons for global warming. Diesel / Petrol vehicles emit a lot of black carbon, ozone-producing gases and CO_2 through tailpipe. As per "CO_2 emissions from fuel combustion statistics 2016 HIGHLIGHT" by IEA, in 2014, 23% of global CO_2 emission was only from Transport sector. Road transport alone was responsible for three quarter of this emission. Therefore to make our earth cleaner and green, reduction in greenhouse gas emission especially from road transport is necessary and solutions are being explored in all directions by many agencies/ countries.

1.1 INDIAN SCENARIO

In Indian context, Rapid motorization has affected us in following manner:

- **Increased Crude Oil Import**: We are not having enough crude oil reserves to meet the growing requirement and almost 80% of the demand is met through import only, which costs our economy heavily.
- **Air Pollution**: Air Quality Indices related to India indicate that the air in many cities of India is no longer healthy. Automobile related pollution has been one of the causes for this. As per WHO – Ambient (Outdoor) Air pollution in cities database 2014, five(5) Indian cities are among the top 10 polluted cities in the world.
- **Noise Pollution**: In some of the metro cities noise pollution is causing ill effects on human beings.

To make India self-reliant in terms of energy security, we need to reduce import of fossil fuels. This will improve our international trade balance as well. Equally important, our commitment towards reduction in global warming can be achieved if our consumption of fossil fuels in transportation is reduced. We need a shift towards green automobile solutions that reduces/ do not produce greenhouse gas emissions.

All across the world Governments & Society are working hard to resolve the issue. Electric Vehicles are one of the solutions found suitable everywhere. Government of India has also set an ambitious target to make India 100% electric vehicle nation by 2030.

1.2 WHY WE NEED ELECTRIC VEHICLE

Electric Vehicles (EV) use Electricity partially or fully in driving the vehicles. It helps in resolving some of the major issues like rapid depletion of fossil fuel, incessant increase in energy costs, impact of transportation on the environment & climate change. Some of the benefits are described below:

- **Environmental Benefits**: EVs release no tail pipe air pollutants at the place where they are operated. They also typically generate less noise pollution than an internal combustion (IC) engine vehicle, whether at rest or in motion. Adaptation of EVs would have a significant net environmental benefit. Another major environmental benefit is EV motors don't require oxygen, like IC engines; hence no combustion phenomenon. EVs reduces 35-60% carbon dioxide emission from electricity than the CO_2 pollution from the conventional car with an internal combustion engine.
  When renewable energy is used to power electric vehicles additional benefits for environment are achieved. Further fossil fuel which is not used in vehicles may be more efficiently used at thermal power plants to generate electricity.
- **Efficiency:** Electric motors are mechanically very simple and often achieve 90% energy conversion efficiency over the full range of speeds and power output and can be precisely controlled. They can also be combined with regenerative braking systems that have the ability to convert movement energy back into stored electricity. This can be used to reduce the wear on brake systems (and consequent brake pad dust) and reduce the total energy requirement of a trip. Regenerative braking is especially effective for start-

and-stop city use. EVs provide quiet and smooth operation and consequently have less noise and vibration than IC engines.

EV 'tank-to-wheels' efficiency is about a factor of 3-4, higher than IC engine vehicles having efficiency of about 20%. In EVs, energy is not consumed when the vehicle is stationary, unlike IC engines which consume fuel while idling.

- **Economic:** The cost of operating an EV is much less compared to petrol / diesel fuelled vehicles. In Indian context, cost of operating EVs may be half of diesel vehicle and quarter of petrol vehicles on per Km basis.
- **Stabilization of the Grid:** Though it is premature, Vehicle to grid (V2G) concept of EVs can help in stabilization of grid. It can be plugged into the electric grid when supply is more than demand and in peak times batteries in EVs can power grid by sending energy back to grid. Owner is also benefited on price differential of peak and off-peak energy. In case of higher renewable penetration, EVs provide flexibility in generation as well as in load allowing integration of renewable energy sources efficiently.

1.3 National Electric Mobility Mission Plan 2020

The National Electric Mobility Mission Plan 2020 (NEMMP 2020) of Govt. of India is an ambitious initiative that has the potential to bring about a transformational paradigm shift in the automotive and transportation industry in the country. This is a culmination of a comprehensive collaborative planning for promotion of hybrid and electric mobility in India. NEMMP 2020 envisages a combination of policies aimed at gradually ensuring a vehicle population of about 6-7 million electric/hybrid vehicles in India by the year 2020. This plan intends to support EV market development and its manufacturing system. This plan envisaged a total fuel saving of about 9500 million litres by 2020 that will be around Rs. 62,000 crore of fuel cost. Highlights of this scheme are:

- Demand side incentives to facilitate acquisition of hybrid/electric vehicles
- Promoting R&D in technology including battery technology, power electronics, motors, systems integration, battery management system, testing infrastructure, and ensuring industry participation in the same
- Promoting wide variety of charging infrastructure

- Supply side incentives
- Encouraging retro-fitment of on-road vehicles with hybrid kit

The 2020 roadmap estimates a cumulative outlay of about Rs.14000 Cr. during the span of the scheme, including industry contribution.

As part of NEMMP, Department of Heavy Industries (DHI) has launched a scheme namely FAME (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles) in India. The scheme is proposed to be implemented over a period of two (2) years, starting from April 2015 till March 2017. As on 31st March'17 total 1,36,862 electric vehicles have been purchased under this scheme.

FAME scheme encourages buyers to purchase electric vehicles over the traditional fuel based cars, where GoI shall reimburse the automakers the discount that the auto makers will pass on to the customers. Almost 60% of these funds are allocated towards Demand Incentives. The scheme is applicable to all cities and towns including – smart cities, metropolitan cities of Delhi, Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad, north eastern cities and cities with more than 1 million population. FAME shall also focus on developing indigenous technology and R&D capability to develop and manufacture components and systems for hybrid vehicles in India. Through this a number of R&D and pilot projects are already running in India.

Definitely Electric Vehicles are the focus area to reduce woes generated through conventional transportation sector. Initial phase of EV implementation is struggling with various issues related to standardization, charging infrastructure, technology adoptions, regulatory & policy transformation etc., which have been discussed in subsequent chapters.

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CHAPTER-2

EVS AND CHARGING INFRASTRUCTURE

Batteries, essential part of EVs, are energy storage device that provide electricity to Vehicle drive. As applicable to all energy storage devices, batteries also have limited capacity and therefore when put in use, provide limited power to the vehicle. Hence recharging of them is required to use the vehicle again for movement. This makes requirement of charging infrastructure equally important for higher penetration of EVs and in-fact both are interdependent for their growth. This chapter covers a brief introduction to different types of electric vehicles and their charging infrastructure.

2.1 TYPE OF ELECTRIC VEHICLES

Electric Vehicles use electric motor to drive the vehicle, where batteries in them serve as power source. The electric vehicles can be categorized into three categories based on their uses of batteries as source of power:

2.1.1 BATTERY ELECTRIC VEHICLE (BEV)

This type of electric vehicle uses only battery as power source to operate the electric vehicle. Batteries power the DC motor which drives the vehicle. The range of BEV depends upon the capacity of the battery. The charging of electric vehicle is accomplished by connecting the vehicle with electric grid through connector.

Figure 2-1: Battery electric vehicle

Generally this type of electric vehicles are equipped with regenerative braking, in which propulsion motor during braking turns into generator enhancing the range of vehicle by 5 to 15%. Figure 2-1 shows the schematic of a typical BEV.

2.1.2 Plug-in Hybrid Electric Vehicle (PHEV)

PHEV comprises of both electric motor and Internal Combustion Engine (ICE), to drive the vehicle and it uses typically two energy sources for driving of vehicle i.e. Batteries & Diesel / Petrol /Gas. Plug is provided to charge the batteries in vehicle. When battery is in charged condition, PHEV is used as pure electric vehicle and when battery exhausts, PHEV becomes conventional vehicle running on fossil fuel.

PHEV can further be categorized as series hybrid and parallel hybrid. A series hybrid is propelled solely by electric motor. In absence of power from batteries (when batteries exhaust) Petrol / Diesel / Gas are used first to generate electricity, which is further used to drive the electric motor. Whereas parallel hybrid EV is propelled by the electric motor as well as ICE. When battery is used, it drives electric motor and when petrol / diesel / Gas are used, ICE drives the vehicle. In this type of vehicle simultaneous operation of both electric motor & ICE is also possible. Thus series hybrid requires larger motor & battery capacity to match the performance criteria of parallel hybrid. The typical series and parallel hybrid PHEV are depicted in Figure 2-2 (a) & (b) respectively.

