Solar-Based Electric Vehicle Charging Stations in India: A Perspective

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1 Introduction

1.1 Background

Many countries are quickly adopting the technologies related to EVs and slowly eliminating fossil fuel-based vehicles to battle climate alteration and increasing pollution. Most air pollution produced the world over is by burning fossil fuel to produce electricity, heating, transportation, and industries. Fossil fuels accounted for 80.110% of the world's total primary energy supply in 2019 (monthly energy review 2020). It is observed that energy-related use of fossil fuel is a major source of air pollution amongst high- and middle-income countries, while the use of biomass is a prime concern for air pollution resulting from energy generation in the case of low-income countries. The combustion of fossil fuels in vehicles produces harmful gases which have an adverse effect on the environment and human beings. Emissions of acidic sulfur dioxide and nitrogen oxides, mixed with atmospheric moisture, cause acid rain that leads to harmful effects to the community as well as forest area. The most hazardous impact of fossil fuels is carbon dioxide (CO_2) emission into the atmosphere (Perera 2018). CO_2 is one of the major trace gases in the atmosphere, the level of which had increased by 35% in the last 200 years. From 1985 to 2005 along the level of CO_2 had increased from 316 to 375 ppm, resulting in global warming, which results in the overall increase of 1.25 °F (0.7 °C) in the temperature level of the

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planet. This may result in rising sea levels which could threaten a large population and may cause extreme environmental changes. The international community has taken action on global warming and has been working on reducing carbon emissions through the Kyoto Protocol. Therefore, a move toward EVs and plug-in hybrid electric vehicles (PHEVs) are much promising and promising alternative. PHEVs have both, an electric motor and an internal combustion (IC) engine. These vehicles are powered by conventional fuel, such as gasoline (petrol) or by an alternative fuel such as electricity and using a battery for charging. The charging can be done by plugging either into an electrical outlet or at a charging station. Due to the good response of EVs worldwide, national and international governments have come out with various policies and allocated funds to support EVs and PHEVs implementation in the market. Long-term planning scenarios express that the EVs will capture the whole of the global vehicle fleet, mostly run by renewable energy sources, by 2050 (https://www.theicct.org/electric-vehicles).

1.2 Worldwide Adaptation of EVs

The occurrence of major events taken place in the European countries that announced to phase out petrol and diesel-based vehicles in support of EVs are as follows (https://www.roadtraffic-technology.com/features/european-countries-banning-fossil-fuel-cars):

- In 2016, Norway announced its proposed ban on fossil fuel vehicles. By 2025, the purchasing of vehicles run on petrol and diesel will be banned. More than half of the new vehicle sold in Norway in January 2017 was either electrical or hybrid. This turned Norway amongst the first nation to sell cars with zero or low emissions. Till 2018, over 135,000 EVs have been registered in the country. In order to continue this hike, the association of EVs in the country is making policies for having more than 4 lakh battery-powered vehicles on highways by 2020.
- Germany's Bundesrat federal council agreed to ban on vehicles based on fossil fuels by 2030. In October 2016, the European Commission announced an EU prohibition on petrol and diesel vehicles. The nation plans to reduce its CO_2 emissions by 95% by 2050, hoping that EVs will help accomplish this objective.
- In July 2017, in addition to phasing out oil and gas production, France proposed to ban all petrol and diesel vehicles by 2040. This will play a major part in the country's objective of becoming carbon neutral by 2050. By 2030, Paris suggested the removal of all fossil fuel cars from the city. The city is implementing a provisional ban to reduce air pollution. In 2018, nearly 150,000 EVs were registered in France and 1.98% of new cars registered in 2017 contributed to electric cars.
- In July 2017, the UK supported banning the sale of new petrol or diesel vehicles with a 2040 target of a full ban. When plans were first announced, plug-in vehicles' contribution is less than 1% of total car sales in the country. This figure increases in the first half of 2018 to 2.2% of the UK's total vehicle sales.

- In September 2017, Scotland plans to remove fossil fuel vehicles by 2032. When compared with the rest of the UK and Scotland is eight years ahead.
- In October 2018, Netherland gives its confirmation to ban gasoline and diesel vehicles by 2030, and all new vehicles are emission free. Plans were initially developed in April 2016. In the Netherlands, 6.4% of the cars were electric when plans were acknowledged.
- Within the framework of the climate action scheme, Ireland plans to completely ban nonzero emission cars by 2045. To accomplish this goal, Ireland plans to have 500,000 EVs on its highways and prevent nonzero emission vehicle sales by 2030.

2 India's Growth in EV Global Market

In 2013, the GoI made a significant shift toward the adoption of EVs by 2030 to resolve the issues of national energy security, vehicle emissions, and the development of domestic built-up capacities, reiterating its pledge to the Paris agreement (https://beeindia.gov.in/content/e-mobility). Indian car manufacturing companies, like Reva Electric Car Company (RECC) and many other companies such as Nissan, TATA, Mahindra, Maruti Suzuki, would launch their EVs by 2020 (Taumar 2019). Niti Aayog's draft proposal which is chaired by the Prime Minister of India is playing a significant part in policy making and has suggested electrifying most motorcycles and scooters over the next six to eight years. It further insisted to electrify the country's famous three-wheeler auto-rickshaws (Shah 2019).

India sold more than 21 million motorcycles and scooters in 2018–19 making it one of the world's largest two-wheeler markets. Over the same time, it sold only 3.3 million cars and utility vehicles. Although the electric scooters accounted for just a fraction of the total sales of two-wheelers in India, the data from the society of manufacturers of electric vehicles reveals that the sales of scooter rose to 126,000, more than doubled, in the last fiscal year, from only 54,800 a year earlier (Shah 2019). If the initiative to electrify vehicles operating with the Ministries of Heavy Industry, Road Transport, and Power were to be accepted, a new market will open up for companies such as Japan's Yamaha Motor and Suzuki Motor, which are developing plans to introduce electric two-wheelers in India. The state now supposes electric cars to make up 15% of all fresh revenues in 5 years from presently less than 1%. India's cabinet endorsed a plan in February 2019 to spend $1.4 billion over three years sponsoring electric and hybrid vehicle sales (https://www.reuters.com/article/us-india-electric-policy-idUSKCN1SS2HS).

2.1 The Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME)

In 2012, the GoI has launched the National Electric Mobility Mission Plan (NEMMP) 2020, to encourage eco-friendly vehicles in the country. The main objectives of this plan are providing economic and financial incentives for the implementation of both hybrid and electric technologies vehicles. Incentives have been imposed on all vehicle segments including two-, three-, and four-wheeler vehicles, light commercial vehicles, and buses. This plan covers hybrid and electrical technologies such as powerful hybrid, plug-in hybrid, and battery EVs (National Electric Mobility Mission Plan 2020).

