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Comprehensive Analysis of Global Electric Vehicle Charging Infrastructure

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Abstract. A dramatic shift is taking place on a worldwide scale as the transportation sector moves away from vehicles fueled by fossil fuels and towards those with zero or ultra-low tailpipe emissions. An information-based network of recharging stations (CSs), along with innovative, decentralized energy producing units, and supportive governmental policies, are necessary for the widespread adoption of electric vehicles. This paper examines the global landscape of electric vehicle (EV) charging infrastructure, including its evolution, different kinds of charging stations, essential components, policy support, obstacles, and emerging trends. Technology has made Level 1, Level 2, Level 3, wireless charging, and battery switching faster and more efficient. The power source, charging station, charging cable, and connection are all essential parts of the EV charging infrastructure that work together to provide dependable and efficient charging for EV owners. Funding programs, tax incentives, and laws have helped EV adoption, but additional investment, charging connector and protocol standardization, and range limits of some EV models remains a challenge. This paper is an invaluable resource for researchers, policymakers, and industry professionals who are interested in gaining a more in-depth understanding of the current state of electric vehicle charging infrastructure as well as the potential and difficulties that lie ahead.
Keywords—Electric Vehicle, EV Charging Station, Charging Infrastructure

INTRODUCTION

The network of charging stations and associated infrastructure required to recharge electric vehicles is referred to as electric vehicle charging infrastructure. It incorporates both standard and fast-charging infrastructures for electric vehicles. Building out a network of charging stations for electric vehicles is a crucial step towards a more sustainable transportation system. This is because drivers may be unwilling to switch to electric cars if there isn't a reliable and easy-to-use charging infrastructure, out of fear that they'll get stuck without power. The elimination of "range anxiety" and the provision of electric car owners with the assurance and convenience required to make the move to electric vehicles can be facilitated by a charging infrastructure that is both sturdy and well-designed. It also reduces greenhouse gas emissions, air pollution, and fossil fuel use.The significance of EV charging infrastructure for environmental sustainability cannot be overstated. Greenhouse gas emissions from transportation, a major contributor to environmental degradation, will decrease as more people opt for electric vehicles over gas-powered automobiles. Further reducing emissions and assisting in shifting to a future that uses sustainable energy is the use of renewable energy resources, such as wind or solar energy, for fueling electric vehicles [1-2].

The paper supervised "An overview of EV charging infrastructure" has been written with the intention of providing readers with an in-depth comprehension of the present scenario of electric vehicle (EV) charging infrastructure. The purpose of this paper is to give readers an overview of the many different kinds of electric vehicle charging stations as well as the advancements in technology that are employed in those stations. The scope of this paper covers a review of the many types of electric vehicle charging stations, such as Level 1, Level 2, and Level 3 charging stations, along with the distinctions that exist between each of these charging stations. Various charging protocols and connectors that are utilised around the world will also be covered. In addition to this, the paper will talk about the current situation of the charging infrastructure for electric vehicles in several different locations, such as the United States, Europe, and Asia. It will give a synopsis of the programs and regulations that are already in place to facilitate the expansion of EV charging infrastructure.

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In general, the purpose of this paper is to give readers with a comprehensive overview of the current state of electric vehicle (EV) charging infrastructure, the issues that need to be solved, as well as the prospects for growth and innovation in this crucial subject.

EVOLUTION OF EV CHARGING INFRASTRUCTURE

Electric vehicles (EVs) have been around for a long time, but it wasn't until the early 2000s that automakers and customers really started to pay attention to them. The initial stages of the electric vehicle (EV) charging infrastructure were characterized by simple, slow-charging outlets that were primarily restricted to public venues and corporate campuses. These charging stations frequently had restricted ranges and capacities, which rendered them unsuitable for usage in regular life situations. However, the landscape of electric vehicle charging infrastructure has been drastically altered by technological and innovative advancements over the past two decades. Currently, drivers of electric vehicles have access to a wide range of options for charging their vehicles, ranging from standard level 1 charging points that can be placed in residences or parking lots to fast speeds level 3 charging points which can offer a full charge in less as half an hour [3].

