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Review

Analysis of Electric Vehicles with an Economic Perspective for the Future Electric Market

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Abstract: The automotive industry is marching towards cleaner energy in the impending future. The need for cleaner energy is promoted by the government to a large degree in the global market in order to reduce pollution. Automobiles contribute to an upper scale in regard to the level of pollution in the environment. For cleaner energy in automobiles, the industry needs to be revolutionized in all needed ways to a massive extent. The industry has to move from the traditional internal combustion engine, for which the main sources of energy are nonrenewable sources, to alternative methods and sources of energy. The automotive industry is now focusing on electric vehicles, and more research is being highlighted from vehicle manufacturers to find solutions for the problems faced in the field of electrification. Therefore, to accomplish full electrification, there is a long way to go, and this also requires a change in the existing infrastructure in addition to many innovations in the fields of infrastructure and grid connectively as well as the economic impacts of electric vehicles in society. In this work, an analysis of the electric vehicle market with the economic impacts of electric vehicles is studied. This therefore requires the transformation of the automotive industry.

Keywords: electric vehicles; electric grids; renewable energy; economic impact

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1. Introduction

Across the globe, there is a complete change debouching towards cleaner energy in order to reduce greenhouse gas emissions by a large degree. Greenhouse gas emissions are mainly from industries, power plants that use nonrenewable energy [1–8] sources, and automobiles that also use nonrenewable energy [9–12]. Industries have to move from the usage of nonrenewable sources of energy to renewable sources [13–22]. Most passenger and commercial vehicles now uses the internal combustion engine (ICE), and the main sources of energy that power an ICE are nonrenewable. Therefore, if the automotive industry has to move towards renewable energy sources, various transformations are involved. The existing ICE [22–26] has to be changed to reduce carbon emissions for a green environment at the global level. An alternate source of energy that can power a vehicle is the electricity stored in a battery array. Electric vehicles (EVs) are now the transformation in the automotive industry that focuses on cleaner energy. Alternatively, plug-in hybrid electric vehicles [27–35] are suggested as a feasible solution to increase the fuel economy; however, they will make a major impact on the energy demand on the power grid [36]. Thereby, only changing the automotive industry to more electric vehicles is not enough for more electrification.

There are many targets that the electric vehicle industry [37–43] is facing in the present situation for the future electric market. Still, many technical and nontechnical barriers slow down the growth of the EV market [44–48] globally. When compared to ICE vehicles, EVs are moderately expensive; additionally, EVs are considered as unsafe due to many unwanted incidents that have happened in recent years. The present EVs have limitations on their drive ranges, but ICE vehicles [49–53] have managed to run for longer distances. In addition, EVs' [36,54–57] maximum speeds of operation are restricted when compared to ICE vehicles [58]. The existing ICE is powered by nonrenewable energy sources, and as the fuel is low refilling is faster and a higher drive range can be achieved. Gas stations are easily accessible on both extensive and small routes, making refilling faster. A full refilling of a passenger vehicle takes a maximum of 5–10 min. However, for electric vehicles, once the battery charge is low it needs to be recharged. The charging will also take more time. Once a battery is low, fully charging it takes hours. Additionally, for recharging EVs, as with a fuel station, recharging stations have to be available. Even if there are recharging stations available, since the charging of the battery in an electric vehicle takes more time, there will be more clogging at a charging station. This leads to congestion at charging stations. This problem needs to be addressed to a greater degree.

The charging infrastructure has to be enhanced in the public, home, and work environments. The economic impact of this issue needs to be addressed. Meanwhile, adapting to EVs leads to more dynamic and higher power consumption from the energy distribution system, which may affect the smart grid system designed for residential purposes [55]. Furthermore, charging stations use electric energy that is generated from nonrenewable sources. To have cleaner energy in electric vehicles, the energy that powers the electric vehicles also has to be from renewable or sustainable energy sources. To overcome the problems and to achieve more electrification, these problems need to be addressed. In [53], a fuzzy-based cognitive maps theory is proposed to address charging management issues by implementing a decentralized energy management system that uses multiagents for the smooth charging of EVs. This system resulted in a considerable deduction in the microgrid investment cost. To minimize the EV charging time and efficiently utilize the grid energy, a fuzzy-logic-based energy management approach is introduced by analyzing the location of charging EVs near a substation [54,56,58]. A detailed case study was made in [56] to understand the significant impact of EVs on various elements of a low-voltage power grid, which include a transformer, cable section, and the power quality. Similarly, the impacts of plug-in EV charging on a power grid system, including transformer aging, voltage variation, and load shortage, are analyzed, and a suitable charging control model is proposed for the efficient charging of EVs [57–61]. The main aspect of this work is to accomplish the need for full electrification, the achievement of which is a long way to go in a global market perspective. Therefore, the need for changes in the existing infrastructure with respect to the grid connectivity and economic impact of EVs on society is important. The work exhibits a clear analysis of the electric vehicle market with respect to the economic impact. This indeed requires a transformation of the automotive industry for a longer analysis.

The work in this analysis is structured as follows: Section 2 provides a review of the electric vehicle market as well as the trends in the industry towards electrification, Section 3 provides an analysis and the details of the impacts of electric vehicles, Section 4 discusses renewable energy sources further and reviews the electric grid connectivity, Section 5 provides an analysis of the economic impacts of electric vehicles and the infrastructure, and Section 4 provides details on the economic impacts of electric vehicles with the existing data and trends from the electrification market objective.

2. Electric Vehicle Market

The electric vehicle market has shown an increasing trend in the past few years [2]. There was an increase in the sales of electric vehicles in the past few years [45]. One of the major reasons for this increase in the trend is the evolution of the world to the electrification of vehicles. Modern electric vehicles range from EVs with a lower power or torque to EVs with a high speed; Tesla vehicles, for example. The drive range of the vehicles also mostly ranges from 200 to 300 m. A pictorial graph showing the different ranges of electric vehicles is exhibited in Figure 1.