The government introduced the faster adoption and manufacturing of hybrid and EVs (FAME India) scheme under NEMMP 2020 in the Union Budget for 2015–16 with an initial expenditure of INR 750 million FAME II scheme has been launched by the union cabinet on February 28, 2019, with a total amount of 10,000 crores. The chosen amount will be laid out in the next 3 years with the scheme being implemented from April 1, 2019. The current allocation of 10,000 crores has been utilized to speed up the development of EVs and EVs infrastructure in a bid to meet the target of 100% electrification of vehicles by 2030 (Cabinet approves Scheme for FAME India Phase II 2019). FAME II scheme basically aims to incentivize the purchase of EVs and establishing the required charging infrastructure for EVs. The emphasis will also continue to be on the electrification of public transport vehicles and other shared mobility solutions like last-mile connectivity solutions such as three-wheelers and light commercial vehicles. The government is planning to sell only electric three-wheelers from April 2023 and electric two-wheelers of less than 150 cc from April 2025. Steps will be taken to lessen the level of rising air pollution in India. The incentives will be mainly distributed to the commercial three-wheeler and four-wheeler vehicles along with a private two-wheeler. Incentives will be distributed only to those vehicles which are powered by a lithium-ion battery or work on other advanced technology like fuel cell as an effort to encourage new technologies. This will eliminate the use of EVs powered by lead-acid batteries which form a major chunk of electric two-wheelers in India. The revised FAME II scheme eliminates all the ambiguity and places EVs in the fast track. Mahindra promotes the government's focus on increasing public transportation EVs and is now calling on local authorities to assist promoting the use of EVs on Indian roads. Government support under the FAME II scheme is holistic and also would include focusing on charging EV infrastructure with a clear vision of "Make in India."

The idea is to make at least one charging station in a 3×3 km grid, according to the FAME II scheme. The charging stations will also be set up at a distance of 25 km on either side of major highways which connect major cities of India. The easy availability of charging stations also helps to give a boost to the sales of EVs as well. It will also be influential for automakers like Mahindra and Tata Motors who are selling electric cars in India and also encouraging other automakers to include EVs in their product lineup. The state-run energy efficiency services (EESL) declared its plan to acquire up to 20,000 EVs for government use with an investment of 2,400 crores. The scheme aims at promoting the quicker implementation of electric and hybrid vehicles by proposing excellent incentives for the buying of EVs and likewise by developing the required charging infrastructure for EVs. The scheme will help to deal with the problem of air pollution and fuel security.

3 Electric Charging Infrastructure

Approximately, 200 million vehicles are currently on Indian roads, of which less than 1% are EVs. By 2040, India is expected to be home to 31 million EVs. In order to keep this fleet running, widespread charging infrastructure for EVs is needed. With the government's goal of achieving 30% e-mobility by 2030, we need not only to step up efforts in the manufacturing of EVs but also to ensure that there are adequate charging stations in the country (https://www.eeslindia.org/content/raj/eesl/en/Programmes/EV-Charging-Infrastructure/About-EV-Charging-Infrastructure.html). In this section, different levels/types of EV charging stations and the components of EV chargers are discussed.

3.1 EV Charging Station

A charging station for EVs, also known as an EV charging station, electronic charging station (ECS) is a component of an infrastructure that provides electrical energy to recharge EVs, including electric cars and plug-in hybrids. EV chargers are classified as follows: (i) Level 1 charging stations: home charging, (ii) level 2 charging stations: home and public charging, and (iii) level 3 charging stations: DC fast charging—public charging. Table 1 illustrates the comparison between level 1, level 2, and level 3 charging stations.

3.1.1 Level 1 Charging Stations: Home Charging

Level 1 chargers mean an alternating current (AC) plug that connects the on-board charger and a standard household (120 V/15–20 A). All EVs are equipped with a portable cord set charger. Only a three-pronged plug should be attached to a cord set charger. Therefore, these kinds of chargers do not require any extra equipment to be mounted and are ideal for residential usage. EV will charge at a slow rate by using these chargers. This option may not work great; however, this is good for those commuters whose traveling distance is not more than 40 miles in a day and has to charge the EV throughout the night.

Table 1 Comparison between level 1, level 2, and level 3 (DC fast charger) charging stations (electric vehicle charging stations 2015)

	Level 1	Level 2	Level 3 DC fast charger
Voltage (V)	120 1-Phase AC	208 or 240 1-Phase AC	200–450 DC
Current (A)	12–16	12–80 (Typ. 32)	<200 (Typ. 60)
Useful power (kW)	1.4	7.2	50
Max. output (kW)	1.9	19.2	150
Charging time	12 h	3 h	20 min
Connector	J1772	J1772	J1772 combo, CHAdeMO and supercharger
Charging speed	3–5 miles of range in 1 h	10–20 miles of range in 1 h	24 or 50 miles of range in 20 min
Cost	Generally low	Generally higher	Much higher
Access control	Available	Available	Available
Energy monitoring	Not available, but available on the secondary system	Available	Available

3.1.2 Level 2 Charging Stations: Home and Public Charging

Level 2 charging stations offer charging through a 240 V, AC plug and need a dedicated 40 Amps circuit. These are useful for both housing and public charging stations. Specialized installation equipment is required for the plugging of these chargers. Depending on the electric car and the charger, the charging rate is 5 to 7 times faster than the level 1 charging station (https://chargehub.com/en/how-to-choose-home-charging-station.html). An electric car battery can be charged within three hours by using these chargers. Therefore, it is a good option for the customers seeking fast charging as well as for business purposes providing charging stations as a benefit for the customers when shopping, banking, etc. More efforts are given to boost the charging capacity and reduce the charging time of level 2 chargers. ClipperCreek, JuiceBox, Chargepoint, and Siemens are the popular manufacturers of level 2 chargers. Most producers of EVs, such as Nissan, have their own level 2 charger goods.

Due to the increased demand for electric cars in the market, there are more level 2 home charging stations. Different types of AC vehicle-side connectors used in level 2 charging stations are as follows (https://chargehub.com/en/how-to-choose-home-charging-station.html): Type 1 (SAE J1772), type 2 (Mennekes, IEC 62196), Tesla connector. There should be a universal SAE J1772 connector for all charging stations. This connector can be used with both EVs and PHEVs which is shown in Fig. 1. The SEA J1772 connector has been modified by Tesla chargers and cars. Every Tesla car is fitted with a SAE J1772 connector to Tesla adaptor which is shown in Fig. 2, which helps the driver quickly charge the vehicle in the charging station. Level 2

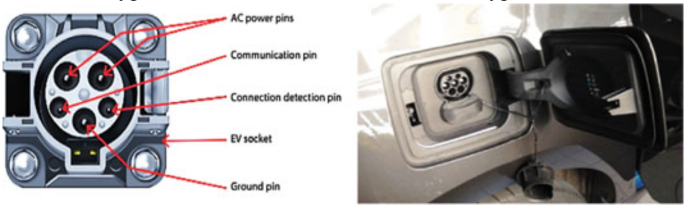


Fig. 1 AC connectors: Type 1 (SAE J1772), type 2 (Mennekes, IEC 62196) (https://www.hydroquebec.com/data/electrification-transport/pdf/technical-guide.pdf; https://www.flickr.com/photos/120167116@N06/14120629806/in/photostream/)

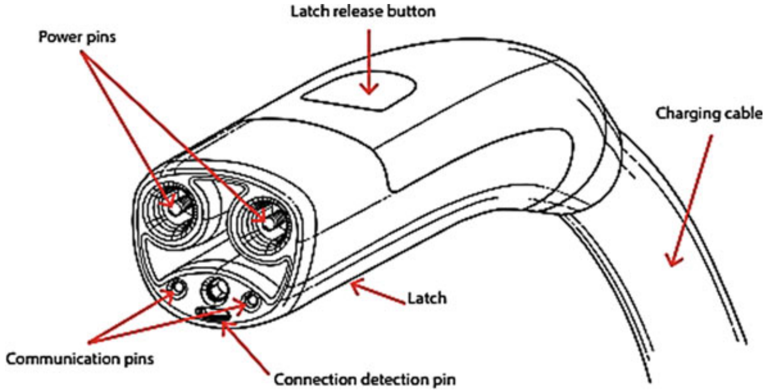


Fig. 2 Tesla connector (https://www.hydroquebec.com/data/electrification-transport/pdf/technical-guide.pdf)

home charging stations operate at 208–240 V voltage range. The factors on which the fast charging will depend are as follows:

- Charger amperage (i.e., 16, 30, 32, or 40 A)

  Powers that can be taken from 16, 30, 32, and 40 A chargers are the follows:

Charger amperage (Amps)	Power (kW)	Voltage (V)
16	3.84	240
30	7.2	
32	7.7	
40	9.6	

- The acceptance rate of the car in kW.

