

# Investigating the Impact of Electric Vehicle Charging on the Electrical Grid and Understanding Smart Grid Solutions that Can Manage the Variability and Uncertainty of Electric Vehicle Charging Demand

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**Abstract:** The paper studies the mechanical functioning of an electric vehicle and the extent of carbon emissions from it. The necessity of such vehicles in ensuring the sustainability of the environment has now become an absolute necessity. The problem associated with adopting such technology exists, but as demand and research increase, cheaper and more viable options are expected. **Research Question:** The paper would attempt to look at the waveform distortion as a result of electronic vehicle (EV) charging as well as the impact on the voltage capacity of a particular area. What would be the solution to the above issues? Would it be possible to enhance the grid capacity of the system or make a change in the prototype of the batteries and EVs that are being used? These would be some of the questions that would be researched during the paper.

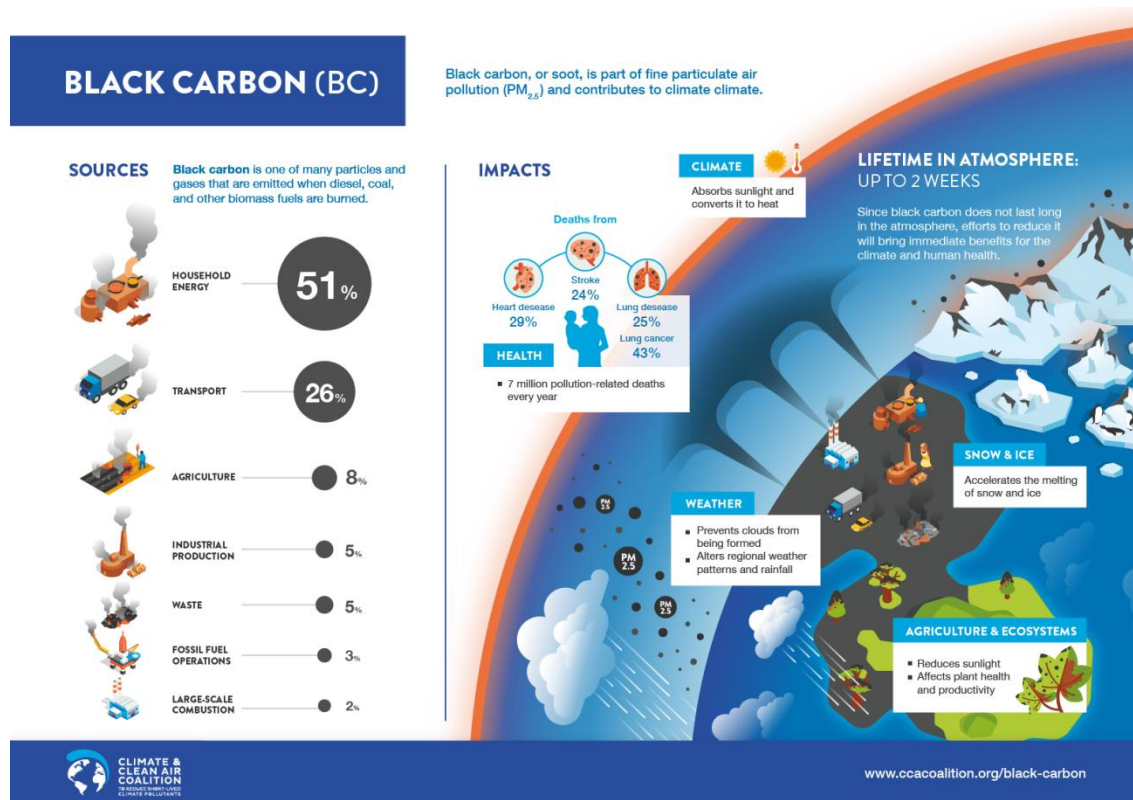
**Keywords:** Electric Vehicles, Electric Grid, Zero Emissions, Battery Management System, Charging Stations, Climate technology

## 1. Introduction

The sudden increase in EVs is due to the realization that this is the only way to save the world from adverse climatic conditions. The imperative need to move to this type of 'fuel' that reduces the adverse impact on climatic conditions has become necessary. Every country is facing unprecedented high temperatures, floods, and droughts.

These have led to the loss of human lives and animals, environmental degradation, and a reduction in the economy's Gross Domestic Product (GDP), to name a few.

Most of this has occurred due to our over-dependence on fossil fuels, which has led to excessive carbon emissions in the atmosphere.