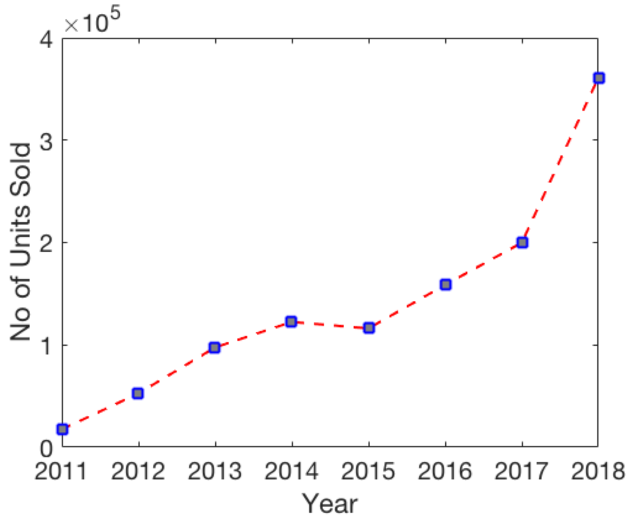

Figure 1. Electric vehicles sold in the US market—economic analysis for the units purchased.

From Figure 1, it is observed that there has been a shift in users from the internal combustion engine to electric vehicles in the past decade. Most of the electric vehicles' sales and usage were for commuting in the city. Therefore, to perform a market analysis of electric vehicles, there is a requirement to classify electric vehicles.

There are many ways to classify electric vehicles, such as based on the electric vehicle type, the usage, and the vehicle size. EVs are purely driven by a battery, and the battery drives the motor of an electric vehicle. The electric vehicle classification is based on electric vehicle technology and battery technology:

- Electric vehicle.
- Hybrid electric vehicle.
- Plug-in hybrid electric vehicle.

A hybrid electric vehicle (HEV) uses a conventional IC engine and a battery array together, and switches between the ICE and battery depending on the demand of the vehicle. Nowadays, HEVs are more common in the automotive industry, due to the fact that their fuel economy has increased [6]. Their drive range is more comparable to that of an IC engine with the same fuel capacity, which is due to the fact that the drive is switched between the engine and the electric drive train.

HEVs require a special drive train with sophisticated drive methodology and software to switch between the IC and battery array drive. Additionally, the cost is increased as they use battery arrays and because the vehicle sizes are large, to accommodate both of the engine methods. Therefore, the increase in size introduces the risk that HEVs are not suitable for all vehicles of a smaller size. This can be more convenient for a vehicle with a bigger size, which has the ability to accommodate both of the engine types. Emissions exist as a problem but are reduced, as the vehicles switch between the IC engine and battery [14]. A comparison of the drive range increase between an IC engine and HEVs is presented in Table 1. In this comparison for analysis, 2019 Toyota Camry and Toyota Camry Hybrid vehicle models are considered as the present trend.

A detailed analysis of the delta increase in the increase between the two vehicles with a market perspective is exhibited in Figure 2.

Table 1. Comparison of HEVs and an IC engine.

Parameter	ICE			HEV		
	Toyota Camry	Audi A3	Honda Accord Sport	Toyota Camry Hybrid	Audi A3 E-Tron	Honda Accord Hybrid Sport
Fuel capacity (liters)	50	50	56	50	54.8	48.4
Fuel efficiency (Kmpl)	17.4	19.2	13.6	22.5	30	18.2

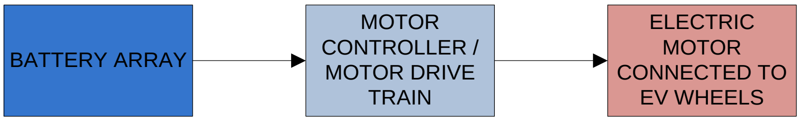

Figure 2. Major components of an electric vehicle.

The main difference is that plug-in HEVs will be connected to the grid through a charging station in order to be charged [3,13]. The main source of the power to a vehicle is an electric motor powered by a battery [4,5,38,46]. It uses the electric motor at all ranges [50]. When the power is reduced and reaches a significantly lower level, the IC engine, which is powered by gasoline, will be activated, and it will act as a generator, powering up the battery, which in turn drives or provides power to the motor [20]. In simple terms, a plug-in electric vehicle is an abstraction of the internal combustion engine, in which the IC engine supplements the battery with power when required. Unlike a hybrid vehicle, in which both the ICE and motor work independently and complement each other, a plug-in EV only has one source of energy. Additionally, it requires advanced infrastructure to recharge the battery. In order to understand the economic analysis of present-day EVs, a study of Toyota Prius Hybrid and Toyota Plug-in Hybrid vehicles is exhibited in Table 2. The fuel efficiency comparison of plug-in hybrid vehicles and hybrid electric vehicles is also given in Figure 3.

Table 2. Comparison of hybrid EVs and plug-in hybrid EVs.

Parameter	Hybrid EV			Plug-In Hybrid EV		
	Toyota Prius	Audi A7 Quattro	BMW 7 Series	Toyota Prius Prime	Audi A7 Quattro	BMW 7 Series
Cost in USD ($)	24,525	73,000	86,800	28,220	75,900	95,900
Fuel efficiency in mpg (miles per gallon)	52	24	19	54	29	22
CO_2 emission level from vehicle (g/Km)	106	48	54	80	40	46

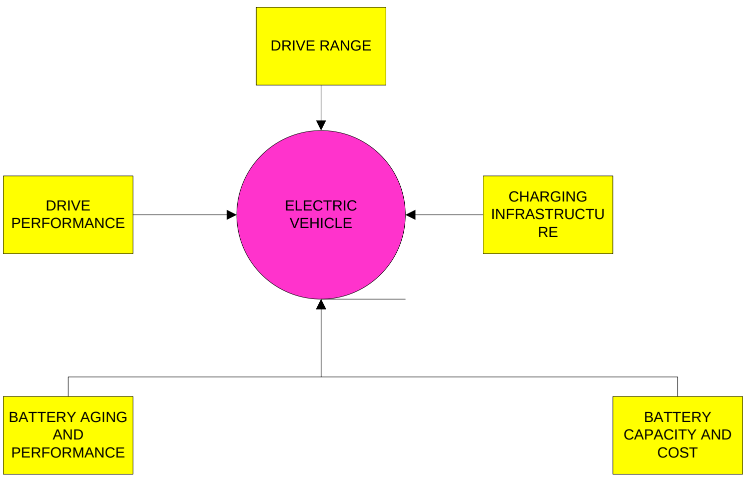

Figure 3. Parameters affecting EV overall performance.