Most EVs have a maximum power acceptance of 7.2 kW or less. It means that mostly EV cannot charge quicker by using a charger of 9.6 kW at 40 Amps. With a 40 Amps charging station, an EV with a power acceptance greater than 7.2 kW can charge quickly (Figs. 1 and 2).

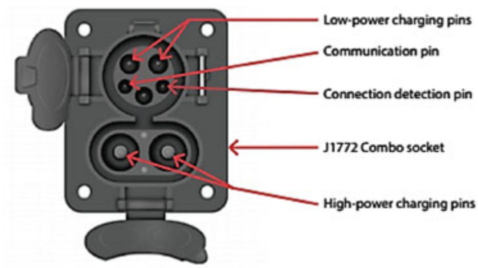
There are two ways for linking level 2 charging station to the electrical panel: a plug or a direct (hardwired) connection. Plugs are further of two kinds: The first one is NEMA 6-50P (welder plug), and the second one is NEMA 14-50P (dryer plug). Length of cable is also an important part of the charging station that charges EVs. Cable length varies between 12 and 25 ft, but the recommended cable length is at least 18 ft long. One can charge EVs with a 25 ft cable whether it is parked backward or forward. Another important factor is the flexibility of the cable. If the cable is more flexible, rolling it up or using it during winter conditions will be easier (https://www.flickr.com/photos/120167116@N06/14120629806/in/photostream/).

3.1.3 Level 3 Charging Stations: DC Fast Charging—Public Charging

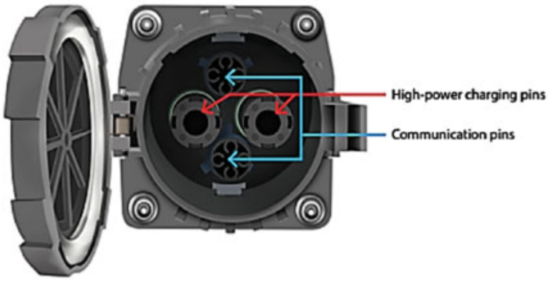
Most of the consumer of EVs wants quicker charging in lesser time; thereby, the fast-charging DC chargers were developed. DC fast chargers use three different types of plug and cannot be interchanged. DC fast chargers use three different types of connectors as shown in Fig. 3: combined charging system (CCS), CHAdeMO, Tesla (https://evcharging.enelx.com/news/blog/552-ev-charging-connector-types). The CCS connector uses the J1772 charging inlet and adds two additional pins (high-speed charging pins) below. CHAdeMO connectors do not share part of the connector with the J1772 inlet and therefore require an additional CHadeMO inlet on the car. Usually, Japanese manufacturers use the CHAdeMO model; the CCS is used by many European and American manufacturers; Tesla's supercharging stations use their own vehicle-specific adapter. Tesla uses the same connector for level 1, level 2, and DC fast charging (Fig. 3).

The own vehicle-specific adapter initiative was taken by Japanese when Nissan Leaf and Mitsubishi i-MiEV were introduced. They developed the chargers known as CHAdeMO EV charging stations. This form of charger is identical to a traditional petrol pump-sized unit as shown in Fig. 4. In just 20 min of charging this adapter will deliver 60–100 miles of range. The charging infrastructure of CHAdeMO has not grown very rapidly. The reason is that many manufacturers protested against the introduction of CHAdeMO because the model was not as per the standard approved by SAE. It was standard co-developed by Tokyo electric power company (TEPCO) and the Japanese automakers as an alternative of adopting CHAdeMO, the SAE prepared their own fast-charging standard (combo charging system), and Tesla Motor developed a fast-charging system called as superchargers (2018). Tesla is deemed the leader creator in the EVs sector, taking advantage of the fact that fast-charging does not have a single standard. Tesla superchargers with a maximum power output of 120 kW will charge a battery in about 20 min (Fig. 4).

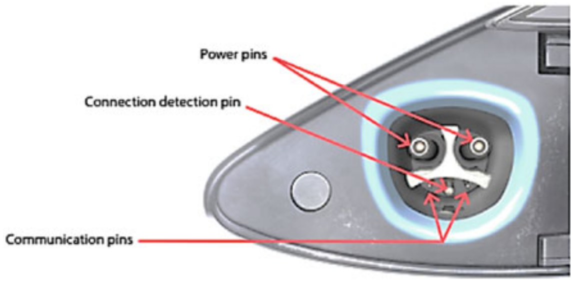
The international electro-technical commission (IEC) is another standards organization which describes the charging in various modes as follows:



(a)



(b)



(c)

Fig. 3 Three different types of connectors used in DC fast chargers: **a** CCS, **b** CHAdeMO, and **c** Tesla (https://www.hydroquebec.com/data/electrification-transport/pdf/technical-guide.pdf)

Mode 1	Slow charging from a standard single or three-phase electrical socket
Mode 2	Slow charging from a standard socket but with unique safety commitments for some EV (e.g., the Park and Charge or the PARVE systems)
Mode 3	Slow or fast charging with a unique EV multi-pin socket with control and safety features functions (e.g., SAE J1772 and IEC 62196)

(continued)

(continued)

Mode 1	Slow charging from a standard single or three-phase electrical socket
Mode 4	Quick charging with special charger technology like CHAdeMO

There are three connection cases (2019):

- In case A, any adapter connected to the power supply (the power supply cord is attached to the adapter) is typically concerned with modes 1 or 2.
- Case B is an on-board vehicle adapter with a power supply cord, typically mode 3, which can be disconnected from both the supply and the vehicle.
- Case C is a charging station with a DC supply to the vehicle. The cable of the power supply can be permanently attached to the charging station as in mode 4.