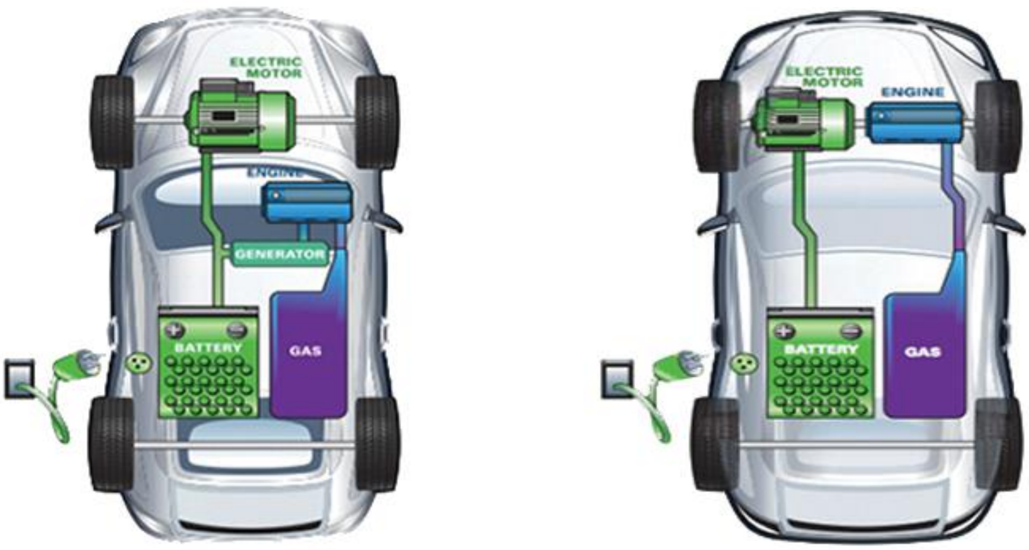

Figure 2-2: (a) Series plug-in hybrid vehicle (b) Parallel plug-in hybrid vehicle

2.1.3 Hybrid Electric Vehicle (HEV)

Hybrid Electric Vehicle does not have plug-in feature to charge the batteries from electrical grid. Such type of vehicle generally uses small capacity batteries which are charged through regenerative braking to provide the power during acceleration of vehicle. A typical HEV is shown in Figure 2-3.

Figure 2-3: Hybrid electric vehicle

2.2 On Vehicle Charging system

To facilitate the charging of electric vehicle, all the electric vehicles are equipped with on vehicle charging system. It receives power from outside charging infrastructure and converts it into suitable form to be stored in batteries. Energy stored in batteries are used to provide power to electric motor. On vehicle charging system consists of vehicle inlet, AC-DC converter & controller, batteries, motor as shown in Figure 2-4.

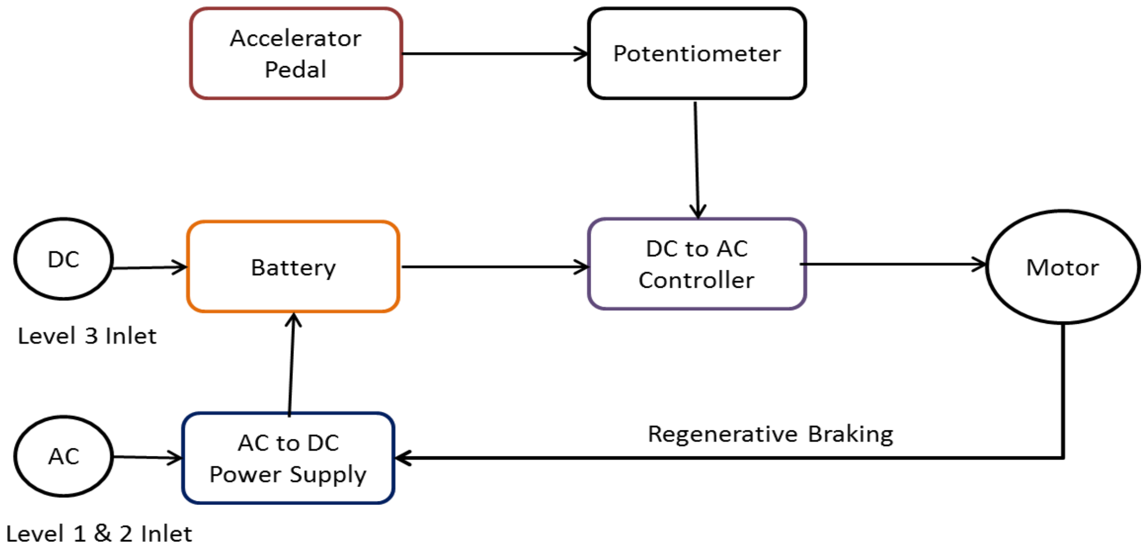

Figure 2-4: On vehicle charging system

The important equipment of on-vehicle charging system is described in detail as under:

2.2.1 Inlet & Connector

The inlet is on vehicle device which is fixed to the vehicle while connector (plug) is a device which is fixed to flexible cable and associated with electric vehicle supplying equipment. The inlet may be single AC inlet or combination of individual AC & DC inlet. The DC inlet is used for level-3 charging while AC inlet is used for level 1 & 2 charging as discussed in later section of this chapter.

2.2.2 AC to DC Power Supply

The AC to DC power supply is used for level 1 & 2 charging. In this the conversion of AC to DC takes place to charge the battery. This system is also equipped with battery management system to monitor & control the charging of battery based on battery parameters.

2.2.3 Battery

The batteries in electric vehicle are the energy storing devices. In general the battery used in for electric vehicle application have ability to be charged at high rate as well as have good energy density. The lithium ion battery technology can charge/discharge from 4C[1] to 8C, thus majority of electric vehicle manufacturers are using lithium ion battery as energy storing devices.

2.2.4 DC to AC Controller

Accelerator pedal gives signal to potentiometer, from which signal is sent to DC to AC controller. This controller regulates the frequency and voltage supply to motor which in turns control the speed.

2.3 Electric Vehicle Charging System

Charging of EVs require infrastructure outside the vehicle compatible with the system inside the vehicle. EV charging system takes power from grid and converts it in suitable forms compatible with vehicle requirement. It includes hardware such as electric vehicle supplying equipment, socket, cables, the electric vehicle couplers, attachment plugs etc. The typical electric vehicle charging infrastructure is shown in Figure 2-5.

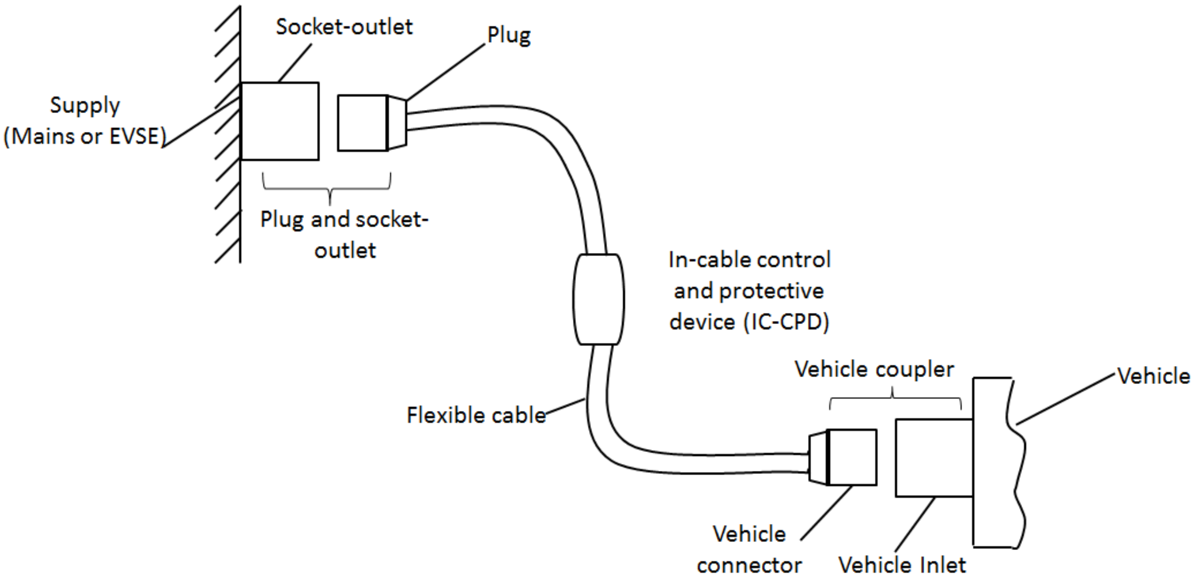

Figure 2-5: A typical electric vehicle charging system

2.4 Type of Charging Infrastructure

The electric vehicle charging infrastructure can be set up in two formats. In one format Electricity is provided to vehicle using EV supplying equipment, connectors,