One of the key drivers of this evolution has been the emergence of new technologies and innovations that have made EV charging faster, more convenient, and more accessible than ever before. For example, the development of lithium-ion batteries has enabled EVs to achieve longer ranges, which in turn has increased the demand for charging stations that can provide a quick and convenient charge. Another major factor in the evolution of EV charging infrastructure has been the emergence of new business models and partnerships that have helped to drive investment and innovation in the sector [4]. Today, there are a growing number of companies and organizations that are working together to build out charging networks and make EV charging more accessible to consumers.

The rapid expansion of public charging networks, on the other hand, has been undoubtedly the most important breakthrough in the growth of the infrastructure used to charge electric vehicles (EVs). Tesla and Volkswagen, two of the largest manufacturers in the world, have both made large investments in charging infrastructure in recent years, constructing extensive networks of fast charging stations across major roadways and urban centers. At the same time, an increasing number of third-party providers are working to build up their own charging networks, with the intention of providing drivers of electric vehicles with a charging environment that is efficient and transparent. There is now a better developed and easily accessible network for charging electric vehicles [5]. The majority of electric vehicle charging takes place in private homes and offices. Consumers will have a growing expectation that electric vehicles (EVs) will provide the same services, ease of use, and independence that conventional automobiles do. According to the IEA's Global EV Outlook 2023, there were 2.7 million public charging sites around the world by the end of 2022. More than 900,000 of these charging points were set up in 2022 alone, which represents an increase of around 55% from the stock in 2021 and an expansion rate that is close to a pre-pandemic expansion rate of 50% during 2015 to 2019 [6].

In 2022, over 600,000 public slow electrical charging stations were built around the world. Slow chargers have power ratings of less than or equal to 22 kW. Of these, 360,000 were in China, bringing the total number of slow chargers in the nation as a whole to more than 1 million, as illustrated in Fig. 1. The majority of the world's public slow charging stations, as of the end of 2022, were located in China. Europe comes up at number two with 460 000 overall slow charging stations in 2022, which is an increase of 50 percent from the year before. In Europe, the Netherlands has the most residents with 117 000, which is followed by France with around 74 000 and Germany with 64 000. In 2022, the number of slow chargers in the U.S. grew by 9%, which was the lowest growth rate of any big market [6-7].

Fast chargers, which are available to the public and have a power rating of more than 22 kW and up to 350 kW, make it possible to travel longer distances and can help alleviate range anxiety, which is a barrier to the widespread adoption of electric vehicles. Public fast chargers, just like public slow chargers, provide users with charging alternatives even if they do not have dependable access to personal charging, which in turn encourages the adoption of electric vehicles across a wider segment of society. Slow chargers. In 2022, the world gained 331,000 fast chargers, with China accounting for about 90% of the increase as can be seen Fig. 2. In Europe, the total number of fast charging stations will surpass 70 000 by the end of 2022, a rise of approximately 55 percent compared to 2021. In the year 2022, the United States of America constructed 6,300 fast chargers, among which nearly three-quarters were Tesla Superchargers. By the end of 2022, the overall number of fast chargers in existence had reached 28,000 [6-8].