3.2 Wireless EV Charging System

Early EV's adopters are highly probable to have easy access to charge EV, either in the home, garage, or on the drive. However, the mass market will bring different charging needs with them. Because of a shortage of dedicated private parking spaces, many EV drivers would have to use street parking, in city apartments. Thus, demand for public charging will rise as ownership of EVs grows. Accordingly, authorities have two options: to implement plug-in charging with a rise in street furniture, which carries the risk of damage, theft, and loosening and oxidizing electrical connections; or to introduce ground-based or underground wireless charging without street congestion. Underground wireless charging also reduces the possibility of tripping and falling over high-voltage cables to the general public about health and safety. EV drivers themselves will also choose the simplicity of wireless charging; no mess and no hassle from bulky, filthy cables that are hard to manage when it is cold and wet. Furthermore, we agree that many drivers should be careful to use plug-in cables in heavy rain. Wireless charging also has a direct economic benefit; keeping the battery charge between 40 and 80 percent will maximize the battery life of the EV (https://www.qualcomm.com/media/documents/files/wireless-charging-for-electric-vehicles-brochure.pdf). Therefore, wireless EV charging systems can provide a possible alternative solution for charging EVs without any plug-in problems. Wireless charging system (WCS) will offer benefits in the context of usability, performance, and user-friendliness relative to plug-in charging systems (Barth et al. 2011). The flaw or disadvantage identified with WCS is that it can only be used when the car is in stationary conditions, such as parking lots, garages, or road signals (Leskarac et al. 2015). Furthermore, stationary WCS has also several challenges, e.g., problems with electromagnetic compatibility, bulky structures, limited power transfer, and shorter range (Covic and Boys 2013, 2013; Moon et al. 2014). The EVs with dynamic (in motion) wireless charging method is explored in order to increase the range and adequate battery storage capacity (Eghtesadi 1990). This method permits battery storage systems to be charged while the EV is in motion. The

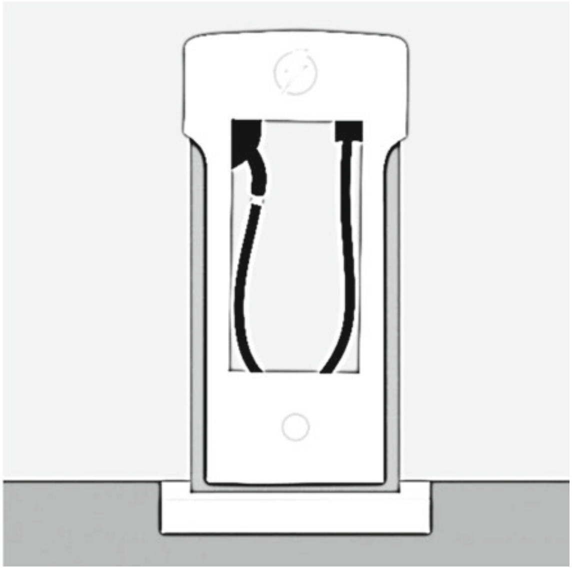


Fig. 4 Level 3 DC charging stations (https://pxhere.com/en/photo/1453945)

EV needs inexpensive battery storage and requires more travel range (Fuller 2016). Nonetheless, before it becomes widely adopted, a dynamic WCS has to meet two major challenges, coil misalignment, and large air-gap. Both coil misalignment and large air-gap affect power transfer efficiency.

There are four methods for the design of wireless EV charging systems are employed: capacitive wireless power transfer (CWPT), inductive power transfer (IPT), magnetic gear wireless power transfer (MGWPT), and resonant inductive power transfer (RIPT).

3.2.1 Inductive Power Transfer (IPT)

Convenience is the main benefit of inductive charging. This facilitates the transfer of electrical energy from the grid to an EV without the help of wires. Energy transfer occurs at the same frequency through magnetic resonance coupling between two copper coils known as primary and secondary coils (embedded in roadways and EVs). The primary coil named the Magne-charge charging paddle (inductive coupler) is placed in the charging port of EV, whereas the power is picked up by the secondary coil that enables charging the EV. The AC power received by the secondary coil is transferred to a standard charger such as the level 1 and level 2 chargers (Musavi and Eberle 2014). For more than 10 years, the system has been in use in shuttle buses that pursue a quick, well-defined path, picking up energy from coils placed on the road at each bus stop. While this method is still not used in light passenger vehicles, researchers are working on appropriate solutions with power transfer levels of up to 10 kW.

3.2.2 Capacitive Power Transfer (CPT)

Due to the relatively directed nature of electrical fields, CWPT systems have potential benefits over inductive systems which eliminate the need for electromagnetic field shielding. These can also be worked at higher frequencies as CWPT systems do not use ferrites, causing them to be smaller and less costly. Therefore, CWPT could allow dynamic charging of EV a reality.

In the CPT, coupling capacitors are used instead of using coils or magnets to transfer power from the transmitter to the recipient. The main AC voltage is transmitted by the power factor adjustment circuitry to an H-bridge converter. The H-bridge produced high-frequency AC passes through the receiver side of the coupling capacitors. In order to reduce the impedance in the resonant system between the transmitter and the receiver side, the extra inductors are mounted in series with the coupling capacitors. The level of power transfer depends entirely on the size of the capacitor and space between two plates. The CWPT offers excellent output for a small air gap and enhanced field constraints formed between two capacitor plates (Kim and Bien 2013). Because of large air differences and high-power demands, the implementation of CWPT for EVs has been restricted to date.

However, due to the extremely limited capacity between road and vehicle surfaces, effective power transmission can only work at very high frequencies, making it very difficult to develop these systems. With the latest development of wide-band (silicon carbide (SiC) and gallium nitride (GaN)) performance semiconductor devices for higher-frequency application, medium-range high-power CWPT systems are becoming feasible (Regensburger et al. 2017; Zhang et al. 2016). Two major challenges of CWPT charging for EVs are: (i) attaining high-power transmission rate at reasonable efficiencies thus meeting the requirements of electromagnetic protection and (ii) maintaining efficient transfer of power even when the relative position of the couplers shifts.

3.2.3 Magnetic Gear Wireless Power Transfer (MGWPT)

Every transmitter and receiver in this method consists of winding armature and synchronized permanent magnets inside the winding. At the transmitter, the side process is alike to motor operation. As AC is supplied to the transmitter winding, it produces a mechanical torque on the transmitter magnet, which causes it to rotate. Due to the change in the transmitter's magnetic contact, the permanent magnet field induces torque on the receiver permanent magnet which results in the transmitter magnet being rotated synchronously. The alteration in the permanent magnetic field of the receiver also produces the AC in the winding, i.e., the receiver works as a generator for the mechanical input of a permanent magnet to the receiver converted into an electrical output at the winding of the receiver. The magnetic gear is considered the coupling of revolving permanent magnets. After rectification and filtering via power converters, the produced AC power on the receiver side fed into the battery (Leskarac et al. 2015).

3.2.4 Resonant Inductive Power Transfer (RIPT)

The RIPT is one of the most common and improved variants of the standard IPT for power electronics and wireless transformer coils. Resonators with high-quality factors transfer energy at a much higher rate, and working at resonance will transfer the same quantity of power as in IPT, even with weaker magnetic fields. The power can be transmitted without wires too long distances. Max. power transmission over the air occurs when the transmitter and receiver coils are matched, i.e., the two coils will suit the resonant frequencies. In order to obtain reasonable resonant frequencies, the transmitter and receiver coils are connected to additional compensation networks in the series and parallel configurations. An expanded network of compensation together with increased resonant frequency further eliminates further losses. The operating frequency of RIPT is between 10 and 150 kHz (Leskarac et al. 2015).

3.2.5 Wireless EV Charging Standards

If each company makes its own specifications for WCS that are not compliant with other systems, then that is not going to be a good thing. Several international organizations such as the society of automotive engineers (SAE), the international electro-Technical Commission (IEC), Underwriters Laboratories (UL) Institute of Electrical and Electronics Engineers (IEEE) are collaborating on standards to make wireless EV charging more users friendly (Vilathgamuwa and Sampath 2019).