[1] A C-rate is a measure of the rate at which a battery is discharged relative to its maximum capacity. A 1C rate means that the discharge current will discharge the entire battery in 1 hour.

plugs etc. as shown in Figure 2-5. These are categorized into three levels depending upon magnitude of voltage & current used for charging. On the other hand, battery swapping stations may be put into service where simultaneous charging of tens / hundreds of batteries is possible and swapping of charged batteries takes place with discharged batteries of EVs. Details of different types of charging infrastructures are described below:

2.4.1 LEVEL-1 CHARGING INFRASTRUCTURE

Level-1 charging infrastructures are generally installed at residential spaces. It uses 120/230 volts AC supply system (depending upon local residential supply voltage) with 15-20 Ampere rating system to charge the electric vehicle within 7-10 hours preferably during off-peak conditions. In general, this type of infrastructure is least expensive and is favourable for residential purpose because vehicle can be charged in night with less expensive energy during off-peak conditions. A typical level-1 electric vehicle charging infrastructure is shown in Figure 2-6.

Figure 2-6: Level-1 electric vehicle charging infrastructure

2.4.2 LEVEL-2 CHARGING INFRASTRUCTURE

This type of charging infrastructure generally installed at office & commercial spaces. It uses 230/415 volts AC supply system (depending upon local power supply voltage) with 32 Ampere current rating system. This type of infrastructure is planned to charge one or more vehicle simultaneously. Level-2 charging infrastructure require communication capability for data access and charging station management. It has ability to measure & record energy usage and time of use statistics for different users. It charges vehicle with medium rate in 3-4 hours. This type of charging infrastructure can be established by distribution supplier/companies/malls etc. A typical level-2 electric vehicle charging infrastructure is shown in Figure 2-7.

Figure 2-7: Level-2 electric vehicle charging infrastructure

2.4.3 Level-3 Charging Infrastructure

Level-3 charging infrastructure is equivalent to petrol/diesel pumping station on the road. This type of infrastructure is consist of electric vehicle charging/supplying equipment which converts AC to DC power within the charging equipment and supply DC power directly to batteries. The DC output voltage may vary from 50 to 500 V_{dc} with current range upto 120 A. Typically this type of charger shall take 10-30 minutes for 50-80% charging. Such type of charging infrastructure involves charging of vehicle at high power, therefore power requirement of such charging infrastructure are large. A typical Level-3 electric vehicle charging infrastructure is shown in Figure 2-8.

Figure 2-8: Level-3 electric vehicle charging infrastructure

2.4.4 Battery Swapping Charging Infrastructure

EV charging at stations takes considerable time. Even Level-3 charging takes approx. 15-30 min. which limits the number of vehicles served per charging equipment per day. In high penetration scenario of EVs, charging may be challenging. Therefore a solution call battery swapping stations came into existence. Some of the manufacturers of electric vehicles have come up with battery swapping technology to charge the vehicle by swapping the discharged battery with the charged batteries. In the pilot project of Tesla, USA the average battery swapping time came out to be 7-10 minutes. Thus, this technology facilitates fast charging of electric vehicle. In swapping stations, service provider can charge batteries in bulk based on electricity prices of grid, hence benefitted from price differentials.

If battery swapping stations are to be made complementing to grid stabilization, a central management centre is required to be established, having control capability of battery charging rates according to grid conditions.

2.5 Electric Vehicle Plug Type

The plug type of EV refers to physical design of the plug(s) with which the vehicle is connected to the charging equipment. The plug type varies according to type of power supply & order of power. The plug types can broadly categorized into two AC plug and DC plug.

2.5.1 AC Plug

Initially when the development of electrical vehicles started, AC power was easily available at any place like residential, commercial buildings etc. for charging purpose. Therefore, all the manufacturers planned the charging of electric vehicle through AC power only. At present, three types of AC plugs are available worldwide which are discussed in detail as under:

2.5.1.1 Type 1 (Yazaki Plug)

The type 1 plug is the first standardized plug made for charging of electric vehicle. This plug was developed on the initiative of the Society of Automotive Engineers (SAE). This plug was finally approved by SAE in January 2010 as SAE J1772 standard plug. The plug permits charging at 120 or 220 V and it has two additional pins, next to two power pins and one ground pin, for safety and communication features. Because of its manufacturer, this plug is often referred to as the Yazaki plug. It is designed primarily for use at charging stations with cables that are permanently fixed to the charging stations. This plug is widely used in USA & Japan.

Figure 2-9: Yazaki plug

2.5.1.2 Type 2 (Mennekes Plug)

As type 1 plug was developed after taking grid scenario of Japan & USA. It was deemed insufficient in Europe where electrical grid is typically more powerful and would permit fast charging as compared to the USA & Japan. This plug was developed by Mennekes Elektrotechnik, in association with leading automakers Daimler, BMW, Volkswagen, Fiat, Ford, GM, Toyota and Mitsubishi and electricity companies RWE, Vattenfall, EDF, E.on, Npower, Endesa and Enel. It is referred as the Type 2 plug according to the IEC nomenclature. As this plug was not physically compatible with Type 1 plug, it lacks in global standardization and compatibility. It is widely used by Association of German Carmakers (VDA). Amongst its members are Volkswagen, Dailmer, BMW, Opel and the German division of Ford & Fiat.

Figure 2-10: Mennekes plug

2.5.1.3 Type 3 (Scame plug)

As there is no shutter in outdoor sockets of Type 2 plug, it lacks safety for children from maneuvering their fingers in the sockets. Therefore, group of French & Italian electrical equipment manufacturers organized themselves in the EV plug alliance and rejected the Type 2 plug design and comes with their own plug as Type 3 plug. It was original designed by Italian plug manufacturer Scame.

Figure 2-11: Scame plug

2.5.2 DC PLUG

To cater increasing penetration of electric vehicles, it was felt that either installation of more charging equipment would be required or increase in utilization of existing charging infrastructure through fast charging. As there is limitation of space at some places it was difficult to place new charging equipment. Therefore utilities and car manufacturers decided to find new plug which can permit charging at fast rate. To carry out fast charging through AC require larger power electronics equipment on the vehicle which was not feasible due to limitation of space and commercial unviability therefore DC plug was innovated. DC plug permits fast charging by converting AC into DC in charging equipment itself and charging battery directly through DC power supply. DC plug has also different types as mentioned below:

2.5.2.1 CHAdeMO Plug

In Japan & USA, where 110 Volts system is in operation, requirement of DC charging system was needed for fast charging. TEPCO, Japanese power utility took initiative and formed an association of Japanese car industry (Mitsubishi, Nissan, Subaru and Toyota) including some of the electric utilities. The CHAdeMO plug was designed for high voltages and high direct current. As Japanese EVs were globally marketed, it made the CHAdeMO as de-facto global standard for DC fast charging. CHAdeMO is widely used in Europe & Japan for DC fast charging.

Figure 2-12: CHAdeMO plug

2.5.2.2 Combo Plug

The major drawback of CHAdeMO plug standard is that it prescribes the separate vehicle inlet that is used for DC charging exhaustively. American & European car manufacturers have therefore refused to adopt CHAdeMO and proposed an alternative plug that combined AC and DC charging in one vehicle inlet. Five German car manufacturers (Audi, BMW, Daimler, Porsche and Volkswagen) along with GM and Ford come with Combo plug. The USA version combines Type 1 with additional DC pins while European version combines the DC pins with Type 2 plug.