From the above comparison for plug-in hybrid electric vehicles, it can be seen that they are more efficient and produce less CO_2 than hybrid electric vehicles. However, the costs of the vehicles are higher than those of hybrid electric vehicles, since the battery is more expensive and the drive train is also expensive. Additionally, the grid connectivity of plug-in electric vehicles is required, so the drive range of these vehicles poses a major problem. This is also a parameter that needs to be considered in electric vehicles, which is vividly explained in the sections below as a comparative analysis with the market.

There are also electric vehicles called pure electric vehicles, which only use a battery to power the motor. There are no other sources of energy for electric vehicles. The major components of electric vehicles are provided in Figure 2 [8,9].

One of the major components that decides the efficiency of an electric vehicle is the battery used in a vehicle. Depending on the capacity of the battery used, the drive range of an electric vehicle is calculated. Additionally, an electric vehicle's cost factor also depends on the battery capacity [16,19]. The different types of batteries used in electric vehicles include lead–acid batteries, nickel metal hydride batteries, and lithium-ion batteries. The storage capacity, the state of charge, and the rechargeable cycle vary depending on the type of battery being used. As the battery capacity increases, the cost and drive range increase. A comparison of present-day electric vehicles' battery capacity, price, and drive range is given in Table 3.

Table 3. Comparison of electric vehicles' different parameters.

Model	Battery Capacity (kwh)	Drive Range (km)	Top Speed (kmh)	Price USD (EUR)
Audi e-tron	95	402	199	69,975
BMW i3	42.2	246	149	41,582
Chevrolet Bolt EV	60	383	144	34,258
Fiat 500 e	24	135	136	30,866
Tesla Model X	100	465	249	128,163
VW e-Golf	35.8	201	149	29,837
Nissan LEAF	40	241	144	28,055
Jaguar iPACE	90	376	199	65,017
Kia Soul EV	30	176	-	31,760

Figure 4 shows details about the comparison of battery charge, range, and different parameters by comparing different electric vehicles in the market, respectively. From the vehicle models and ranges available, if we derive various parameters and correlations we can infer that as the vehicle battery capacity increases the drive range increases, as does the cost of a vehicle [29]. Therefore, the battery is one of the important components that determine the cost and drive range parameters of an electric vehicle.

From the above details, we can come to some conclusion regarding the different parameters that affect electric vehicles' range, price, and performance, shown in Equation (1):

$$EV \left\{ \begin{array}{c} price \\ speed \\ range \end{array} \right\} \alpha \; Battery\, Capacity \tag{1}$$

The above observation provides us with clear information on the fact that the parameters affecting electric vehicles are mostly associated with the batteries used in them. Another major factor of electric vehicles is the weights of the vehicles. As the battery capacity increases so does the weight. If the weight increases then aspects of vehicle performance, such as drive range and speed, decrease. For example, for increasing the drive range, if we increase the battery capacity then the additional factors that need to be considered include the weight as well as the space required to accommodate the additional battery array:

$$EV\ Range \propto Weight\ of\ the\ battery \tag{2}$$

$$EV\ Weight \propto 1/EV\ Range \tag{3}$$

$$EV\ Weight \propto 1/EV\ Efficiency \tag{4}$$

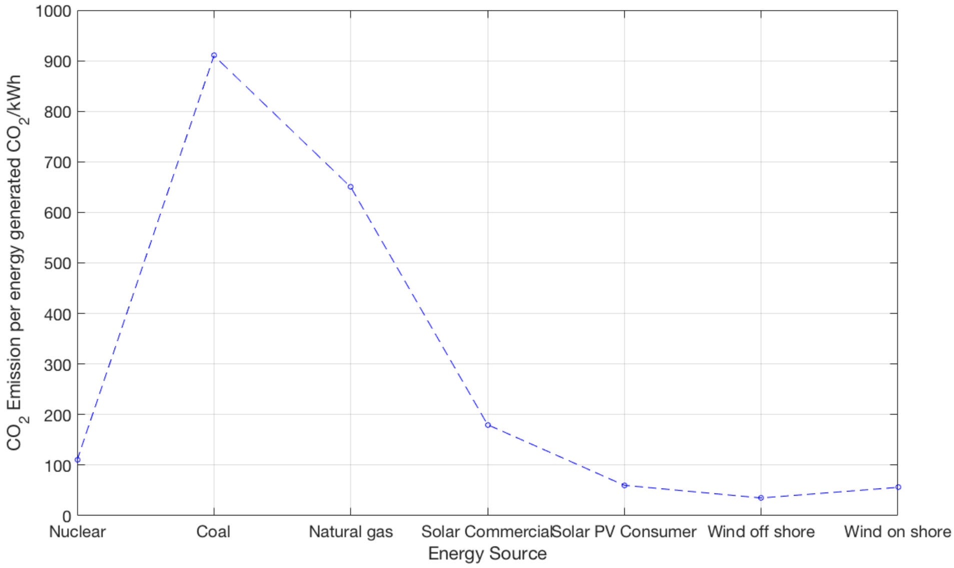

Figure 4. CO_2/kWh generated from different energy sources.

The conclusion is that an optimum rating of the battery needs to be selected. The different parameters that affect the electric vehicle are shown in Figure 3. All of the above *EV* parameters play crucial roles in the electric vehicles that are considered by customers.