- SAE J1772 standard outlines EV/PHEV Conductive Charge coupler.
- SAE J1773 standard describes EV inductively coupled charging.
- SAE J2847/6 standard defines communication between wireless charged vehicles and wireless EV chargers.
- SAE J2836/6 standard outlines use cases for wireless charging communication for PEV. SAE J2954 standard describes WPT for light-duty plug-in EVs and alignment methodology.
- UL subject 2750 defines outline of investigation, for WEVCS.
- IEC 61980–1 Cor.1 Ed.1.0 describes EV WPT systems general requirements.
- IEC 62827–2 Ed.1.0 expresses WPT management: multiple device control management.
- IEC 63028 Ed.1.0 describes WPT air-fuel alliance resonant baseline system specification.

3.3 Solar-Based EV Charging System

Renewable energy comprises approximately 66.7% of worldwide power capacity for roughly 165 gigawatts (GW) in the Renewable 2017 report (Momidi 2017). Solar photovoltaic (SPV) has been noted to be the fastest growing industry in 2016. The SPV electricity offers a possible source of mid-day charging of EVs and PHEVs

Fig. 5 Solar-based EV charging station (Mouli et al. 2015)

(Renewables 2009). EVs charging by using SPV provide a sustainable method for charging the batteries of EVs. Places like factories, official buildings, and warehouse areas are perfect places to use solar EV charging where the space under the rooftops of the building and car parking can be used to mount PV modules as shown in Fig. 5. The power generated in a PV module is used immediately for EV charging without the need for the storage system. Employee vehicles usually stay parked at the parking lot for 6–9 h with a long charge period and also cover the grid support through vehicle-to-grid (V2G) technology (Li and Lopes 2015). Vehicle-to-home (V2H) technology is reachable in the off-grid system.

The advantages of solar-based EV charging station are as follows:

- There is a decrease in load on the grid.
- The voltage issue is eliminated in the distribution system (Cheng et al. 2015).
- There is also a drop in power rates charged to the utility.
- Higher efficiency in direct DC EV-PV interconnection.
- Possibility of V2G and V2H strategies (Mwasilu et al. 2014, 2012; Xu and Chung 2016; Fattori et al. 2014; Shemami et al. 2017).
- Charging cost is lowered and no emissions at the tailpipe (Mouli et al. 2016).
- Due to no moving part, there is no maintenance/noise.
- Easy installation is possible (Fara and Craciunescu 2017).

3.3.1 Solar Rooftop or Ground-Mounted System

In the world, this is mostly used and practice-wise accepted system. In this, the solar modules are installed on the roof of the domestic and commercial buildings, or the land area can be used as a ground-mounted system. For electricity generation, the system includes PV modules, solar inverter, cables, mounting systems, and other

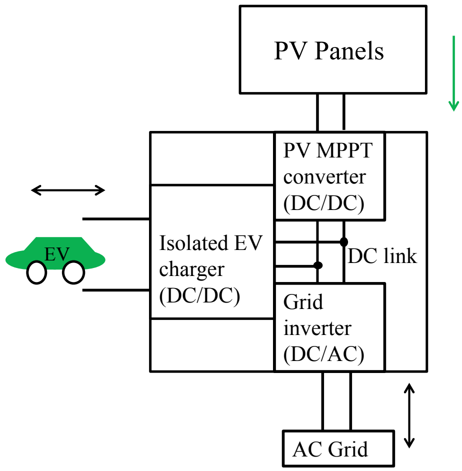


Fig. 6 On-grid solar EV charging system (Mouli et al. 2016)

electrical equipment. The roofing system is small in size 5–20 kW for domestic buildings and 100 kW (or more) for commercial buildings, while the ground-mounted system can be very high in megawatt capacity (Anto and Jose 2014). A research on the installation of a 6 kW_p (kW_p stands for kW peak of the system) grid connection solar system capable of generating 25 units is explained (Ghosh et al. 2016). There are three categories based on grid interface: on-grid, off-grid solar rooftop system, and hybrid systems.

On-Grid Solar EV Charging System

An on-grid solar rooftop system is the system in which the PV modules are mounted on a building's roof catering individual load and are also connected to the grid power (Sharma and Goel 2017). The output of the PV module is connected directly to the delivery system through grid-controlled inverters and cannot work without the grid reference voltage and frequency. There is no requirement for a battery bank, the power supply, and the load fluctuations are balanced by the grid, i.e., the augmented load demand is met by the grid supply, and if the load requirements are small and solar is available, additional energy may be applied to the grid, as shown in Fig. 6. The PV power, EVs and battery energy storage are integrated into a grid-based charging station (Singh et al. 2015, 2016). The charging facilities can be used in the grid-connected during cloudy or rainy seasons. The grid connection also enables transferring electricity from the PV modules to the grid in excess generation conditions. It is suggested that the second-life lithium-ion batteries be included in the system to act as a power reserve and offer immediate support during the grid supply shortage (Khan et al. 2018).

Off-Grid Solar EV Charging System

The off-grid charging system is a stand-alone power system which forms a micro-grid to feed the charge during the day without a battery bank (Sharma et al. 2016, 2017). An off-grid electrical car charger can also be called "EV Autonomous Renewable Charger." PV modules are installed for distributing the loads to the individual proprietor or domestic/commercial EVs and are not linked to any utility grid which is called the off-grid solar power system (Mueller and Mueller 2014). Off-grid electric car chargers can be mounted almost everywhere because there is no need for an electrical grid link. For a continuous nonstop power supply, a battery bank is required to compensate for changes in the input side due to differences in solar radiation on the PV module. For deserted places that are not linked to the grid, an off-grid PV charging system is a good option (Ciric 2017).

Hybrid Solar EV Charging System

Hybridization means that EVs are charged from different sources that work together. An example of one such system is the solar–wind system (Castillo et al. 2015). There is a grid connection of the system along with a battery backup. Without grid reference voltage and frequency, one can work in island mode under unsuitable grid situations (Adithya 2016).

3.4 *Vehicle-Integrated PV (ViPV) System*

The ViPV system marks an accompanying power source not only to charge the battery during the stoppage of the vehicle but also during the operation of the vehicle. This is a complex source that can provide extra power to electronic control systems, displays, actuators, ventilation, heating, and other electronic equipment such as 110 or 230 V_{AC} power converters, freezers, and microwave ovens (Kronthaler et al. 2014). When the vehicle is in a parking lot, unused generated electrical energy can provide the power to a ventilation/air cooling system in a hot climate (https://www.renewableenergyworld.com/articles/2005/05/from-bipv-to-vehicle-integratedphotovoltaics-31149.html). This could be perfect in India's tropical climate for public buses. The regular air conditioning on buses is not provided adequate ventilation and can danger to the health of passengers during the spread of diseases. The third-generation Prius provides a roof-mounted solar module (optional) for operating an air cooling/ventilation system. Besides, roof-mounted solar modules can be efficient in trickle charging the battery and avoiding self-discharge. The Nissan Leaf is known to pursue these technologies for India. The efficiency of PV modules with multi-crystalline technology is between 11 and 18%, while the usage of mono-crystalline silicon makes it possible to improve the conversion efficiency by about 4%. Gallium arsenide has allowed reaching 40% of cell efficiency. In ViPV systems, solar cells to be implanted into the chassis part exposed to solar radiations like the cover, roof depending on the design of the car. As a result, the vehicle itself looks like a massive solar power plant, and hybrid cars have become much more environmentally friendly. The source of supply is the electric motor and combustion engine to the vehicle.