Figure 2-13: Combo plug

2.6 Additional Requirements for EV Charging Infrastructure

Apart from charging equipment, EV charging infrastructure requires additional facilities, which are customer centric and enables commercial operation of infrastructure. Some of the additional requirements for charging infrastructure are discussed as under:

- **Mobile App / Web Portal for Booking of Slots:** Since EV charging takes time it would be better if charging slot booking facility is provided through mobile / web. It would empower users to search nearest EV charging infrastructure, availability status and booking facility. Various prepayment / post-paid payment options can also be offered through these apps.
- **Central Management Centre:** EVs are seen as complementing mechanism for more integration of RE in grid. Therefore all charging infrastructure would require to be integrated to a Central management Centre through SCADA system. Complete information of these infrastructures in real-time would be available at Central Management Centre, which would be coordinating with grid operators as well. Based on grid conditions pricing mechanism may also be evolved using such system. Figure 2-14 shows the Central Management Centre setup.

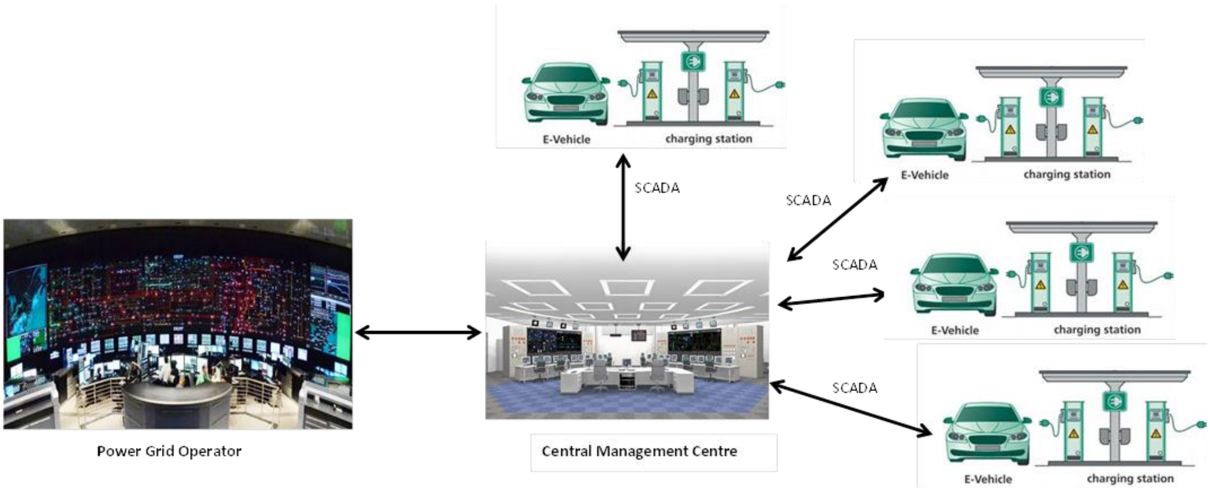

Figure 2-14: Central management Centre Setup

- **Metering & Billing System**: For commercial Operation of the system. Charging options may be provided in terms of amount, charging levels or energy
- **Maintenance Mechanism**: For all electrical and other facilities
- **Signage**: Required for locating the facility, proper operation, safety, space availability etc.
- **Lighting and Shelter**: For safety. Convenience etc.
- **AC & Ventilation**: For providing conditioned atmosphere for batteries
- **Fire Protection System:** For safety

- **Data Analytical Facility**: To improve charging mechanism according to uses

Large scale deployment of EV charging infrastructure as mentioned in this chapter would facilitate more penetration of EVs benefitting society and earth.

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CHAPTER-3

CHALLENGES IN EV CHARGING INFRASTRUCTURE

Electric Vehicles are future of transportation and every effort is needed to make them wide spread. This technology is in development phase and a lot of innovations are happening in this space. Even battery technology has improved significantly in recent years making EVs more performing. However, there are many challenges, which are needed to be resolved to facilitate EVs on the roads. Some of the major challenges are discussed below:

3.1 TECHNOLOGY CHALLENGES

- Travel range of EVs is one of the bottlenecks for deployments. EVs have limited range due to limited capacity of energy stored in batteries. Therefore EV charging stations are required at frequent intervals. Initially it may be useful in city travel but intercity travel would be possible only when range of EVs increases as well as EV charging infrastructure is provided along the highways.
- It has been already discussed earlier that there are different type of charging technologies as well as plug types to connect EVs. Unlike in fossil fuel stations, energy transfer to vehicle battery requires physical connection between charging equipment and electric vehicle battery system. Therefore, there should be common standard of plug and accordingly suitable charging equipment. If more than one plug standards allowed in the market then multiple number of charging equipment would be required. This would increase cost of initial infrastructure creation. Common plug standard would optimize the infra requirement and would increase economy of scale.
- In battery technology a lot of innovation is taking place in terms of chemistry. Few years back, it was lead acid, now it is lithium ion. Therefore changing equipment technology and battery swapping stations shall have greater risk of becoming obsolete in coming years.

- If battery swapping stations are installed, then there would be requirement for limiting battery types with respect to ratings otherwise multiple requirements would have to be created for each type of battery.

3.2 Financial Challenges

- Presently EVs are costly than the conventional fossil fuel vehicles even though they are highly subsidized by Govt. Operating cost of EVs is comparatively less but initial cost works as entry barrier to the segment. If initial cost is reduced while shifting cost in running the vehicles then more vehicles may be deployed. This may be done by reducing size of batteries in vehicles while providing EV charging infrastructure more frequently.
- EVs and EV charging Infrastructures are interdependent. Without charging facilities EV penetration would be difficult, whereas investment in infra would come only when volumes are high and solution is cost effective. Therefore uncertainty in future EV deployment poses a greater risk for deployment. This is the reason, presently in new markets, EV charging infrastructure is being provided by EV manufacturer only.
- EV charging infrastructure on commercial model is still under development stage. With more EVs on roads, this model would shift from subscription basis to Pay-per-use basis.
- EV charging infra requires a lot of investment. Presently it is being supported by governments in many countries, but investment from public would be possible only when returns would be attractive.

3.3 Policy & Regulatory Challenges

- Various international bodies are working on finalization of standards for EVs. IEC 62196 is an international standard for electrical connectors for electric vehicles, which is based on IEC 61851 Electric vehicle conductive charging system. IEC 62196 comprises of three sections, (i) General requirements (IEC-62196-1), (ii) Dimensional compatibility and interchangeability requirements for AC pin and contact-tube accessories (IEC-62196-2), and (iii) Dimensional compatibility and interchangeability requirements for DC and AC/DC pin and contact-tube vehicle couplers (IEC-62196-3). Every connector includes control signalling, for control of local charging and also to allow the

EV to participate in a wider electric vehicle network. Currently SAE J1772 (Yazaki connector) of Northern America; (ii) VDE-AR-E 2623-2-2 (Mennekes connector) of Europe; (iii) EV Plug Alliance proposal, (Scame connector) of Italy; and (iv) JEVS G105-1993 (CHAdeMO) of Japan are following IEC standards.

However above connectors also differ in plug level, therefore more standardisation is required. Once the plug standardization is completed, it would be easier for deployment of more vehicles and their charging stations.

- In many countries including India for automobiles and power have separate ministry / institutions and accordingly policies. For EVs they need to come on common platform.
- Sale of electricity through EV charging infrastructure has not been considered in regulations. Necessary amendments are required to enable it.
- Policies need to be made for EV charging equipment installation within home or society

Apart from above land requirement in cities is another major challenge. EVs are likely to come in metro cities first where vehicle density is more and people are economically sound. But in such cities locating EV charging station at every 8-10 Km in all directions would be very difficult.

However, above challenges are generally encountered in any technology adaption, therefore we need to look positively towards future for such infrastructure.

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CHAPTER-4

WORLDWIDE EXPERIENCE

Worldwide many countries have made their commitments on EV deployment for the 2020, 2025 or 2030 time horizons. Among them China, USA, Netherlands, Norway, United Kingdom, Germany, France and Sweden are way ahead from other countries. According to IEA report “Global EV Outlook 2016” the number of new registered electric cars (including both battery electric and plug-in hybrids) have increased by 70% between 2014 and 2015, with over 5,50,000 vehicles being sold worldwide in 2015. As per the study by IEA as shown in Figure 4-1, USA and China alone account for more than half of the global new electric car registration in 2015.