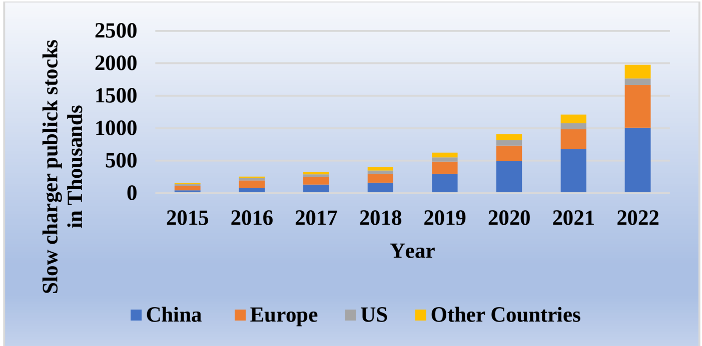


Figure.1. Slow publicly available chargers

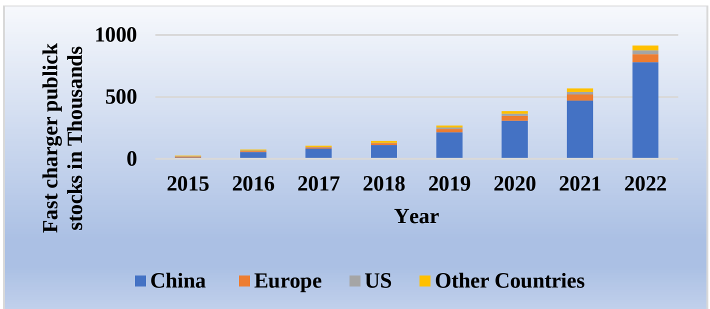


Figure.2. Fast publicly available chargers

CHARGING TECHNOLOGY FOR ELECTRIC VEHICLE

An EVCS is an essential component of the infrastructure for charging electric vehicles. It allows electric vehicles to be charged with electricity from a variety of sources. Its classification is influenced by a wide range of elements, such as the power source, how the charging station is integrated into the power grid, the power levels used during charging, the infrastructure used while charging, mobility, and the direction of power flow. The following is a categorization of EV charging stations according to several criteria [9].

Electric vehicle charging stations can be divided into three categories according to the type of power source that is utilised throughout the charging process [10]. This includes:

- **AC charging stations:** Charging electric vehicles at these charging points is accomplished using an alternating current (AC) power source. AC charging stations are typically more time-consuming than DC charging stations, that's why you will typically find them in home as well as business environments where cars can be left for a few hours.
- **DC fast charging stations:** Electric vehicles can be charged at these charging points with a direct current (DC) power source. Drivers frequently utilise DC fast charging facilities around highways and other high-traffic locations where they need to refuel their automobiles quickly because they are considerably quicker than AC charging points.
- **Wireless charging stations:** The transfer of electrical power from the charging point to the electric car is accomplished by the use of wireless charging technology at these charging locations. When a car parks over a recharging pad, electromagnetic induction is used to transmit energy from the pad to the vehicle. The technology behind wireless charging is still in its infancy, and its adoption has not yet been widespread.

Electric vehicle charging stations can be divided into three categories based on their interconnection with the electrical grid [11]

- **Unidirectional charging stations:** These nodes can only take power from the grid and have no way of contributing to it. Most homes and businesses have one of these standard charging stations installed.

- **Bidirectional charging stations:** These facilities can both draw energy from and contribute to the grid. They can be used to help the grid out during times of high demand, and so another name for them is "vehicle-to-grid" (V2G) charging stations.
- **Smart charging stations:** These stations are linked together through a network, and they are able to exchange information with the power grid in order to streamline the charging procedure. They have the potential to alter the charge rate according to the availability of renewable energy sources as well as the demand on the grid, which can help to alleviate the strain that is placed on the system during times of high demand. Additionally, smart charging stations have the ability to provide real-time data on the amount of energy being consumed and can be controlled and monitored remotely.

Electric vehicle charging stations can be divided into three categories according to the amount of power that is utilised during the charging process [12]:

- **Level 1 charging:** A conventional 120-volt/15Amp AC power outlet is used by level 1 charging stations, which offer a charging rate of roughly 2–5 miles of range per hour. It is commonly done to use Level 1 charging at residence or in similar weak-demand settings because it is the slowest charging option available. The Level 1 charging methodology is simple: simply connect your EV into a conventional electrical socket using the charging cord that came with the vehicle. The cable for charging has a connection on one end that fits into the vehicle's charging port, and a conventional three-prong plug on the other end that fits into a typical electrical outlet. Level 1 charging usually adds between 2 and 5 miles of range per hour of recharging. Depending on the size of the battery and how charged it was to start with, it might take many hours or even overnight to completely charge an EV battery. If you have an automobile with a battery capacity of 40 kWh and the battery is entirely depleted, for instance, utilising a Level 1 charging station to get the battery up to its full capacity might take up to 20 hours. Despite being sluggish, there are benefits to Level 1 charging. There is no need for special equipment or costly installation when using this method to charge your electric vehicle. Additionally, Level 1 charging can be accomplished through the use of any regular electrical outlet. This enables you to charge your electric vehicle wherever there is access to an electrical outlet, such as in your own home, at your place of employment, or in a public parking garage.
- **Level 2 charging:** Level 2 charging is an improved rapid and efficient method of fuelling an electric vehicle (EV) than Level 1 charging. It operates on a 240-volt alternating current (AC) supply, which is normally mounted by a professional electrician and necessitates the use of specialised devices such as a charging station or EVSE (Electric Vehicle Supply Equipment). With the exception of using a more potent charging facility that offers a faster charging rate, Level 2 charging is similar to Level 1 charging in its charging process. Connecting your electric vehicle to a charging location using the charging cable that either came with the vehicle or was offered by the place of charging is required in order to charge an electric vehicle employing a Level 2 charging method. Connectors on either end of the charging cable allow it to be inserted into the vehicle's charging port and the charging station, respectively. Depending on both the car and the charging station, a level 2 charging station can typically provide a charging rate of anywhere from ten to thirty miles of range for every hour of charging. If you have a vehicle with a battery capacity of 40 kWh and the battery is entirely depleted, for instance, it can take anything from four to twelve hours for a Level 2 charger to fully recharge the battery. The Level 2 charging method is superior than the Level 1 charging method in various respects. It can offer a substantial amount of range in a relatively short period of time because it is significantly faster. In addition, Level 2 charging can be performed at a committed charging station that has been constructed especially for the purpose of charging electric vehicles. This can assist to reduce the amount of wear and tear that is placed on the electrical system as well as raise the level of safety. Level 2 charging stations are versatile enough to be installed anywhere an electric vehicle needs power, including private residences, commercial buildings, and public parking garages. In comparison to Level 1 charging, they typically have a higher initial investment and ongoing operating cost, but they offer a greater degree of convenience and a more rapid rate of charging. Wi-Fi access, app integration, and real-time monitoring of charging sessions are just a few of the extras available at certain Level 2 charging stations.
- **Level 3 charging:** The quickest charging technique, Level 3, is frequently utilised in high-traffic locations like motorways where drivers need to swiftly charge their cars. Charging an electric vehicle (EV) with a level 3 charger, which is sometimes referred to as DC fast charging, is the approach that provides the greatest amount of power while simultaneously being the quickest. An electric vehicle's battery can be charged to 80% in as little as 20-30 minutes due to the system's usage of a high-powered direct current (DC) power supply. The procedure of charging with Level 3 is comparable to the process of charging with Level 2, with the

exception that it makes use of a charging station that is far more powerful and is specifically intended for rapid charging. Level 3 charging necessitates the use of a charging cable, either supplied with the car or purchased separately, to connect the vehicle to the charging station. A connection on one end of the charging cable can be inserted into the port on the back of the car for charging, and the other end of the cable has a connector that can be inserted into the charging station. Level 3 charging may replenish an electric car's battery to 80% capacity in as little as twenty to thirty minutes, though this varies by vehicle and charging station. However, it is essential to keep in mind that not all electric vehicles (EVs) are capable of receiving Level 3 charging, and the rate at which the vehicle is charged may change depending on the battery capacity as well as the charging capabilities of the vehicle. When compared to Level 1 and Level 2 charging, Level 3 charging offers a number of benefits. It is much faster, which means that a full charge can be given in a short amount of time. This is especially helpful for long-distance trips, where stopping often to charge can take time and be annoying. In addition, Level 3 charging points can be located alongside highways and other strong-traffic locations, which makes it simpler for drivers of electric vehicles to receive rapid charging when they require it. Level 3 charging is the fastest and most efficient way, but it also has the highest upfront and ongoing expenditures. It is not very common for residential charging to make use of this technology because it is typically only present in business and public settings. Furthermore, the battery's lifespan may be shortened due to fast charging's increased heat production and stress on the battery. Therefore, Level 3 charging should be reserved for emergencies, and Levels 1 and 2 should be used on a regular basis.