**Figure 1:** Technical Impact of Carbon Emissions in the Atmosphere

Source: [www.ccacoalition.org/black-carbon](http://www.ccacoalition.org/black-carbon)

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The above image indicates the extent of carbon emissions by the transport industry. There has been an attempt in recent years to counter this phenomenon by finding an alternative that would work towards zero emissions. Electric Vehicles have been found to reduce pollution in the atmosphere.

## 2. Definition

All EVs, including plug - in hybrid electric vehicles (PHEVs) and hybrid electric vehicles (HEVs), produce lower tailpipe emissions than conventional vehicles do, and if the vehicle is only running on electricity, then there are zero tailpipe emissions.

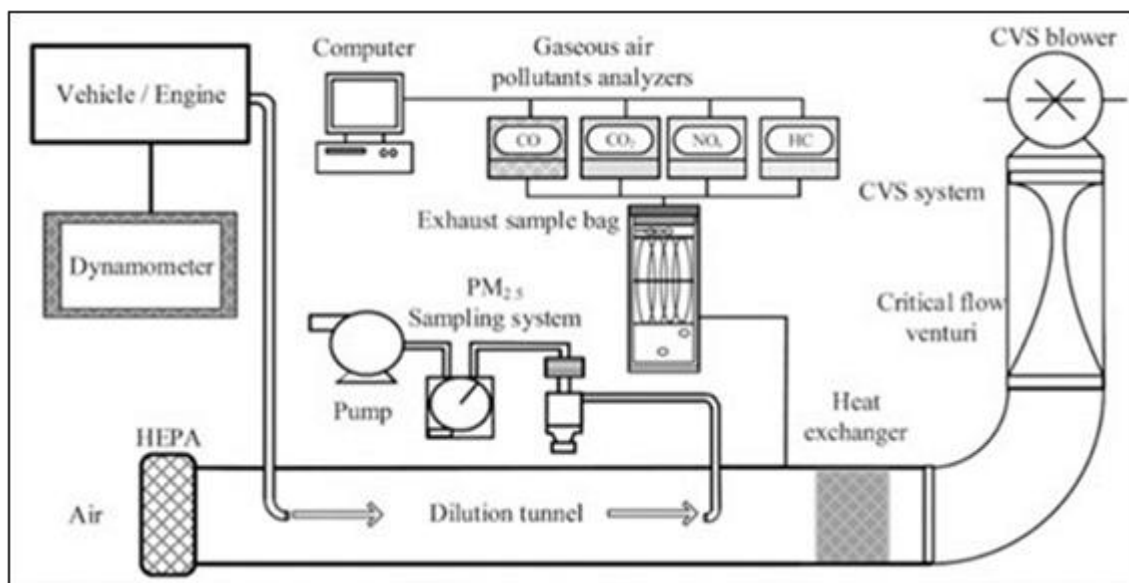


Figure 2: Diagram of Fuel pipe emission

Source: Google image

Tailpipe emission specifies the maximum amount of pollutant allowed in exhaust gases discharged from an internal combustion engine.

Electric vehicles and hydrogen - fueled vehicles do not produce tailpipe emissions.

The types of pollutants emitted from normal combustion cars are greenhouse gas (GHG) emissions and hazardous air pollutants. In recent times, the negative impact of climate change has been witnessed all over the world. In terms of large variations in temperature as well as the melting of ice.

In India, and northern India in particular, the toxic haze that covers the National Capital Region (NCR) during winter is unbearable and extremely harmful for all its citizens, especially the very young and very old. A large portion is attributed to vehicular emissions. It is in this context that the government is extremely keen to move to electric vehicles, which do not emit any emissions.

### 2.1 Electric vehicles (EV)

An electric vehicle uses one or more electric motors for propulsion. Motors are powered by a collector system with electricity from extravehicular sources or batteries. Those powered by electric motors draw electricity from a battery that is capable of being charged from an external source. They have low running costs and are very environmentally friendly, as they use no fossil fuels.