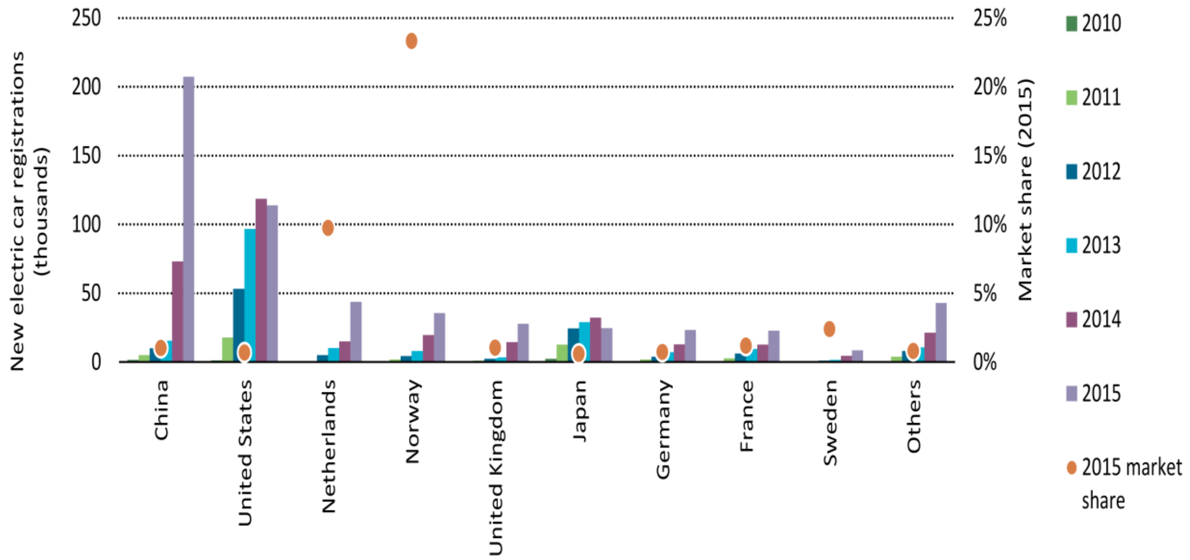


Figure 4-1: EV Sales and market share, 2015 **(Source: IEA report “Global EV outlook 2016)**

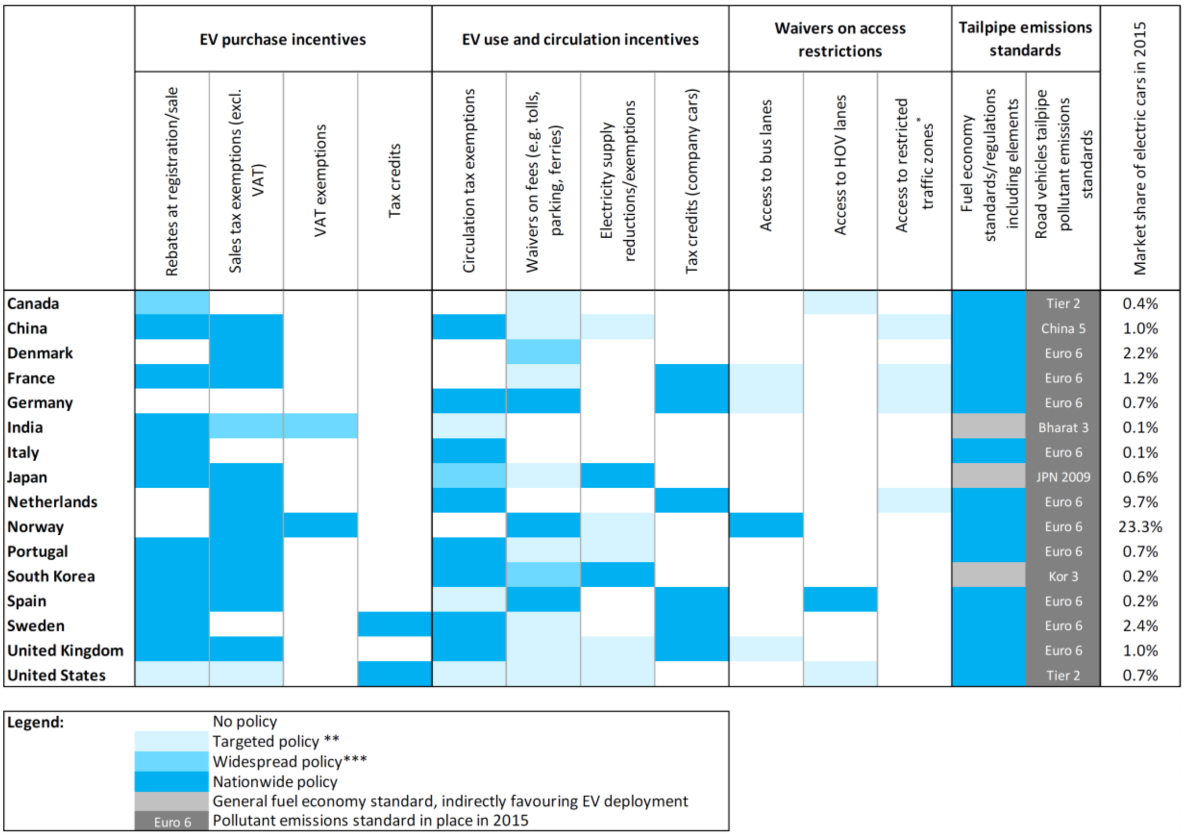
Financial incentives and the availability of charging infrastructure are two major factors that are positively correlated with the growth of electric vehicle market shares. The Netherlands and Norway, the two markets with the highest market shares, implemented a range of measures favouring consumers that opt for electric cars.

In deployment of electric two-wheelers, China is the global leader. The strong uptake of electric 2- wheelers in China was primarily spurred by policies banning the use of conventional motorcycles in Chinese cities.

The various factors supporting purchase and use of electric vehicles worldwide are as follows:

4.1 Policy Support

Benefits for local pollution reduction, energy diversification and climate change mitigation, as well as the encouraging signs observed in cost and performance developments in the recent past, are the main drivers of the deployment of a variety of policy support mechanisms supporting the market uptake of electric cars and attempting to overcome these barriers. Figure 4-2 shows the various policy supports provided in many countries.



Notes: * Such as environmental/low emission zones.

** Policy implemented in certain geographical areas (e.g. specific states/regions/municipalities), affecting less than 50% of the country's inhabitants.

*** Policy implemented in certain geographical areas (e.g. specific states/regions/municipalities), affecting more than 50% of the country's inhabitants.

Figure 4-2: Summary of policy support mechanisms for EVs (Source: IEA report "Global EV outlook 2016")

Some of the highlights of above policy support are:

- Electric cars in China enjoy an exemption from acquisition tax, circulation/ownership taxes and from the excise tax, normally based on engine displacement and price (Mock and Yang, 2014).

- France began offering in 2013 purchase incentives for BEVs and PHEVs through its bonus scheme (MEEM, 2016a). A supplementary bonus is also provided for scrapping diesel vehicles.
- In Japan, subsidies are based on the price difference between an EV and a comparable gasoline car, with capping at certain maximum amount. It has also EV exemptions from annual tonnage tax and reductions for automobile tax.
- In the Netherlands, in 2016, cars emitting zero CO_2 at the tailpipe are exempt from paying registration tax, road taxes. For other cars there is a differentiated taxation scheme with five levels of CO_2 emissions with progressively increasing taxation per g CO_2/km. (Energielabel, 2016). EVs also enjoys privileged access to some portions of the transport network restricted for other cars.
- In Norway, EVs are exempt from purchase taxes (OECD, 2015). BEVs are also exempt from VAT. The VAT exemption does not apply to PHEVs (Mock and Yang, 2014). Norway also provides strong incentives in the form of registration tax reductions and waivers on road tolls and ferries, and access to bus lanes.
- In Sweden, passenger vehicles with emissions levels lower than 50 g CO_2/km have been granted tax rebate since 2011. EVs are also exempted from road taxes (based on CO_2 emissions) and part of company car taxes in Sweden.
- In the United Kingdom, BEVs receive a purchase incentive for cars, light commercial vehicles and Plug-in Hybrid Electric Vehicles (PHEVs) (GOV.UK, 2016a). Excise duties starting from the second year of purchase are based on the CO_2 emissions per kilometre ratings: BEVs and some PHEVs are exempted (this is also the case for the first year, due to purchase incentives). BEVs are also exempted from company car taxes.
- In the United States, EVs enjoy tax credits at the national level. PHEV models with all-electric ranges (18 km to 40 km) receive credits; BEV models and some PHEV models with relatively high all-electric range (e.g. Chevrolet Volt) receive the maximum credit (Lutsey at al., 2015). States also apply purchase incentives (AFDC, 2016). For instance, California offers incentives for EVs and Fuel Cell Electric Vehicles (FCEVs) (or more for low-income consumers);

Colorado offers an income tax credit; Connecticut and Delaware offers rebates.