Electric vehicle charging stations can be divided down into three distinct categories according to the type of charging technology or method that is installed [13].

- **Centralized charging stations:** These are charging outlets that are positioned in a central location and provide service to a significant number of electric vehicles in a specific region. Level 2 and Level 3 charging stations are often established and managed by utility providers.
- **Distributed charging stations:** These are charging stations that have been built in a number of different places across a city or region with the intention of making it easier for drivers of electric vehicles to charge their vehicles. Level 2 and Level 3 charging stations are available and can be installed in public parking lots and retail centers.
- **Battery swapping stations:** These are charging points that give owners of electric vehicles the option to swap their dead batteries with one that is fully charged rather than having to wait for their battery to be recharged. Battery swapping stations are not generally available just yet, but they have the potential to drastically cut the amount of time it takes for electric vehicles to charge.

Electric vehicle charging outlets can be divided into two categories according to the mobility they provide [13].

- **Fixed charging stations:** These are stations for charging that have been put in a site for an extended period of time and are designed for use over an extended period of time. Level 1, Level 2, and Level 3 fixed charging stations are all available for installation in private residences, businesses, and public spaces.
- **Mobile charging stations:** These mobile charging stations can be set up wherever they are most conveniently needed. Level 1, Level 2, and Level 3 charging stations are all available in portable forms for usage at events or other locations where installing a permanent charging station would be impractical or impossible. Portable charging stations can be moved around on a trailer or by some other means, and they can be run on either a generator or a battery pack.

Fixed charging stations and mobile charging stations both play a significant role in supporting the rise of electric vehicles (EVs) by providing EV drivers with charging alternatives that are convenient and easily accessible.

COMPONENT OF EV CHARGING INFRASTRUCTURE

Different types and levels of charging may require different parts of an EV charging infrastructure [8]. Nonetheless, the majority of EV charging stations share the following components [14]:

Power Source

The source of electricity utilised to charge electric cars (EVs) at charging stations is referred to as the power source. It could be a solar array or a wind turbine connected to the regional electricity grid.

Local power grid:

The greater number of charging stations today obtain their power from the public power grid in their immediate vicinity. This indicates that the charging facility is linked to the power system that is maintained by the community's primary provider of utility services. The electricity is drawn from the grid by the charging station and sent to the EV via the charging cable and connector.

Renewable energy sources:

There are charging stations that get their power from renewable resources like solar or wind power. These charging stations will generate their own electricity through the installation of photovoltaic panels or wind turbines on the premises. The EVs will be charged with the power that comes from these sources.

It is essential to keep in mind that the power source will have an effect on the charging speed as well as the cost associated with charging. For instance, recharging from a solar-powered charging station may take significantly longer than recharging from a grid-connected charging station. This is because the quantity of electricity provided by the solar panels at such a station may be restricted. Similarly, the greater installation expenses associated with charging from a renewable energy source could make it costlier than recharging from the electrical grid.

Charging station

This is the actual piece of equipment that links the EV to its power supply. The charging station is usually equipped with a charging cable, connection, and user interface, and it can be a Level 1, Level 2, or Level 3 charging station [13].