Economic Impact of Electric Vehicles

In this section, details on the socioeconomic impacts of the major parameters that influence the electric vehicle market and towards electrification are studied with a detailed analysis. An overview of the major parameters that affect the EV is provided in Figure 5 [24]. The major factor is the drive range of *EV*s, which has to be addressed in the future market at a larger scale. Table 4 exhibits the availability of different electric vehicles in the market. From the analysis, we can see that the maximum drive range that can be covered with a fully charged battery is 293 km. This can be well-suited to city driving conditions, but for long-distance travel between cities or towns this drive range seems to be lesser or skimpy.

Table 4. ICE vs. BEV.

Parameter	ICE			BEV		
	VW Golf R	**Hyundai Venue**	**Nissan Altima**	**VW e-Golf**	**Hyundai Kona**	**Nissan Leaf**
Fuel economy in mpg (miles per gallon)	30	23	28	111	120	114
Range in km	702	1066	630	300	452	226
CO_2 emissions in g/km	163	170	300	0	0	0
Price in USD ($)	31,315	18,900	24,900	38,895	21,150	27,400

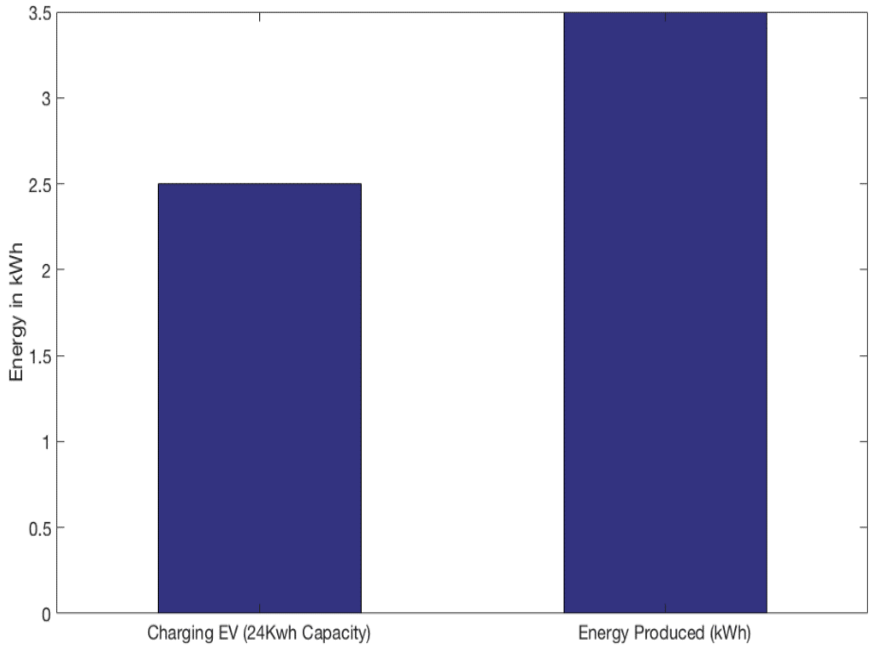

Figure 5. Comparison of the energy produced by a solar PV on a household roof top and the power required to power up a battery.

As an example for this study, the VW Golf is chosen so that the vehicle parameters are compared against the same vehicle conditions in an IC engine and in battery EVs. Figure 6 depicts a different vehicle parameters comparison of an IC engine and EV from the same manufacturer (Volkswagen (VW)). Apart from the drive range, in the other categories the electric vehicle outperforms the internal combustion engine. However, the only advantage of the internal combustion engine is the drive range, which is 133% more than that of the electric vehicle. Another factor to consider for the EV is its CO_2 emissions, which are zero, compared to the ICE's, which are an important feature for a green environment, as there is a reduction in greenhouse gases. From a government perspective this is a crucial factor, as no CO_2 emissions means that there is less impact on the environment and climatic changes, which in turn makes the environment cleaner. Another critical issue for the government is to steer the market [47,48] towards full electrification and to make electric vehicles the first choice for consumers; it is very important to make electric vehicle charging station infrastructure accessible to consumers when required, in a similar manner to gasoline stations. Without good infrastructure, electrification in the field of electric vehicles is rather impossible, as is making the EV market more attractive for a future positive market approach.

The major infrastructure that needs to be addressed is vehicle charging station availability. For IC engines, a vehicle refueling station is available on an average of 10 m, while on the contrary, for EVs a charging station is available in 3.8 m, which is comparatively larger [10]. In order to achieve electrification, the government has to provide better charging infrastructure to accommodate the electric vehicle charging traffic in public places. As the number of electric vehicles on the road increases, so does the need for charging stations. Vehicle manufacturers are also aiming to install more charging stations to sell vehicles and create more electrification. As an example, Tesla vehicles are considered for a market analysis: Tesla has many charging stations in the USA, and some of the refueling stations are yet to be deployed. Tesla is claiming that, by using their super charging system, a battery can be charged by 50 percent and 100 percent in 30 min and 75 min, respectively. Most of the charging stations will have a maximum of 10 chargers, and vehicles have to wait for at least 30 min to be charged. This leads to demand-side management and congestion management for electric vehicles. For the charging stations, the energy or electricity has to be supplied from the grid, and with the smart innovations and methods in grid technology, the charging stations can be part of the grid for better usage. As the charging stations of EVs require maintenance at different levels, consider non-networked Level 1 and 2 stations, where any individual or standalone station supposedly requires less maintenance over a long course of time. At Level 1 charging units, which are found to be residences, maintenance is found to be less common, and they do not require many repairs. Non-networked Level 2 maintenance is required where there are larger units with more larger components. Malfunctions of the component maintenance have to be maintained. Many factors influence the condition of an EV unit as well as the need for repair over its lifetime. These factors involve the frequency of use and EV charger repairs over its lifetime.