- In Germany, BEVs and PHEVs are exempted from circulation tax for a period of ten years from the date of their first registration.

4.2 ELECTRIC BUSES

The 2015 global electric bus stock is estimated to be close to 173,000 vehicles, almost entirely located in China. Close to 150,000 of these are battery electric buses, running 100% on electricity. The electric bus stock grew nearly six fold between 2014 and 2015, demonstrating support for rapid public transport electrification from the Chinese government, which is driven by the urgent need to limit air pollution levels in Chinese cities. By 2020, China plans to have over 200,000 electric buses on its roads, accompanied by a network of close to 4,000 charging stations dedicated to buses (EVI, 2016b).

In a few other countries, electric bus fleets exist at the level of a few tens of buses (100 in India, 94 in the Netherlands, 30 in Sweden and 21 in Japan, according to EVI data submissions), and are deployed as pilots and demonstration projects in a few major cities.

4.3 EV CHARGING STATIONS

Total number of Electric Vehicle Supply Equipment (EVSE) outlets available in 2015 reached 1.45 million, up from 0.82 million in 2014 and only roughly 20,000 in 2010. The share of publicly available EVSE outlets stabilized after 2013 to about 13% of the total. Publicly available EVSE outlets increased to 190,000 in 2015 from 110,000 in 2014 and 50,000 in 2013. The average growth of the number of publicly available charging outlets indicates that both slow and fast-charging outlets more than doubled on an annual basis in the past five years. Some of the highlights in this regard are as below:

- In Japan and China, which accounted for more than three-quarters of the fast-charging outlets installed globally in 2015, a single fast-charging outlet was coupled with 21 EVs (in Japan) and 25 EVs (in China).
- The ratio of electric cars per fast-charging outlet is close to 40 in Sweden and the United Kingdom and 60 in Germany.

- The same indicator ranges between 100 and 130 (60 and 90 for BEVs/fast EVSE outlets) in Canada, France, Norway and the United States.
- In the Netherlands there were 188 electric cars (and 20 BEVs) per every fast charger outlet.
- Nearly all the countries with more than 0.5% EV market share either provide incentives or tax rebate for installing private EV charging outlets.

Figure 4-3 shows that policy measures taken by various countries installation of EV Supplying Equipment.

	Direct investment		Fiscal advantages		Total EVSE stock per million inhabitants	Publicly accessible EVSE stock per million inhabitants
	Publicly accessible chargers	Private chargers	Publicly accessible chargers	Private chargers		
Canada					612	98
China					265	42
Denmark					1 732	309
France					970	159
Germany					664	67
India					5	0.3
Italy					129	29
Japan					1 171	174
Netherlands					6 280	1 084
Norway					15 143	1 372
Portugal					302	114
South Korea					113	26
Spain					161	35
Sweden					1 674	175
United Kingdom					933	155
United States					1 340	97

Legend:
No policy
Targeted policy *
Widespread policy**
Nationwide policy

Figure 4-3: Summary of policy support mechanisms for EVSE (Source: IEA report "Global EV outlook 2016")

4.4 Battery Swapping Station (BSS)

In USA, Tesla Motors established a beta version of battery swapping station mid-way between Los Angeles and San Francisco to test the customer acceptance of the technology. But, due to advancement of supercharger station and the cost involved in battery swapping, this option didn't pan out. Now, Tesla motors have stopped establishing BSS.

In China, first batch of ten battery-swap stations has commenced operation in 2016 in Beijing. Also, more numbers of BSS are being established to address at least 30,000 EV taxis.

4.5 EV / EVSE Deployment Targets

The following EVSE deployment targets for the period 2020-30 have been set or are in the process of being set:

- **China**
  - 5 million EV deployment target (including 4.3 million cars, more than 0.3 million taxis, 0.2 million buses and 0.2 million special vehicles)
  - EVSE deployment of 4.3 million private EVSE outlets and 0.5 million public chargers for cars, 4,000 charging stations for buses, nearly 2,500 for taxis, 2,500 for special vehicles, about 2,400 city public charging stations
  - 200 EV battery charging and swapping stations in Beijing to meet the requirements of at least 30,000 EVs by end of 2017.
- **France**
  - 7 million charging outlets over the national territory by 2030
- **India**
  - 6-7 million EVs by 2020
  - 100% EV by 2030
  - Deployment of 175,000-227,000 charging points in different scenarios by 2020
  - Fast chargers of about 10% of the total in both scenarios
- **Japan**
  - 2 million standard chargers and 5,000 fast chargers by 2020

EV deployment across the world is getting pace and it is expected that by 2030, EVs would replace fossil fuel transportation in most of the countries.

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CHAPTER-5

BUSINESS POTENTIAL IN INDIA

India has many reasons to shift its transportation sector mainly on roads to electricity. It is one of the countries which have very low penetration of EVs and at the same time struggling with issues related to fossil fuel dependency. High air pollution, noise pollution, high import bill of oil etc. are challenges, which can be resolved through adaption of EVs in transportation. India has also moved from power deficit to power surplus status in last few years, which has provided opportunity to use its electricity resources towards transportation requirements.

But above all, renowned focus on renewables with target of 175 GW by 2022 is main source of guiding power which is pushing for electric vehicle requirements. EVs can not only absorb surplus power but also may help in reducing volatility of renewables through dynamic market mechanism.

At present due to less numbers of EVs on roads, infrastructure development has not taken place. In Bengaluru only about 25 charging stations are operating, which are established by India’s largest EV manufacturer Mahindra Electric. However, it is expected that with Govt. intervention & focus, EV infra setup shall pick up speed. Costs of the setting up charging infrastructure and business potential in future in India are discussed below:

5.1 COST OF EV INFRASTRUCTURE

As discussed previously, EV charging infrastructure comprises mainly of EV supplying equipment. However other requirements like land, office building, HT supply and other connection arrangements, fire protection system, lighting, signage, connecting roads, drains, shelters etc. shall also be required depending upon the location where it is being established.

Entire public charging systems can be categorised as following:

1. Slow AC charging systems which takes 4-5 hours in charging the vehicle and can be deployed in offices, malls, railway / metro stations, housing societies etc.

2. Fast AC / DC charging systems, which would charge the EVs in 15-20 minutes and should be installed on main roads just like petrol pumps
3. Battery swapping stations which would facilitate replacement of batteries in 4-5 minutes. It would also be installed on main roads.

Cost of sample charging stations for above three categories are given below:

Table 5-1 Estimated cost of one slow charging station for EVs

S. No.	Item Name	Unit	Quantity	Unit Estimated Cost (Rs. Lac)	Total Estimated Cost (Rs. Lac)
1.	EV Supplying Equipment (EVSE)	Nos.	10	10	100
2.	HT connection for 130 kW considering 13 kW for each EVSE	Lot	1	15	15
3.	Metering & Billing	Lot	1	5	5
4.	Fire fighting System	Separate system not required. Existing system of facility may be used			
5.	Land & Infrastructure for office and premises	Not required as this type of charging station would be set up in existing facilities only			
Grand Total (In Rs. Lac)					120

These slow charging system would not be connected to any central management centre hence communication requirement have not been considered.

Table 5-2 Estimated cost of one fast charging station for EVs

S. No.	Item Name	Unit	Quantity	Unit Estimated Cost (Rs. Lac)	Total Estimated Cost (Rs. Lac)
1.	EV Supplying Equipment (EVSE)	Nos.	6	50	300
2.	HT connection for 320 kW considering 50 kW for each EVSE and 20 kW for other load	Lot	1	30	30
3.	Metering and Billing	Lot	1	4	4
4.	Fire fighting System	Lot	1	5	5
5.	Infrastructure for office & premises	LS	1	20	20
6.	Connectivity with Central Management Station	Lot	1	10	10
Grand Total (In Rs. Lac)					369

Land cost has not been considered as it would vary depending upon location and support of Govt. agencies.