With other techniques for painting the surface of the car with a light-resistant material, the technology of thin-film photovoltaic solutions is inexpensive and can be painted on the body (Kadar 2013). The efficiency of the system through the use of thin-film technology is almost 4 to 6%. In the research work, the efficiency of the thin film is more than 20% and with organic matter about 10% (https://www.nrel.gov/pv).

3.5 Solar Parking Lots

Workplaces such as commercial spaces or office buildings are ideal places for the photovoltaic electric solar charging of vehicles, where the roof and the parking lot of the building can be equipped with PV modules (Ma and Mohammed 2014). PV parking lot gives onsite energy generation for supplying the EVs batteries (Lee et al. 2016), and therefore, the power is accessible directly for EV charging via an EV-PV charger (Mouli et al. 2015). For large areas and multi-story car parks, this sort of system is becoming particularly fascinating. Vehicles are parked at office parking spaces throughout the day and can be charged via a PV-based charging system at standard charging levels. Despite its impact on the cost of charging, it will help to lessen the grid load and emissions (Tulpule et al. 2011). This PV-based parking model can be used in nations with strong sunlight and good solar potential (Benela et al. 2013). India is a tropical country where sunlight is accessible at high intensity for longer hours a day. Throughout the year, the daily average solar energy remains above 5 kWh/m^2 for a large part of the country; therefore, this PV-based parking model can be promising in India.

4 EV Charging Infrastructure in India

Under the new guidelines, a regulatory agency under the Ministry of Power has been nominated as the Central Nodal Agency, the Bureau of Energy Efficiency (BEE). Besides, the guidelines provide for a provision for the State Nodal Agency for their own states. Such nodal authorities will serve as the main facilitator in the country-wide deployment of EV charging infrastructure. A phase-wise construction of a sufficient network of charging infrastructure across the nation was proposed in the guidelines to solve the range of concerns of the owners of EVs.

Here is a brief about the guidelines issued for charging infrastructure (https://beeindia.gov.in/content/e-mobility):

- At least one charging station should be located in the cities on a 3 km × 3 km grid.
- One charging station on both sides of the highway/road per 25 km.
- In the first phase (i.e., 1–3 years) for all mega-cities with a population of more than 4 million, all current expressways connecting to these mega-cities and largely linked highways may be covered.
- UT headquarters may be covered for spread and demonstrative impact in the second phase (3–5 years) in large cities such as state capitals.
- Fast charging station for long-range and/or heavy-duty EVs, such as busses/trucks, etc., installed every 100 km, one on either side of the highway/road, conveniently located within/along the public charging station (PCS).
- The guidelines explained that private charges at houses or offices are allowed and that distribution company should encourage the same.
- The establishment of PCS is a de-licensed activity, and any person or organization can set up free public charging stations.
- Domestic billing is similar to domestic energy usage and is paid as such.
- In the case of PCS, the tariff for the supply of electricity to PCS is fixed by the relevant commission in compliance with the tariff policy laid down in Sect. 3 of the Electricity Act, 2003.

In support of the "National Electric Mobility Mission" of the Indian Government, Tata Power set up the first set of charging stations for EVs in Mumbai, India's financial capital. Tata Power has plans to set up and extend the network of charging stations for EVs in India. Currently, the company has 85 charging stations in 15 Indian cities like Delhi, Mumbai, Hyderabad, Bengaluru, Vijayawada, Indore, and Hosur (Soni 2019). The aim is to build 500 charging stations across the country's key cities by 2020, as well as another 100 charging stations in Maharashtra in the coming months. The oil marketing companies (OMCs) tie-up also plays an important role in growing to build a nationwide network of EV charging.

There are nearly 500 eV charging stations today covering major metropolitan cities such as Chennai, Mumbai, Bengaluru, and Kolkata. But by 2030, a city like Delhi alone could need around 300,000 fast chargers, assuming an EV penetration of 30% into an approximate 10 million car park. Meeting this need for infrastructure will require an investment of approximately $1–1.5 billion. Therefore, the total investment will rely on how widely EVs enter the automotive market. According to the Maharashtra Electricity Regulatory Commission (MERC) latest tariff orders, for the next two years, the electricity tariff for EV charging will be charged at ₹6 per unit. The commission has proposed a "time-of-the-day" tariff to facilitate charging during non-peak charging hours, thus ensuring that the local power grid is not burdened unnecessarily by the overconsumption from the charging of EV. A benefit of ₹0.75 per kWh is given for charging during low-load night hours, while an additional charge of ₹0.50–1.00 per kWh for morning and evening peak load hours is imposed. Moreover, tariffs for power supply for EV charging stations have also been announced by some other states. In addition to these power supply rates, a service charge may be added to public EV charging stations. To encourage greater use of EVs, though, Tata Power currently does not offer any service charges to EV users. Tata Power will introduce a mobile app that EV users can use to find chargers, control the charging process, book a charging slot, and finally make payments (Garg 2019).

MG Motor India planned to release the ZS EV in the country in December 2019, and before the launch of the new electric SUV, the car manufacturer had built its first fast-charging station in the county. The new 50 kW DC fast charging station is located at the company's flagship dealer in Gurugram and was built in partnership with the Finnish clean energy company major Fortum (Contractor 2019). The latter has constructed four public 50 kW fast-charging stations in West Delhi, South Delhi, Gurugram, and Noida under the alliance between MG Motor and Fortum. Furthermore, six more public 50 KW DC fast chargers were installed at MG's Mumbai, Hyderabad, Bengaluru, and Ahmedabad dealer locations. Bharat Heavy Electricals Limited (BHEL) is installing on the Delhi-Chandigarh highway a network of solar-based EV chargers. The first in the series was commissioned at Rai (Sonepat) in March 2019. The new five charging stations are situated at Haryana Tourism Corporation Ltd's resorts on Delhi-Chandigarh highway at Ambala, Kurukshetra, Karnal, Panipat, and Samalkha (Sonepat) (Gupta 2019). The project is covered by the FAME scheme of the Indian Government. The establishment of EV chargers at regular intervals over the entire 250 km distance between Delhi and Chandigarh is expected to ease the range anxiety among EV users and enhance their confidence in inter-city travel. Each EV charging station shall be equipped with a roof solar power plant for the supply of renewable energy to EV chargers.

In partnership with Exicom, Magenta, a renewable energy solution company, launched the DC fast charger in Navi Mumbai with a commitment to extending by the end of the year. Mumbai-based Magenta Power is setting up EV charging stations across the Mumbai–Pune expressway. In April, Shah Complex IV, a residential complex located in the Sanpada area of Navi Mumbai, has constructed three solar-powered charging stations for EVs. The installation was completed by Magenta Power, a Mumbai-based firm (Wangchuk 2019). And now, India's first EV charging corridor has been developed by the firm. The charging station network was set up at the Mumbai–Pune Expressway, Lonavala, Hotel Center Point (https://www.financialexpress.com/auto/car-news/after-indias-first-solar-charging-station-magenta-power-sets-up-countrys-first-ev-charging-corridor/1283569/). Finally, the network will be expanded to Bangalore and Mysore. The solar-powered charging station at Navi Mumbai, established by Magenta Power, is already a first in India. Because the fast charger connected to the grid uses solar power to charge the vehicles, the cost was incurred in almost nothing.

5 Challenges and Social Barriers

The transition to electric mobility gives India not only the potential to increase its productivity and change the transport market but also the many problems and social barriers that the country is currently facing.