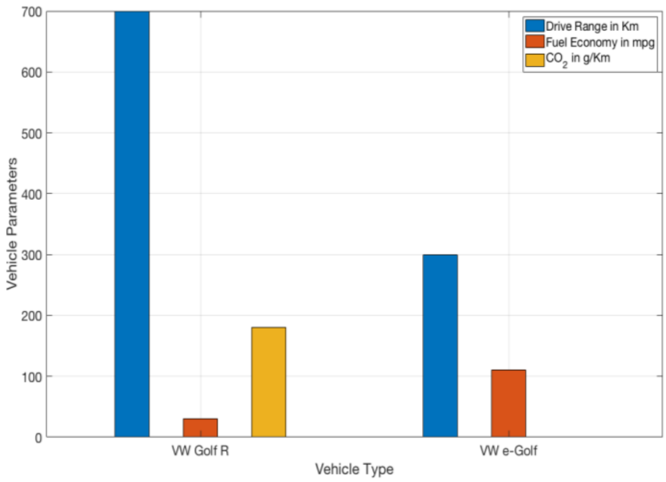

Figure 6. Different vehicle parameters comparison of an internal combustion engine and an electric vehicle from the same manufacturer (Volkswagen (VW)).

3. Renewable Energy Impact on Electric Mobility

The main advantage of electric vehicles is the CO_2 emissions. However, a periodic recharge of the battery is required. For recharging the battery, electricity is required. There are many sources of electrical energy. The energy source can be from renewable sources and nonrenewable resources [21–23]. From the renewable energy sources, the CO_2 emissions are low or close to 0 mg. Some of the sources of renewable energy are solar, wind, hydroelectric, etc. The nonrenewable energy sources include energy generated from coal or diesel, as well as nuclear energy. The nonrenewable energy sources emit CO_2 at considerable levels, which depend upon the power generation unit. In order for the environmental emissions to be lower, the greenhouse gas emissions from a vehicle need to be lower. This also implies that a vehicle's battery needs to be powered by clean energy, so that the greenhouse emission levels are made as low as possible, hence making electric vehicles more ecofriendly. A comparison of the emissions from renewable energy and nonrenewable energy sources is given in Figure 4.

From the comparison, we can see that renewable energy sources are the ones that are suitable for the environment as well as for clean energy sources for electric vehicles [23]. As more and more electrification is trending, renewable energy sources also need to be increased to meet the electrification demand of vehicles to be more environmentally friendly [44]. One of the hurdles of renewable energy sources is the consistent availability of natural resources throughout a year. For example, consider solar power; the source of this energy is the Sun/light energy [25,26]. Light energy is not always consistent, e.g., depending upon the seasons the light intensity may vary, which in turn will reduce the energy produced through light sources. Some of the data on the energy produced by solar energy over a period of time are given below.

Climatic changes impact electricity production. For example, if in a year there is more rain, then the exposure of a solar cell to the light will be less, and hence the energy produced will also change [25,26]. For electric vehicles to be charged, the clean energy required to power up the battery needs to be recharged when it is required, and energy needs to be constantly supplied to the system. This is applicable for the energy produced by all renewable sources. The environment has an impact on the energy production and availability:

$$\textit{Energy Generation } (E_g) \propto \textit{Environmental Factors } (E_f) \tag{5}$$

An analysis of the energy produced by different energy sources in addition to a comparison are given below. For charging an electric vehicle with clean energy, there are many ways that are followed. Many of the companies around the world are using solar cell farms to power vehicle that is used in their organizations [27]. Solar energy can be implemented easily in the building of commercial houses or industrial establishments. The main advantage of solar energy over other renewable sources is the ease of installation of solar energy in addition to the simplicity and the ease of implementation; using a simple inverter in a normal house, we can generate the required energy. Information on the energy generated by solar energy in a household is given in Figure 5.

The solar energy generated in a household can be connected to the grid or may not be connected to the grid [27]. The solar energy is stored in the household in a battery and can be used for the household's electric needs.

As explored by the authors of [15,30], a similar process can also be used for storing energy for electric vehicles' batteries. A simple setup of such a system is shown in Figure 7 [42]. In the system, the ease of implementation is simple and cost-effective compared to other renewable energy sources. The components required for this type of system are also very simple and easily available in the market. The ease of installation is reasonable and can be done quickly. The roof of the house is fitted with a solar panel to obtain maximum exposure to the sun to harvest solar energy. The generated energy is stored in the battery.

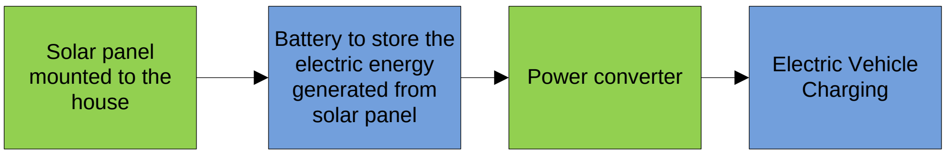

Figure 7. Solar panel and charging system for household purposes.

An inverter is used to step-up the battery power to supply the charging for the electric vehicle. One of the problems that can be faced is shadowing over the panel from adjacent building and trees, which reduces the consistency of the power produced from the solar panel and affects its production. There are various research and techniques being followed and worked on to avoid this and come up with a solution to the problems addressed.

As shown by the authors of [33,39], a solar array is also used in many organizations to power up their business needs and provide the employees of their organization with the ability to charge their vehicles while they are at work. This will provide a good advantage to consumers: to charge their electric vehicles while they are working. This type of setup can be connected to the grid and provide power to different charging units to charge vehicles, or can not be connected to the grid. In this type of setup, a small microgrid within the organization is implemented for the power distribution and demand-side management of the charging stations [17,30]. An overview of an organizational solar charging system is shown in Figure 8.