Table 5-3 Estimated cost of one battery swapping station for EVs

S. No.	Item Name	Unit	Quantity	Unit Estimated Cost (Rs. Lac)	Total Estimated Cost (Rs. Lac)
1.	Battery Charging Equipment	Nos.	100	3	300
2.	HT connection for 320 kW	Lot	1	30	30

S. No.	Item Name	Unit	Quantity	Unit Estimated Cost (Rs. Lac)	Total Estimated Cost (Rs. Lac)
3.	Batteries (approx.15 kWh)	Nos.	100	2	200
3.	Metering and Billing	Lot	1	2	2
4.	Fire fighting System	Lot	1	5	5
5.	Infrastructure for office & premises	LS	1	30	30
6.	Connectivity with Central Management Station	Lot	1	10	10
				Grand Total (In Rs. Lac)	577

Land cost has not been considered as it would vary depending upon location and support of Govt. agencies.

5.2 Business Potential

As per NEMMP 2020, Govt. of India is planning to set up 175,000 – 227,000 EV charging points for 6-7 million vehicle penetration. Out of these about 10% would be fast charging stations, which is about 0.3% of the number of vehicles, whereas remaining charging stations would be about 3% of number of vehicles.

As per Global EV Outlook 2016, density of fast charging station for EV worldwide is 2.22% and that for slow charging station is 12.68%. Therefore, Indian target seems on lower side. However, for meeting the requirement, same may be needed to be upgraded to world standard in subsequent years. For business potential by 2020, we may consider the targets mentioned in NEMMP 2020, which is 22,700 No. fast charging points and 2,04,300 Nos. slow charging points.

In typical arrangement above, we have considered 10 Nos. charging points in slow charging stations and 6 Nos. charging points in fast charging stations. For battery swapping stations 100 Nos. charging points have been considered. Fast charging stations and battery swapping stations may serve equal number of charging equipment in totality. Therefore to meet the target following changing infrastructures may be created:

Slow Charging Stations: 20,430 Nos.

Fast AC/DC Charging Stations: 1892 Nos.

Battery Swapping Stations: 114 Nos.

Estimated potential of EV charging infrastructure would be Rs. 32205 Cr. based on NEMMP targets. However to meet the average world class standard in EV infrastructure, investment potential would be to the tune of Rs. 160,000 Cr. Details are given in Table 5-4

Table 5-4 Business Potential of public EV charging infrastructure in India by 2020

S. No.	Item	Nos.	Cost of Each Station (Rs. Cr.)	Total Cost (Rs. Cr.)	Remarks
1.	Slow Charging Stations with 10 charging equipment	20430	1.20	24516.00	For world average penetration investment required would be Rs. 103,620 Cr.
2.	Fast AC/DC Charging Station with 6 Nos. charging equipment	1892	3.69	6981.48	For world average penetration investment required would be Rs. 56,530 Cr.
3.	Battery swapping stations with simultaneous charging facility for 100 batteries	114	5.77	657.78	
4.	Central Management Centre	1	50.00	50.00	
Total Business Potential (In Rs. Cr.)				32205.26 **Say 32205**	

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CHAPTER-6

BUSINESS MODELS

In order to achieve EV targets stipulated in National Electric Mobility Mission Plan 2020, GoI is working on various policies and regulations. The plan suggests two scenarios for EV deployment by 2020: a “high gas/PHEV” scenario calling for the deployment of 175,000 charging points and a “high gas/PHEV/BEV” scenario calling for 227,000 charging points. Being a new technology / concept deployment, there is no designated agency for establishment of EV charging infrastructure across the country. Therefore new business models need to be worked out, which should not only be aligned with existing rules and regulations but also should be innovative and investment friendly.

6.1 BUSINESS MODELS

For taking up the business in EV charging infrastructure, we have considered a model company “PowerCharge” for illustration purpose only. Following business models may be explored:

6.1.1 BUILD-OWN-OPERATE (B-O-O)

In this business model, PowerCharge will build, own and operate publicly accessible charging stations. Electric power will be purchased from distribution licensee or any other power generating station with a long term PPA. PowerCharge will provide prepaid card to electric vehicle owners who will use this card to charge their vehicles at PowerCharge owned charging stations. In EV charging stations having EV Supply Equipment, charges shall be based on energy used to charge the vehicle, whereas in Battery Swapping type, it would be based on number of batteries and their State-of–Charge (SOC). Figure 6-1 shows the working philosophy of this business model.

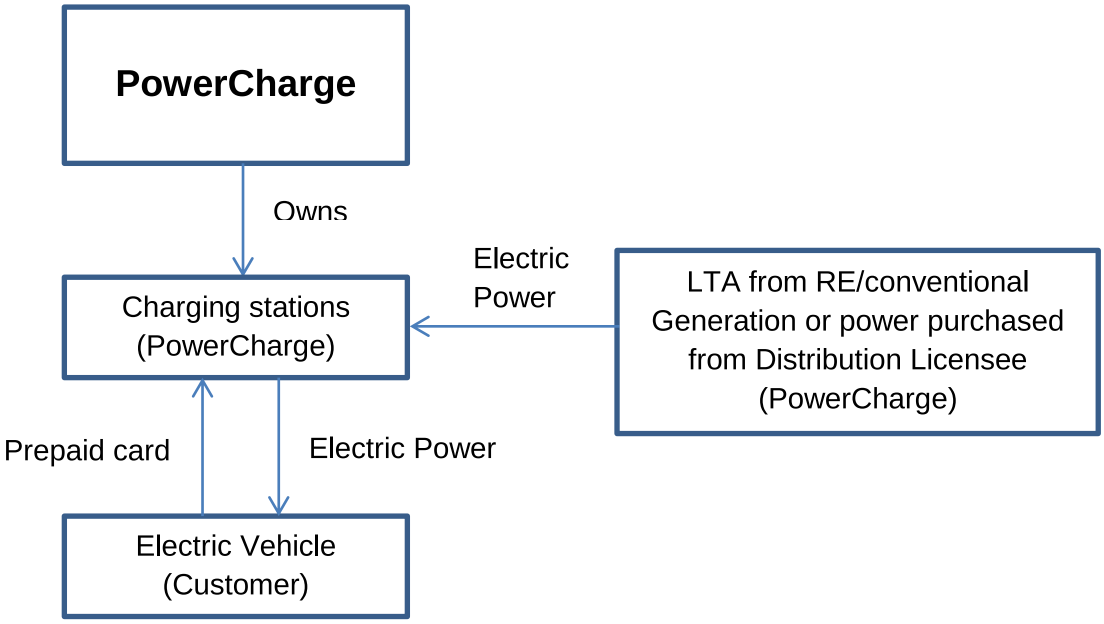

Figure 6-1: B-O-O business model

6.1.2 Build-Maintain

In this business model, PowerCharge will float a requirement for willing land owners to provide their land for establishment of charging stations. Land owner will be the owner and operator of charging station. PowerCharge will receive certain amount from land owner as a franchise fee and maintenance fee.

Also, there can be two alternates for power purchase:

1. Electric Power is provided by PowerCharge which will be used by customers through prepaid cards provided by PowerCharge to customers or charging station owners as shown in Figure 6-2.
2. Figure 6-2Charging station owners get connection from Distribution Company and they are responsible for sell and purchase of power (Figure 6-3)