5.1 Environmental Challenges

IC engine-based vehicles produced harmful gases, which include carbon monoxide and CO_2. HEVs and PHEVs have IC engines, but their emissions of harmful gases are less than fossil fuel-based vehicles. The use of renewable energy sources in conjunction with the EVs can reduce the emission of gases from both the power generation and the transportation sector. EVs cause less emission than fossil fuel-based vehicles. This factor is called as well-to-wheel emission with lesser value for EVs. According to the Paris Agreement, the goal was to reduce the rise in global average temperature below 2 °C above pre-industrial levels (Moriarty and Wang 2017). The adoption of EVs would lead to an increase in CO_2 pollution from the power sector unless the fuel used to charge EVs comes from renewable energy sources.

According to an estimate, CO_2 emissions from thermal plants in India from 2001–2002 to 2009–2010 was 910 g/kWh to 950 g/kWh (https://unfccc.int/paris_agreement/items/9485.php). India's energy consumption and installed electricity capacity have raised 16-fold and 84-fold, respectively, in the last six decades (Mittal 2010). In India, the majority of electricity is generated by coal combustion, generating even more carbon emissions than petrol or diesel. Commonly, coal creates 0.92 kg of CO_2 per kWh and gas, solar energy creates 50 g of CO_2 per kWh, and wind energy creates 10 g of CO_2 per kWh. In 2015, the government set an ultimatum of clean sources generating 175 GW of electricity annually by 2022, including about 100 GW of solar power. Approximately, 50 GW of solar power has already been achieved as per national statistics (Agrawal et al. 2014). Therefore, only when these two components made to act opposite to each other, only then can the actual potential of shifting to EVs will be addressed effectively.

When the price of PV modules decreases, the economic advantage of solar charging can be incredible due to its localized adverse effects (Ba 2017; Almansa Lopez 2016; Dubey et al. 2013). It is very important to transfer to solar energy for the production of electricity. India is highly dependent on foreign companies for technology as there are fewer studies is being conducted in this field. In Indian cars, manufacturers spend almost 1–2% of their turnover on research and development. Lithium-ion battery prices are significantly reduced, and EVs are projected to become as affordable as ICE fuel cars on the automotive market in the upcoming years. Currently, the biggest problem facing in the field of an EV is the price and range of the battery (Khan 2017). Most nations have a common goal of reducing pollution-related problems and global warming. The solution is the worldwide use of renewable energy sources. It is not realistic to think economically of the 100% usage of a renewable-based charging system, one of the key reasons is that fossil fuels are at the heart of the existing grid-connected power network, and constraints on large-scale development and use of PV panels also impede its global adoption. In view of the present situation, there is a need to increase the share of renewable resources. The best way to do this is to provide an on-grid solar charging network with maximum solar energy allocation and the rest is to supply the grid. A stand-alone off-grid system is the other alternative.

5.2 High Price of EVs and Battery

The average cost of electric cars in India is around INR 13 lakh, far higher than the average INR 5 lakh for low-cost cars running on conventional fuel. In India, the price range of electric scooters and bikes is between INR 70 K–INR 1.25 lakh compared to INR 30 K–INR 40 K for the cost range of IC motorcycles and much lower for scooters (Soni 2019).

C V Raman, senior executive director (Engineering) of Maruti Suzuki India, said in his speech that it would be difficult to make a good value proposal quickly under current circumstances unless the cost decreases significantly. This is estimated that the market segment of EVs will also cost two and a half times more than the same type of vehicle powered by a conventional petrol/diesel.

Another challenge is the battery price. Battery price is primarily responsible for the higher prices of EVs. Many EV batteries are designed by combining multiple individual cells; the price of the battery is determined by the cost of each cell. Despite individual cell costs, safety features, packaging costs, mass production, and business strategies are also responsible for driving higher battery prices. The cost of EVs in India is mainly due to Li-ion batteries. Batteries make up around 70% of the cost of the vehicle. That is why the battery packs that are imported cost a lot, about $275/kWh in India. On top of it, the GST component of 28% makes the case even worse. Obviously, the price has dropped in the last five years, but still, it has not reached a value that would allow the general public to opt for EV. Already, annual sales of EVs amount to 0.1 percent of 3 million vehicles a year. The inflection point for such batteries is estimated to be around $100–150/kWh, which is projected to be reached by 2025. When the cost of the battery crosses this level, there will be a big increase in the demand for EVs, and an EV boom will occur in India (Electric Vehicle Industry 2018).

5.3 Charging Infrastructure and Charging Time

India officially had 650 charging stations in 2018, while in the same year China had over 456 K charging points (Kotoky 2019). In addition to charging points, the shortage of private parking spaces is still recognized as a hurdle to the adoption of EVs, and the scarcity of accessible renewable energy indicates that charging EVs will put a strain on the increasingly depleted coal-fired power system. According to research carried out by auto giant Maruti Suzuki, 60% of Indian consumers do not have their individual parking space. "There is no way they can charge the vehicle, therefore they would not adopt it," said C V

Raman, senior executive director (engineering) of Maruti Suzuki India. The shortage of charging stations is also a challenge against the implementation of EVs. Setting up charging infrastructure for fast charging is the most important thing to do. Across India, there are about 222 charging stations for about 187,802 EVs with 353 charging points. For 222 million conventional cars, there are about 56,000 petrol pumps. Unlike in developed countries, people do not have sufficient electrical supplies in their homes to charge or set up charging infrastructure (Chauhan 2018).

Table 2 presents the details of the certified full charge range, battery capacity, maximum power, and charging time of the available EVs in the Indian market

Table 2 Details of the certified full charge range, battery capacity, maximum power, and charging time of the available EVs in the Indian market

EVs		Certified Full Charge range (as per Modified Indian Driving Cycle) (km)	Battery Capacity (kWh)	Max. Power	Charging time		
					Normal Charging Time (0–100%) from any 15 A plug point	AC Charging	Fast/DC Charging Time (0–80%)
Sedans	Tata Tigor EV	213 km	21.5 kWh	30 kW @ 4500 rpm	11.5 h @ 25 ± 2 degrees ambient and battery temperature	Not available	2 h with 15 kW charger @ 25 ± 2 degrees ambient and battery temperature
	Mahindra e-Verito	181 km	21.2 kWh	31 kW @ 4000 rpm	11.5 h (± 15 min) @ 25 °C	Mahindra e-Verito	1 h 30 min @ 25 °C
SUVs	Tata Nexon EV	312 km	30.2 kWh	94.88 kW	State of charge: 10% to 90%: 8.5 h @ ambient temperature	Not available	State of charge: 0%-80%: 60 min @ ambient temperature
	MG ZS EV	340 km	44.5 kWh	104.999 kW @3500 rpm	80% charging in 16–18 h	(0–80%) 6 to 8 h @ Estimated 7 kW	Up to 80% charging within 50 min @ 50 kW
	Hyundai Kona EV	452 km	39.2 kWh	99.92 kW	Not available	(0–100%) approx. 6 h 10 min	Approx. 57 min @50 kW

(https://tigor.tatamotors.com/electric/specification, https://www.mahindraelectric.com/vehicles/everito/, https://nexonev.tatamotors.com/features/, https://s7ap1.scene7.com/is/content/mgmotor/mgmotor/documents/mg-dc-pdf-0060.pdf, https://www.hyundai.com/in/en/find-a-car/kona-electric/specification). The time needed to charge the EV (0 percent–100 percent) is approximately 11.5 to 18 h when normal charging is considered, which creates another time management challenge. It can go well under 90 min or less when talking about the fast charging of EVs, but that depends on the accessibility of charging stations. DC charging requires charging infrastructure, another barrier to overcoming. A petrol pump will normally add about 500 km of range in just 10 min. However, the EVs need to be charged for a longer period, and they give a range of approximately 150–200 km which is very small.