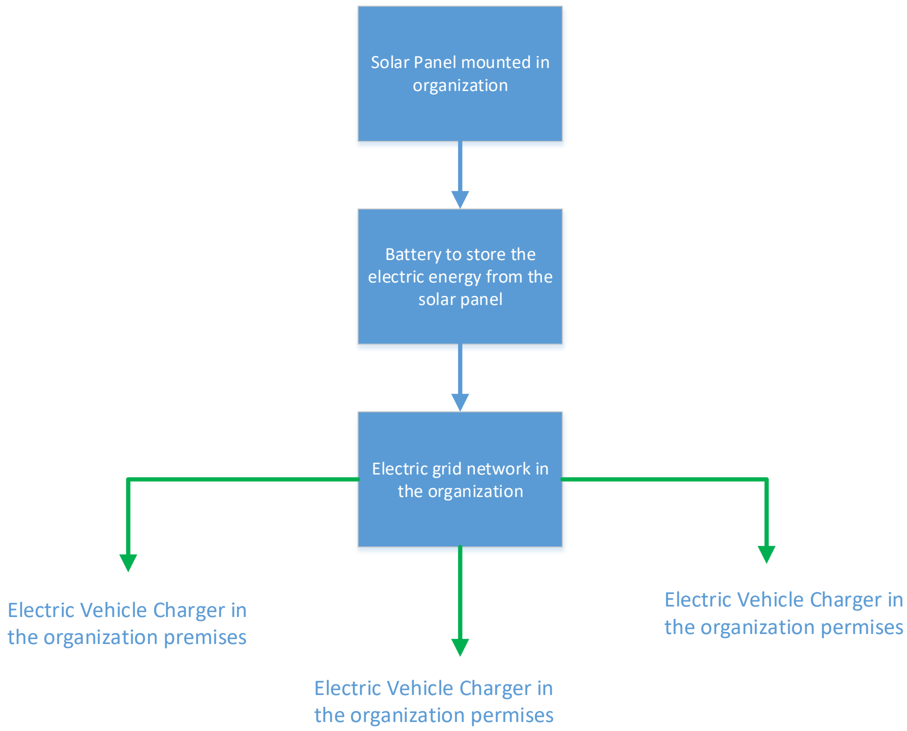

Figure 8. Solar panel and charging system for household purposes.

In an organization, it not only provides power to electric vehicles but also powers the needs of the different utility requirements in an organizational building. Hence, the greenhouse gas emissions are reduced from both the utility part and also from encouraging employees to use cleaner energy for commuting purposes [18,31]. The grid system is used within the organization to manage the power requirements of the building, and is not connected to the large electrical grid of the area.

The other type of energy source is the renewable energy connected to the smart grids and delivered to the electric vehicle charging units. Here, the other renewable energy sources are connected where the installation in all of the parts is not feasible. For example, wind turbines cannot be installed in every place, because wind energy harvesting requires the study of the wind flow in the area and whether it can deliver the power output. This is also applicable to hydroelectric power stations which are usually suited in mountain regions where the water current is high, which is ideal for harvesting energy from water. The energy generated from these sources has to be given to households and also to electric vehicle charging units, and hence the smart grids play an important role here.

As shown by the authors of [32,41], the main components of a smart grid include a generator, where the power is generated, and a consumer, where the power or energy is required. The grid forms an intermediate unit between the generator and consumer. Grid technology is improving day to day, with new algorithms and innovative techniques to determine the load at a particular date. Historical data, along with high processors and data analytics tools, help to predict the energy demand of a region at a particular hour in a particular month and day of the year [31,32,35]. This information and data help a smart grid to optimize the power flow, improve the power loss, and provide the required power to a household when needed. An overview of a smart grid system is given in Figure 9.

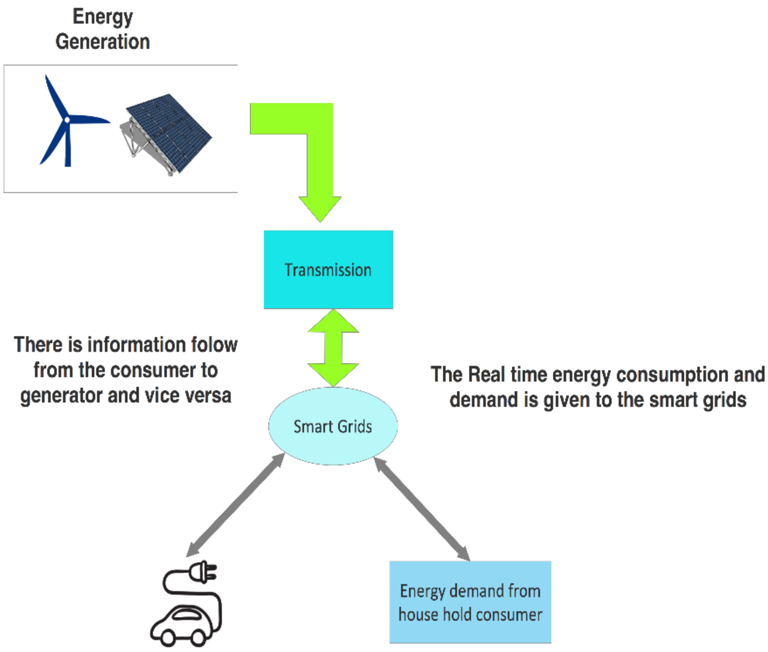

Figure 9. Overview of a smart grid for electric vehicle demand management.

With an electric vehicle in a smart grid and the renewable energy connected to the grid with intelligent algorithms, the energy consumed by a battery for charging can also be made clean [41]. In smart grids, multiple sources contribute to the energy pool. With advanced analytical tools and algorithms, as well as with deep learning methods, the past data can be used to predict the energy demand in a particular period of the day [37,43,49]. This helps the grid to optimize the energy supply to household appliances and electric vehicle charging systems. The advantages of using the grid system are the optimization of the energy flow and the reduction in the cost consumption; thus, increasing consumer usage and contributions towards electrification can be achieved.