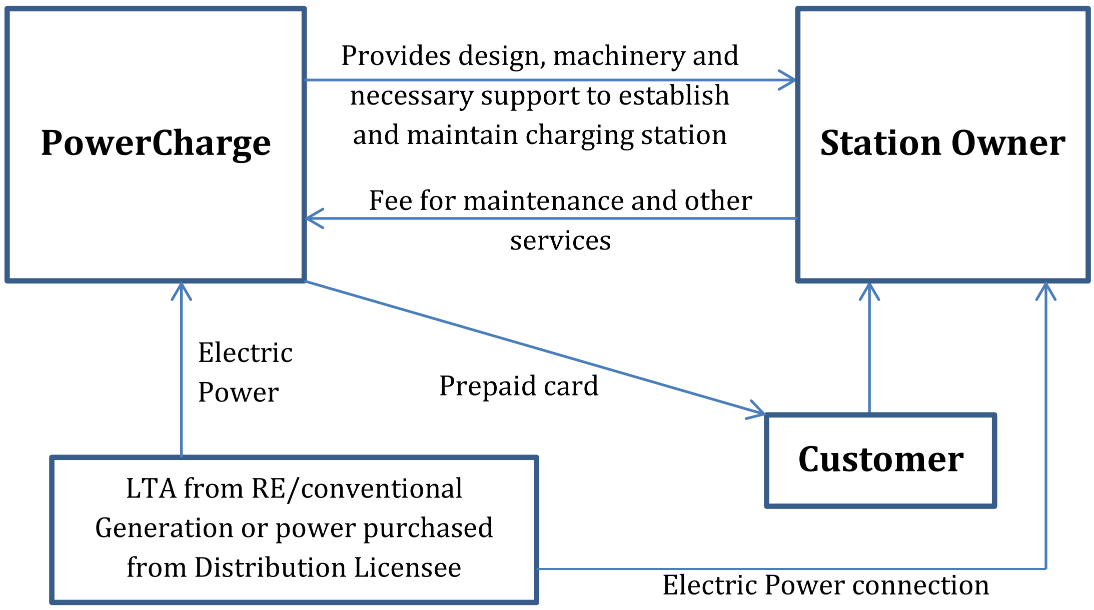

Figure 6-2: Build- Maintain business model (Alternative-1)

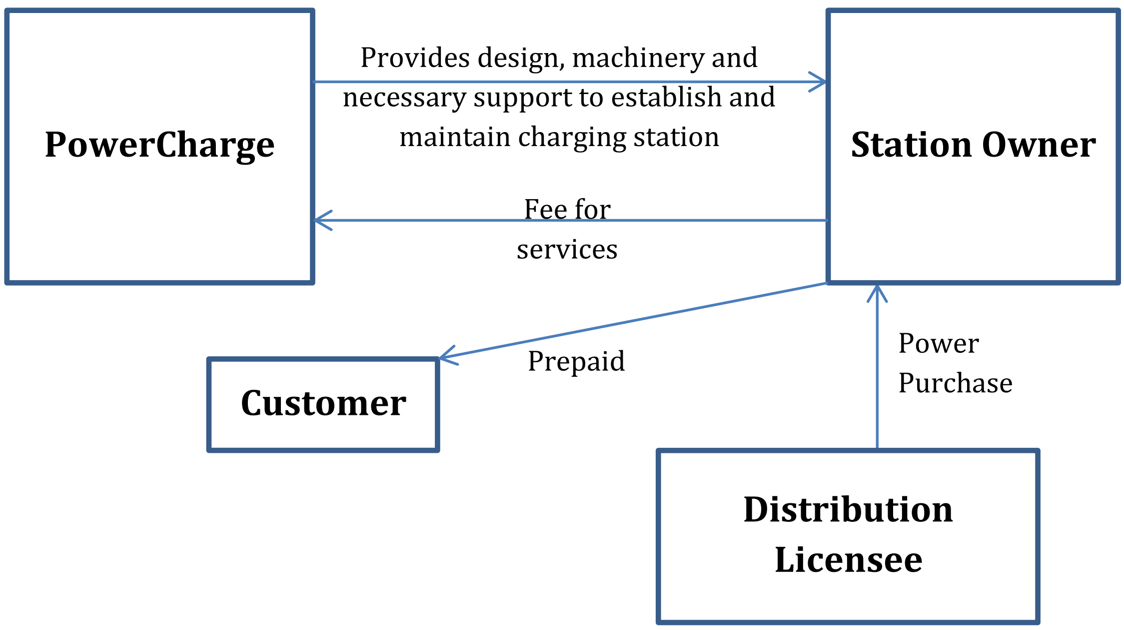

Figure 6-3: Build- maintain business model (Alternative-2)

6.2 Role of Power Grid

POWERGRID is a central PSU working in power sector. It is excellent rated since inception and has given outstanding performance over the years. EV Charging infra requirement provides a good opportunity to POWERGRID for foraying in new business area. SWOT analysis for POWERGRID has been discussed below:

6.2.1 SWOT Analysis of POWERGRID

6.2.1.1 Strengths

- POWERGRID is having pan India presence with offices/ substation in almost all major cities. Therefore any rollout across the country would be easier to implement. Even maintaining the services would also be easy.
- Being in power sector, it provides strengths in understanding regulatory & policy framework
- EV charging infrastructure involves huge investment. POWERGRID has enough financial resources and access to cheaper funding in the market.
- With more than 5000 Engineers from diversified background, POWERGRID can lead this technological intervention
- POWERGRID has very good experience in large scale project implementation with about Rs. 22500 Cr. capital investment every year
- POWERGRID has implemented various control centre schemes under ULDC & NTAMC projects. In case of EV charging infra, setup of Central Management Centre would be similar activity

6.2.2 Weakness

- Being a new area, no experience is available on EV charging facilities.
- Being a Central transmission Utility, we cannot trade the power. Therefore selling of energy to consumer may not be possible. Legal advice in this regard would also be required.

6.2.3 Opportunities

- Diversification from core business of transmission will give strength to company
- No significant market player in the EV charging Infrastructure. Present Infra providers are EV manufacturers who want to restrict their investment in charging infra.

6.2.4 THREATS

- Policy / Regulation are under considerations and may change in short term.
- Charging technology and battery technology are changing very fast.
- In case of less demand than the expected, business potential as well as profits may be affected.
- Problem in getting space as well as high voltage connection from grid due to Right of Way issues.

In view of above, if assigned, EV Charging Infrastructure may be established by POWERGRID or its subsidiary / SPV efficiently within time frames provided by authorities.

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CHAPTER-7

WAY FORWARD

Electric Vehicle production and usage in India are still in infant stage. A lot of efforts are required in formulation in policy changes, standards, incentives, regulatory mechanisms etc. for successful implementation. Some of the activities which are needed to be carried out are mentioned below:

7.1 POLICY AND REGULATORY INTERVENTION

Following policy and regulatory innervations are required, which may be taken up in consultations with representatives from concerned ministries, electrical utilities, electric vehicle manufacturers, battery manufacturers, electrical equipment manufacturers, urban bodies & other stakeholders etc.:

1. Finalization of technical standards for electrical vehicle supplying equipment, plugs etc.
2. Guidelines for setting up different levels of charging infrastructure and modification in vehicle designing for facilitation of battery swapping technology, if required.
3. Regulation on category of energy sales from charging infrastructure and clarity on fixation of tariff
4. Regulation allowing EV charging Infra company to have open access for sourcing renewable power from grid
5. Identification of implementing agency and business model. In initial phase 1-2 companies may be allowed on nomination basis. Later on, it may be made competitive.
6. Establishment of Central Management Centre sourcing data from all EV charging stations irrespective of the ownership
7. Pilot project for fast electric vehicle charging infrastructure & battery swapping stations
8. Deployment of Smart Meters & Time of Use (ToU) tariffs for electrical vehicle charging infrastructure

9. Change in Zone and building codes: 5-15% of upcoming parking spaces can be kept for electric vehicle parking. These parking spaces shall be provided with nearby electric points for installation of level-2 charging infrastructures.
10. Change in Road Designing: In National highway designing, after every 30-40 km proper spaces shall be kept for fast charging infrastructure.
11. Launch of special app for electrical vehicle charging infrastructure through which user can find location of nearby charging infrastructure locations, applicable tariff etc.

7.2 Identification of Implementation Agency

As public charging infrastructure will cater charging facility for large number of electric vehicles economically, predominantly large number of these infrastructures will be level-3 type or battery swapping stations having charging facilities with 100-200 batteries simultaneously. The power requirement of public charging equipment will be high & installation of such charging infrastructure requires installation of large power rated electrical equipment & its operation. Therefore, it would be prudent to assign responsibility of setting of such infrastructure initially to a company, which understands power sector better. Secondly, such infra would also involve establishment of central management centre, therefore implementing agency must have experience on same also. Globally also majority of electric vehicles charging infrastructures facilities are owned by electrical utilities.

Identification of agency(ies) for implementation would help in rolling out the facility quickly. Also in initial phase when standardization in services, operation & maintenance would be very important, implementation through limited agencies would be easier. Facilitation of EV charging infrastructure would ignite the demand of EVs, which will further reduce the cost of vehicles helping in more penetration. Apart from this other initiatives like R&D, pilot projects, indigenization of technologies, Make in India etc. need to be continuously explored to make the electric transportation viable. Above infrastructure is very important for transforming transportation in India, which will be a game changer for our fight towards global warming & climate change.

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