The four types of electric cars can be divided in the following manner:

#### 1) Battery electric vehicles (B - EV)

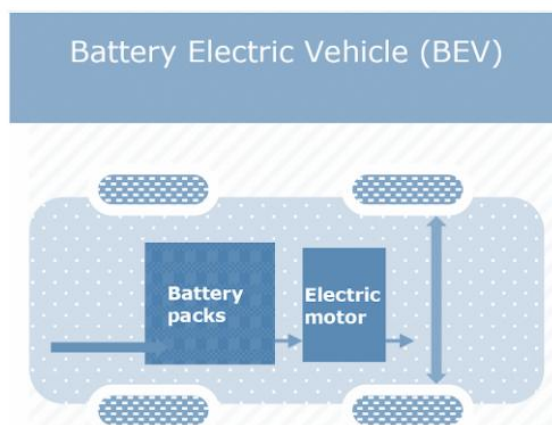


Figure 3: B - EV

Source: GOI, Niti Aayog

#### 2) Hybrid electric vehicles (H - EV)

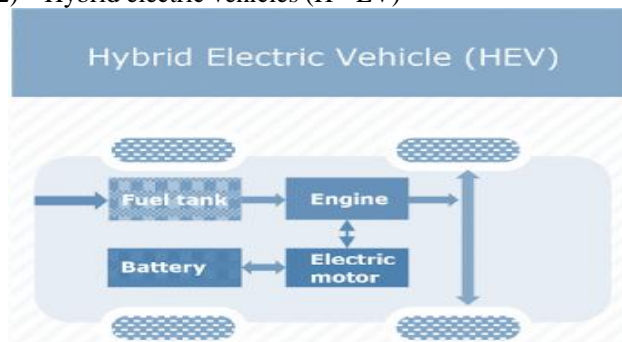
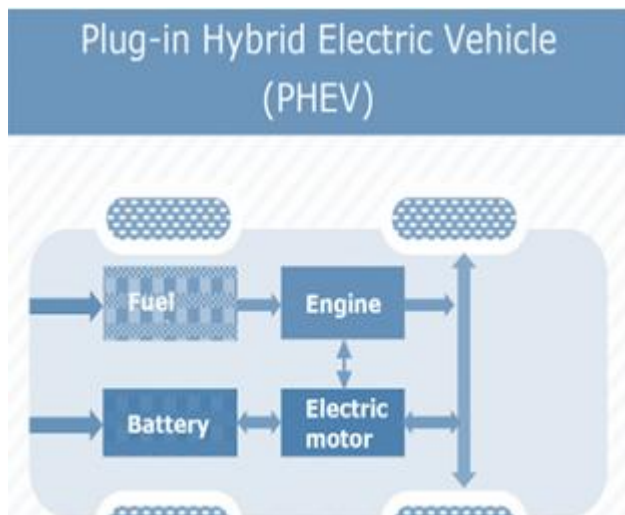


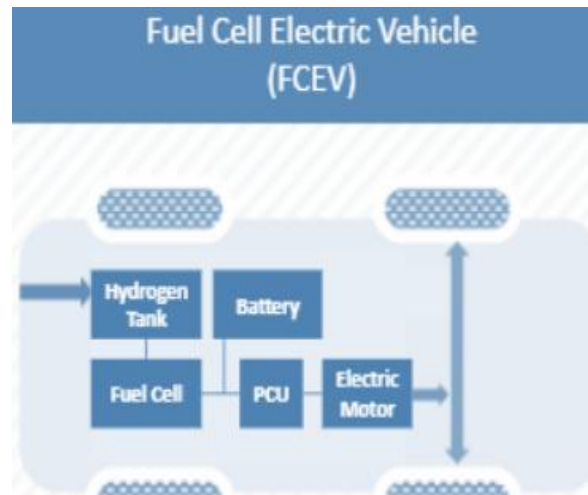
Figure 4: B - EV

Source: GOI, Niti Aayog

3) Plug - in hybrid electric vehicles (PH - EV)