4. Impact on the EV Infrastructure

To achieve more and more electrification, the infrastructure for electric vehicle usage needs to be addressed. One of the major challenges faced in the electric vehicle industry is electric charging station infrastructure availability [12,24]. As per the data available, electric vehicle usage in cities is more than that of rural areas. One of the reasons why there is more and more electric vehicle usage in cities is due to the better infrastructure for electric vehicle charging stations. In many cities, more charging infrastructure is available, which allows the consumers in a city area to use more electric vehicles [34,35]. Furthermore, the charging stations are usually owned by the vehicle manufactures. The vehicle manufactures are installing more charging stations to promote the sales of their electric vehicles. This is a huge investment from the vehicle manufactures, as they are spending more on the development of the infrastructure, whereas in a traditional internal combustion engine the vehicle is manufactured by the vehicle manufactures and the fuel is managed by oil refinery companies, so the infrastructure is well-established and very well-accessible. To increase the infrastructure needs and to achieve 100 percentage electrification, there should be more charging stations available at all places, so that consumers will be using them effectively and moving towards more electrification. A statistical analysis of the available pumps to the number of vehicles in the USA is given in Table 5, and Figure 10 shows the percentage of the internal combustion engines to gas filling stations availability in addition to the electric vehicles to recharging stations availability.

Table 5. Charging and refueling stations.

Type of Vehicle	Approximate No. of Vehicles in 1000 Units	Gas Station or Charging Station Availability (Value in 1000 Units)
Internal combustion Engine	270,000	1200
Electric vehicles	794	484

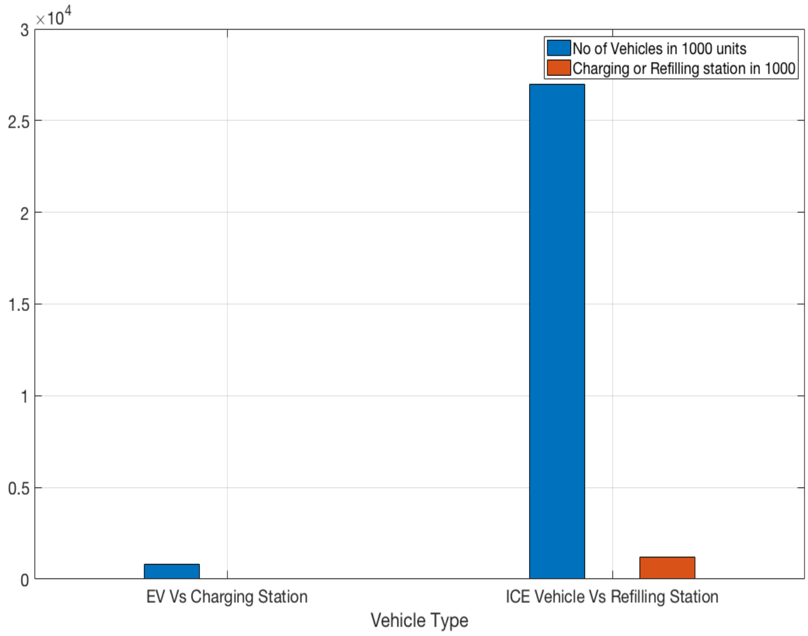

Figure 10. Comparison of internal combustion engines and refueling stations with electric vehicles and charging stations.

The percentage of ICE vehicles to electric vehicles in the USA, as of 2018, is plotted, and from the information we can see that 97 percent of the vehicles used are internal combustion engines and 96 percent of the total refueling stations available are gasoline-based, while only 4 percent of the stations are for electric vehicles.

Another important problem that needs to be addressed is the maintenance of the charging stations. The charging stations consist of many electrical and electronic components. The charging stations have to undergo all climatic conditions, electric vehicle usage, and ageing of the devices. In addition to this, a vehicle sometimes takes longer to achieve full charging. For a Tesla Model X electric vehicle, with fast charging capability, full charging can be achieved within 45 min. This is in comparison to an internal combustion engine, which takes 5–10 min for a full refueling. The amount of charging infrastructure has to increase as the number of electric vehicles increases in the market.

In a gas fueling station, the vehicles follow a queuing system for refueling and the wait time is acceptable, as servicing a vehicle takes about 10 min in maximum likelihood conditions. Therefore, even in a gas station where vehicles are piling up, there will not be much of a wait time. From the statistics presented in the table, we can see that the ratio of the number of vehicles to the charging stations for electric vehicles is 16, i.e., a charging station can accumulate a maximum of 16 vehicles at a time [51].

In contrast to this in electric vehicles, since the charging time is longer, if more vehicles are approaching then this leads to congestion management, and the demand for electric power in the charging station becomes more.

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

5. Analysis of Economic Impact with the EV Market

From all the above facts and Figures on electric vehicles, we will discuss and review the economic impacts of electric vehicles on society [29]. The statistics from the US government on the greenhouse gas CO_2 emission levels, as of 2016, show 65,111 million metric tons of CO_2. Among these, 28 percent is from the transportation segment. The above statistics and percentage of emissions from the automotive sector are given in Figure 11. The CO_2 emissions affect the environmental and climatic conditions, which, if not checked, will cause a paradigm shift in the environmental conditions and increase global warming. Therefore, it is important for governments to take measures to reduce it and propose alternate sources that reduce greenhouse gas emissions. With respect to the transportation industry, the alternate fuel is through a battery, which means the electrification of the automobile industry.

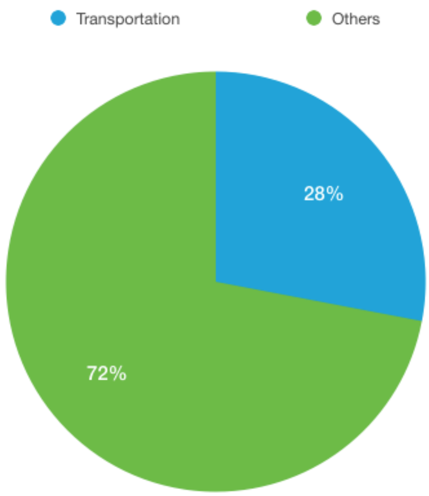

Figure 11. CO_2 emissions from different sectors, from the USA Environmental Protection Agency.