Charging Cable

A charging cable is an essential element of the EV charging system because it provides the tangible connection that exists between the charging point and the EV. The task of transferring electrical current from the charging station to the electric vehicle's battery is the responsibility of the charging cable The ease of use and security of the charging process are both impacted by factors such as the length and flexibility of the charging wire. A shorter connection may be beneficial for charging in a congested or cramped environment, whereas a longer line may be required for recharging in an open region or in a remote location. A cable that is more flexible may be simpler to manipulate and store, but it may also be less robust and more prone to damage.

Connector

A device known as a connector is one that is employed for the purpose of achieving a physical connection between two or more components. Connectors for electric vehicle charging come in a few varieties, including the following:

Type 1 Connector

AC charging of electric vehicles (EVs) utilises the Type 1 connector, which can also be referred to as the SAE J1772 connector. This connector is the standard connector utilised in North America and Japan. The Type 1 connector, which can have either five or seven pins depending on the manufacturer's version of the car, is made to work with both Level 1 and Level 2 charging and can handle a maximum of 16 amps of current, making it ideal for low to medium-speed chargers.

Type 2 Connector

The Type 2 connector, which is often referred to as the Mennekes connector, is a standardized connector that is used in Europe for recharging electric motor vehicles (EVs) using alternating current (AC). The Type 2 connector features seven pins and is intended for use with both Level 1 and Level 2 charging. The Type 2 connector has a locking lever that ensures a safe connection to the charging port of an EV

Combined Charging System (CCS) Connector

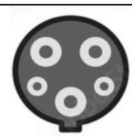
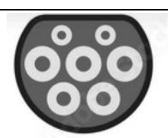
For DC rapid charging of electric automobiles, the Combined Charging System (CCS) connector is a standard connector used in Europe and North America. High-power direct current charging is made possible via the CCS connector, which is a combination of the Type 2 AC connector and additional DC pins. The Level 1 and Level 2 AC charging uses the AC connector, while the Level 3 DC fast charging uses the DC connector. Together, these two components make up the CCS connector. The DC connector features two extra pins that give direct current (DC) power to the battery of the EV. This allows for significantly quicker charging than with AC charging. The CCS connector was developed to allow charging power levels of up to 350 kW, which enables certain electric vehicles to receive a complete charge in as little as 15 to 30 minutes. Because it is backwards-compatible with Type 2 AC charging infrastructure, the CCS connector can be used with a wide variety of electric vehicles (EVs) from different manufacturers.

CHAdeMO Connector

CHAdeMO is a connector for fast charging that is largely utilised in Japan and several other Asian nations for the purpose of providing electric cars (EVs) with DC rapid charging. CHAdeMO, which stands for "CHArge de MOve," which translates to "charge for moving" in Japanese, is the name of the phrase. Since 2010, the CHAdeMO connector has seen widespread application in Japan, and since then, it has also gained acceptance in a number of other nations. The connector is recognizable by its round form and was developed to facilitate the charging of electric vehicles with high levels of DC power. Two of the pins of the CHAdeMO connector provide direct current (DC) power to the EV's battery, and the remaining pins allow for bidirectional communication between the charging station and the EV. The connector is built to enable charging power levels of up to 62.5 kW, which means that certain electric vehicles can receive a complete charge in as little as 20 to 30 minutes. IEC (61851-23-6), IEEE (IEEE Standard 2030.1.1TM-2015), and industry (61851-23, -24, and 62196-3) have all adopted CHAdeMO as part of their respective standards.

Table 1 provides a quick comparison of a few popular models with respect to their maximum charge, maximum range, and efficiency ratings.

TABLE1: Schematic of Connectors with its Characteristic

	Type 1 Connector	**Type 2 Connector**	**CCS Connector 1**	**CCS Connector 2**	**CHAdeMO**
Figure					
Charging Type	AC Charging	AC Charging	DC Fast Charging		AC Charging
No. of Pins	5	7	7	9	4
Voltage	120-240V	400V	600	1000	500
Current	Up to 80A	Up to 63A	Up to 200A	Up to 350A	125-400A
Capacity	7.2 kW	12.8kW	50-100kW	200kW	200-400kW

Charge point management system (CPMS)

A Charge Point Management System, also known as CPMS, is a software platform that gives business owners the ability to remotely manage and monitor electric vehicle charging stations. Operators can control their whole charging station network from a central dashboard made possible by the CPMS, which is often hosted in the cloud [7].