5.4 Safety

The installation of charging stations needs various types of permissions from the local electricity board the municipal corporation and central approval as to what ISI standards need to be maintained. Safety is a crucial parameter when there is a high-voltage charging station. A person can bear a shock from a charging station that carries up to 60 V of electricity. The rise in EV infrastructure is hurdled by these kinds of realistic hurdles. The EVs are noise-free, so it is impossible for a pedestrian to realize whether or not an EV is approaching them. The USA has passed a regulation to adjust the minimum sound level for EVs through artificial sounds when approaching a pedestrian. Nevertheless, since EVs promote concepts such as artificial sounds as factors to noise emissions, the regulation is in question.

5.5 Solar PV Modules

Solar PV modules with multi-crystalline technology have efficiencies varying from 11 to 18%, whereas the use of mono-crystalline silicone improves the output by about 4%. The use of materials such as gallium arsenide and concentrating technologies has allowed reaching 40% of cell efficiency (Rizzo 2010). But the cost is still too high for a mass application on EVs. A moving PV module was found to raise the solar output from around 46%, at low latitudes, up to 78%, at high latitudes (Ai 2016). Regardless of the energy needed to rotate the module and potential kinematic restrictions preventing perfect orientation, the actual benefits will be smaller than those expected.

5.6 *The Need for Public Policy Support*

While nobody believes that the GoI is doing everything it can to promote EVs, the industry has in the past opposed the FAME scheme. Originally, the government concentrated on automotive standardization with FAME, which was abandoned to prioritize manufacturing. At the moment, the government is currently preparing the infrastructure framework for charging EVs. The government still aims to tax more aggressively on non-electric vehicles, even though sales of EVs may not warrant such a forced move and that put undue strain on OEMs in the automotive industry.

EV market growth is projected to keep on increasing quickly. Despite numerous emerging regulatory and economic opportunities for EV implementation and infrastructure growth, there are no specific planning recommendations for selecting a site for the development of an EV infrastructure. The development of EV infrastructure was mainly driven by market factors such as prices, characteristics of the electricity grid, and the choice of interested parties. Present EV programs that prioritize domestic and workplace charging as core places for EV chargers establish exclusivity and inadequacy in the operation of facilities as well as barriers to more EV adoption. Through the continuous promotion of private sector investment (including companies and households) is beneficial, a more active involvement for the public sector is required (Deaton 2019).

5.7 *Range Anxiety*

Range anxiety is when consumers are afraid to think that the EV may not have enough range to take them to their destination. This is directly related to the country's shortage of charging facilities, and although traditional vehicles may be refueled at petrol stations, there is still no such regularized network accessible for EVs. Many studies have shown that consumers remain away from EVs because they are worried about the shortage of charging stations. The studies also indicate that when they see stations around the area, customers are more likely to buy an electric car. Although fears of range anxiety are generally baseless—even the cheapest EVs have sufficient range to meet almost all the driver's needs–the lack of charging stations is a real worry for longer trips, and this discourages consumers from going all-electric (Rahman et al. 2016). The certified full charge ranges (as per modified Indian driving cycle) of Tata Tigor EV, Mahindra e-Verito, Tata Nexon EV, MG ZS EV, and Hyundai Kona EV are 213 km,181 km, 312 km, 340 km, and 452 km, respectively, as given in Table 2. It can be observed that fears of range anxiety are largely baseless, as the lowest certified full charge range is 181 km which is sufficient range except for long trips. The battery capacity of Tata Tigor EV, Mahindra e-Verito, Tata Nexon EV, MG ZS EV, and Hyundai Kona EV are 21.5 kWh, 21.2 kWh, 30.2 kWh, 44.5 kWh, and 39.2 kWh, respectively.

BMW group India's president and CEO, Rudratej Singh, also said earlier that the EV infrastructure is still unclear and unpredictable, impacting Indian consumer's quality and car acceptability. Recently, Toyota has stopped producing electric and hybrid cars for the Indian market, claiming inadequate charging facilities (Soni 2019).

"The problem is that the charging infrastructure does not have a viable business model yet," says David Greene, a professor of Civil and Environmental Engineering at the University of Tennessee. "Although, there are some companies who are working on it hard." Private firms such as EvBox and ChargePoint are aiming to rapidly increase the number of available charging stations, but these plans are focused on an exponential rise in EV purchases. ChargePoint expects to install 2.5 million charging stations on its global network of only 50,000, a goal that it says is based on a "conservative view" of future EV sales. Furthermore, EvBox is planning 1 million new charging stations (Deaton 2019). Analysts expect to see a drastic rise in EV sales in the coming years, but significant roadblocks stand in the way of future adoption. Even if EV sales take off and charging stations increase, hurdles will remain. Making EVs more practical means that not only installing more chargers but also faster chargers that allow drivers to travel longer. There is also the fact that there is no standardization of the technology. Different EVs use different plugs. Ford and GM use one type, and Tesla uses another. Not every station meets the needs of every driver (Deaton 2019). The Ministry of Power has released recommendations and standards for India's EV charging system.

6 Financial Benefits

From the point of view of the EV customer, EV's operating cost is lower due to its superior efficiency (Rahman et al. 2016), and it can be up to 70% relative to IC engine vehicles with efficiencies ranging from 25 to 50%. The customer has earned a financial gain from their EV by delivering grid service using the grid voltage method. The power service provider profits immensely from EV deployment, primarily through the implementation of synchronized charging and grid voltage. EV provides \$200–\$300 savings in cost per vehicle per year. Due to a reduction in the cost of PV modules, there is a major shift to renewable energy through the PV system. The integration of EV and PV creates the potential for efficient EV charging. According to the German Renewable Energy Act, the share of renewable energy will rise by 2025 to 40–45% and by 2035 to 55–60% (Weida et al. 2016). China is the leading contributor to PV and EV production in the number one spot for the PV manufacturing country, with about 58% of global market shares (Li et al. 2017).

7 Conclusions

There are two main fields, solar PV and EVs, which are used for the new mode of transport and can reduce CO_2 pollution and use of fossil fuel, and unfortunately, both have large-scale obstacles. Because of its intermittent existence and concentration of energy generation during the day, PV restricts its commitment to satisfying a large fraction of the average demand for electricity. Compared to the fossil-fuel-based vehicle, EVs offer a clean, effective, and noise-free shifting way.

The future benefits from solar-based EV charging technologies have been outlined. More practical models create social obstacles and bear in mind the robust application of this technology, especially in developing countries where there is a resistance to the adoption of new technologies. Therefore, policy-making choices will be the most effective way. In light of these challenges, if both technologies are used simultaneously, it may be possible to improve the economic performance of EVs by daytime charging, which improves the distance traveled by using low-cost electricity, and carbon emissions will also be controlled. The best option is to install multiple solar PV-EV charging stations globally dispersed. Therefore, the use of renewable energy is growing, and EVs can boost economic growth, generating new job opportunities and ensuring an environmentally sustainable future.

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