In the above sections, the hurdles faced by the automobile industry for full electrification were explained. Electrification is linked with the economy of a country or region. Electric vehicles are now available or seen in countries which are more developed, and the infrastructure availability is well-established. From the statistics of Tesla, we can see that more charging stations in the USA are available to promote the vehicle brand. The government should also plan charging stations and introduce subsidies for electric vehicles. Electric vehicles are cheaper compared to internal combustion engines, and are easy to maintain. Additionally, there are government subsidies for electric vehicles. An analysis of various internal combustion engine and electric vehicle cost parameters helps us to better understand the economic impact of the usage of electric vehicles, and this is shown in Table 6. From the table, some analysis can be performed. The electric vehicles seem to be expensive, but there are tax reductions and subsidiaries from the government to promote the zero-emission vehicles.

Table 6. Economic analysis of gasoline vehicles and electric vehicles.

Price Parameters	ICE Vehicles	Electric Vehicles
Cost in USD	23,245	29,500
Fuel/electric cost over 5 years in USD	8218	2818
US Govt Tax credit in USD	0	−4543
NY City Clean Rebate in USD	0	−1100
Average maintenance cost in the first 5 years in USD	355	120
Total cost over 5 years period in USD	31,818	26,795

Comparing the fuel costs over a period of 5 years., with statistical data on the usage of electric vehicle batteries over 5 years., the fuel cost and electric cost comparison results show that electric vehicles cost 75 percent less compared to gasoline vehicles. The maintenance of electric vehicles and internal combustion engines: Internal combustion engines require periodic maintenance, which adds to the cost of the vehicle over time. Internal combustion engines require servicing at least once yearly, to change the engine oil and replace parts that are worn out, as well as other aspects that have to be changed over a period of time as part of the standard maintenance procedure. For electric vehicles, however, the maintenance costs are lower, and can be approximately zero. Because the main source of energy is the battery, the maintenance of the vehicle can be much less extensive compared to that of an internal combustion engine.

However, the battery also has a lifetime, and due to the charging and recharging of the electric vehicle battery, the battery parameters degrade over time, and this leads to performance and range loss. In an electric vehicle, the battery pack is a huge assembly of battery arrays. Any change in the battery necessitates a complete replacement. This replacement causes some cost, and if it is covered by a warranty period then it costs less. An impact of the battery aging constraint which adds to the maintenance costs of electric vehicles is discussed. Tesla offers 8 years battery warranty and 300–600 charging cycles. The battery life also depends upon the battery charging cycle, and this varies according to the battery design. An estimate of the battery cost of Li-Io over a period of 10 years is shown in Figure 12.

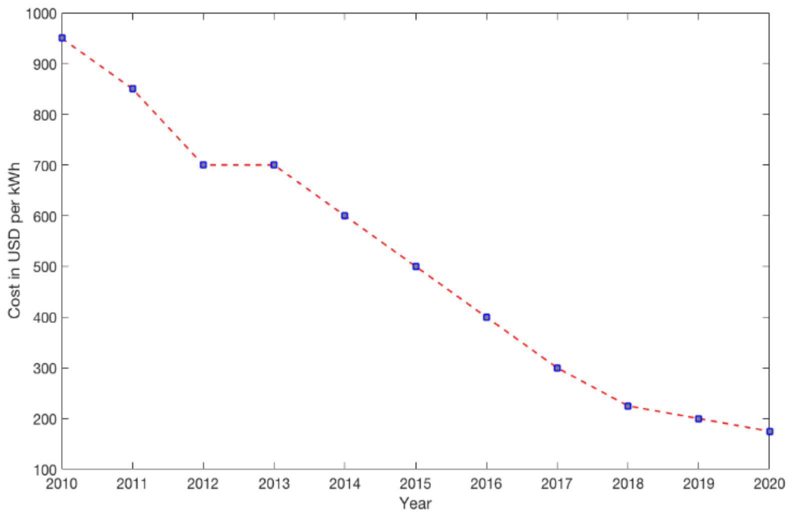

Figure 12. Li-Ion battery cost per kWh over years from 2010.

From the initial data, when the electric vehicle market was beginning to boom, the battery cost was USD 1000 per kWh. With the recent advancements and more research as well as development in the field of electric vehicle battery technology, the cost has been further reduced over time. The other reason for this is as more and more vehicle manufactures are moving towards electric vehicles, and the electric vehicle market is growing over time, the mass production of batteries is increased, and hence the cost of battery production is decreased.

6. Conclusions

In the above work, a review and analysis of electric vehicles from a different perspective are presented. From the work, we can conclude that electric vehicles have a large impact on environmental aspects. Electric vehicles have an advantage over internal combustion engines in the aspects of maintenance cost effectiveness and CO_2 gas emissions. The electric vehicle market has been trending over the last decade, and the recent advancements in the field of smart grids connected to electric vehicle charging stations are offering much more flexibility for electric vehicle consumers to utilize the best advantages of charging stations in a much more cost-effective manner. Another problem that needs to be addressed for full electrification is the improvements in the field of charging infrastructure availability, which deals with congestion management and effective demand-side management. The vehicle to grid (V2G) and vehicle to infrastructure (V2I) areas are also gaining momentum to deal with this situation and provide good infrastructure for electrification for the future. To conclude, organizations and governments across the world are focusing on cleaner transportation and electric vehicles, driving forward for the future with many changes to be adopted by vehicle manufacturers, consumers, and the economy, which help in achieving lower greenhouse gas emissions.

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Nomenclature

ICE	Internal combustion engine
EV	Electric vehicles
HEV	Hybrid electric vehicle
mpg	Miles per gallon
E_g	Energy generation
E_f	Environmental factors

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