User Interface

The charging station's user interface is the part of the device with which the user communicates. The user can input data and manage the charging process using a screen, buttons, or other input devices. The user interface may be included into the charging station itself, or it may be connected to a separate device.

CHALLENGES AND LIMITATIONS OF EV CHARGING INFRASTRUCTURE

The development and deployment of EV charging infrastructure faces a number of obstacles and limits despite the increasing demand for electric vehicles (EVs) [16-17]. The key difficulties and restrictions include:

- **Cost:** One major obstacle to widespread use of electric vehicles is the expense of setting up the necessary charging stations. Costs associated with installing charging stations, such as hardware, labour, and ongoing upkeep, can add up to a sizable sum.
- **Range anxiety:** Many people who drive electric vehicles continue to be concerned about range anxiety, which is the dread of running out of energy while they are behind the wheel. This is due to the limitations of the existing infrastructure for charging, as well as the fact that in some regions there are still insufficient charging stations. This can restrict the range of electric vehicles thus rendering them less suitable for journeys that are long.
- **Grid capacity:** Significant stress on the electrical system can be caused by the installation of EV charging facilities. Especially in regions with low grid capacity, it is possible for power outages or overloads to occur if an excessive number of electric vehicles are charging at the same time [18].
- **Interoperability:** The many electric vehicle manufacturers and operators of charging stations all utilise their own unique protocols and charging connectors for the electric vehicles they produce. Due to the lack of standardization, it may be challenging for EV drivers to locate charging stations that are compatible.
- **Planning and zoning regulations:** The implementation of electric vehicle charging infrastructure may potentially encounter resistance from regional planning and zoning restrictions. This may involve limitations on the locations where charging stations may be put in place or the kinds of charging stations that may be employed.
- **Maintenance and repair:** The upkeep and repair of the infrastructure used for charging electric vehicles might also be difficult. Because this technology is still in its early stages, there might not be a large pool of qualified technicians available to fix or maintain the equipment.
- **Environmental impact:** There may be serious environmental consequences associated with the manufacture and eventual disposal of EV charging infrastructure components. This includes making parts for charging stations, like batteries and connections, and getting rid of parts that are no longer useful.

In general, these obstacles and restrictions need to be overcome in order to encourage the broad adoption of electric vehicles and charging infrastructure for electric vehicles. To accomplish this goal, industry stakeholders, government, and other important parties in the electric vehicle ecosystem will need to work together. Investing in research and development, standardizing charging connectors and protocols, and offering financial incentives for the installation of electric vehicle charging infrastructure in places that are currently underserved are all potential solutions [16].

CONCLUSION

In conclusion, the future of electric vehicles is undeniably promising, driven by advancements in technology and an expanding network of charging infrastructure. This paper has provided a comprehensive analysis of the current state of EV charging infrastructure, highlighting the importance of technical enhancements like intelligent charging systems, communication networks, and coordinated charging approaches. While significant progress has been made, challenges such as investment needs, standardization issues, and limited driving ranges for some EVs still persist.

However, the journey towards a cleaner and more sustainable transportation system continues to evolve. Exciting opportunities on the horizon, including smart charging, vehicle-to-grid integration, and the use of renewable energy sources, hold the key to overcoming these obstacles. Collaboration between policymakers, industry professionals, and scholars will be instrumental in realizing the full potential of EVs and their charging infrastructure. As we look ahead, it is crucial to maintain our commitment to investing in charging facilities, advancing technology, and supporting policy changes. This paper serves as a valuable resource for all stakeholders interested in shaping the future of sustainable and efficient transportation. Together, we can drive the transformation towards a greener, more accessible, and energy-efficient transportation ecosystem.

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