**Figure 5:** B - EV  
Source: GOI, Niti Aayog



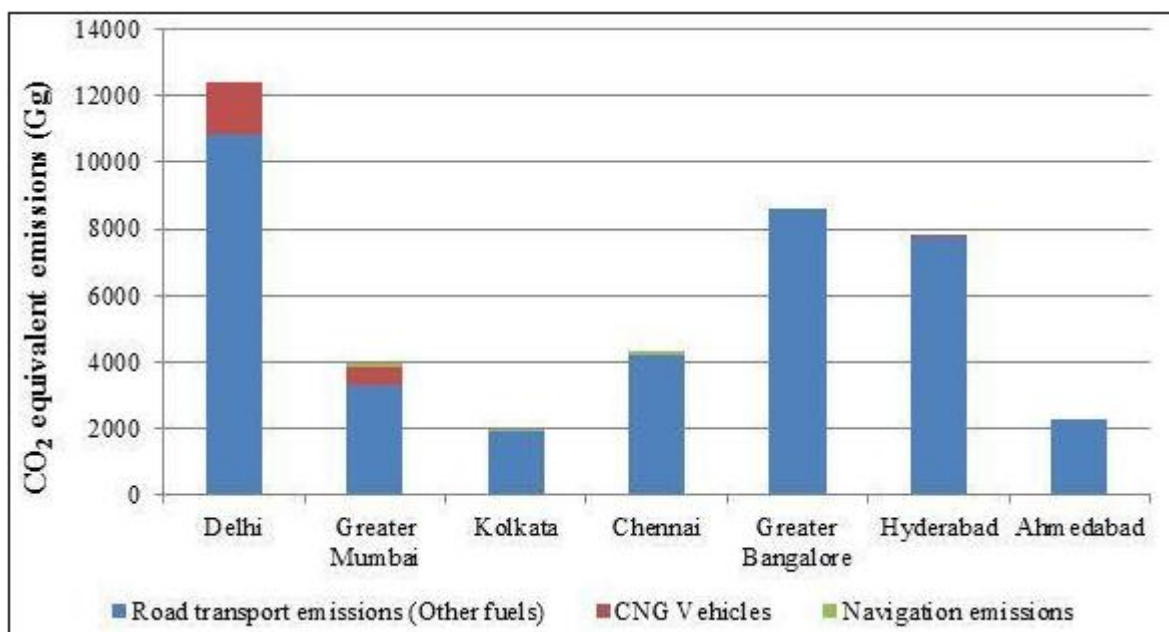
**Figure 6:** B - EV  
Source: GOI, Niti Aayog

The B - EV is fully powered by electricity and is more efficient compared to the H - EV and PH - EV. They are entirely powered by a battery - powered electric drivetrain.

4) Fuel cell electric vehicles (FC - EV)

The charged battery pack provides power to one or more electric motors to run the electric car. Electric vehicles are gaining momentum due to several factors, the major ones being climate change and environmental awareness. The main fundamental component is the battery in these vehicles. The transition was from lead - acid batteries to the present lithium - ion batteries. There are areas of concern concerning the 'charging process' of EVs, 'power control, and battery energy management.

The pollutants that have increased due to the normal use of vehicles in urban areas are nitrogen oxides, carbon monoxide, and sulfur dioxide. Research by the European Union has indicated that the transport sector is responsible for 28% of CO<sub>2</sub> emissions, and road transport accounts for 70% of the transport sector's emissions.



**Figure 7**  
Source: Deccan Herald

## 2.2 Electric Grid

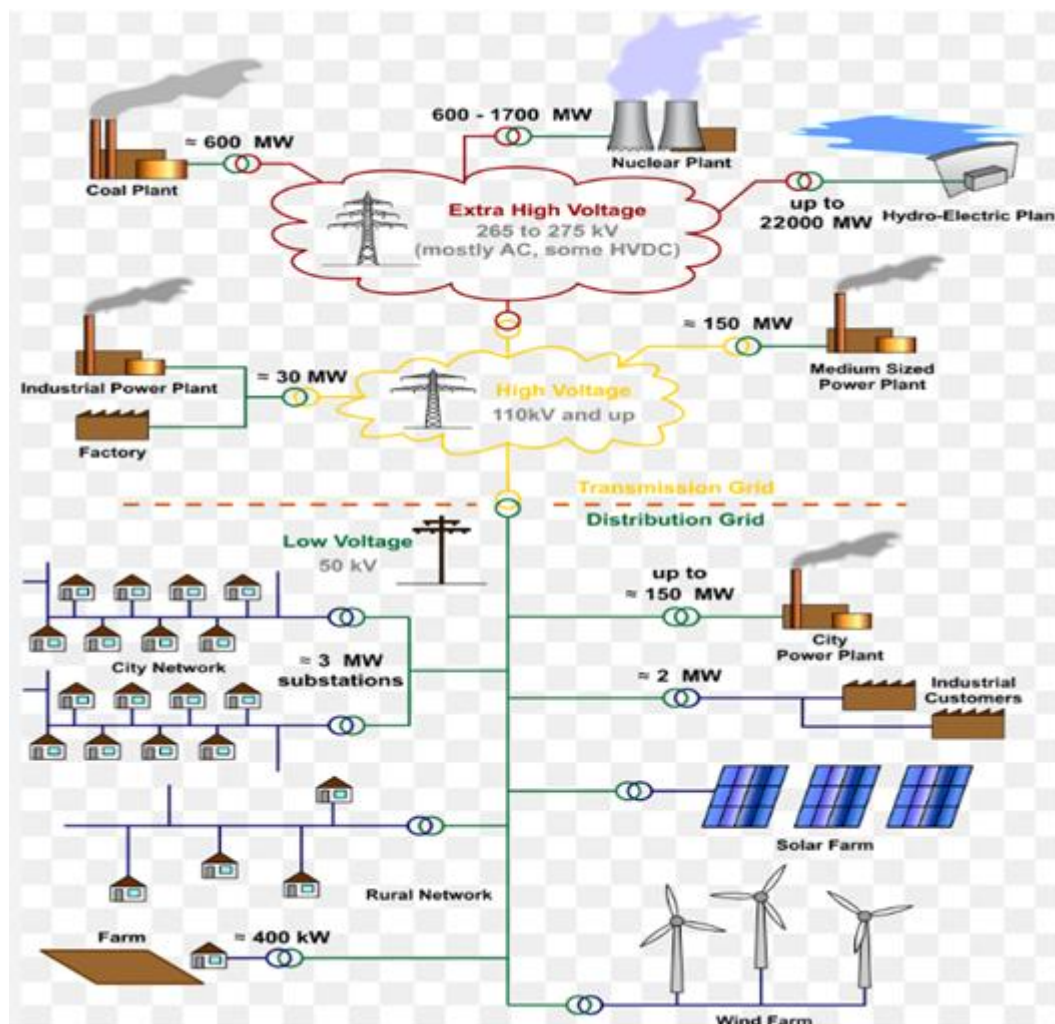
The impacts of electric vehicles on the power grid are:

- 1) Increase in short circuit currents
- 2) Voltage levels are likely to be beyond the standard limits
- 3) Increasing power demand
- 4) Impact on the life span of the equipment

The use of EVs, especially if one uses them for heavier vehicles like buses, is very likely to impact voltage levels, power demand, and active power losses for different penetration levels and power demand scenarios for the

electric vehicle itself. The fact that the charging of these vehicles directly impacts the battery grid. It could affect short - circuit currents and voltage levels. If the power demand is higher, it could impact all types of equipment that runs on the power grid.

Voltage dips are common due to switching actions in the transmission grid, which in turn may impact a large geographic region and thus propagate to the terminals of the electric vehicle charging station. The fact that voltage fluctuates leads to abnormalities concerning the charging station and is likely to reduce the life cycle of the EV batteries.



**Figure 8:** Charging of EV batteries via the grid  
Source: Google Image

## 2.3 Reasons for Increasing the Use of EV

The main reason that there is an increasing need for adopting EVs is the world's concern with climate change. The consensus around the world as a result of various climate change dialogues has led to the agreement that a tax should be imposed on carbon emissions. The system that is being worked out would penalize 'free riders'. A free rider in this case is a country that is not contributing, although it has the means to do so, and is riding on the contributions of others. Developing countries, like India, have not contributed to the problem and have limited means to pay for a 'clean up'. The clean - up here indicates freeing the world from toxic GHG.

The problem that arises is the valuation, and along with this valuation is the solution to the imposition of a 'tax', which in turn would distort the price market for products.

All said and done, EVs are an important means of achieving climate goals. The economic survey of India 2023 has predicted that India's domestic electric market should show a 49% CAGR (compound annual growth rate) between 2022 and 2030, and these are further projected to increase employment and generate jobs. This exponential growth is occurring due to concerns about the growing pollution that the world is facing.

Governments all over the world are encouraging the EV industry through subsidies, and regulations. Consumers are demanding low - emission commutes instead of fossil fuel - driven vehicles, which are endangering the planet.

The earlier EVs had extremely low battery range and low speed, and at that time, concerns concerning the environment were not so important. In the last 10 years, climate change has impacted every country and every citizen. The requirement to protect the planet is becoming more and more important. This has resulted in research towards the manufacturing of cheaper high - range batteries

as well as higher speeds for vehicles running on these batteries. Suddenly, there has been a huge amount of investment, both private and public, which has resulted in successful EV models of cars being developed. Tesla Cars, Lucid Motors, and Rivian are a few of the car manufacturers that have only produced electric vehicles, while several others have now started introducing electric vehicles as a part of their range of vehicles. Most companies in the world today are adding electric vehicles to their traditional ones that use fossil fuels and combustion engines. The need of the hour today is to save the climate and encourage EVs.

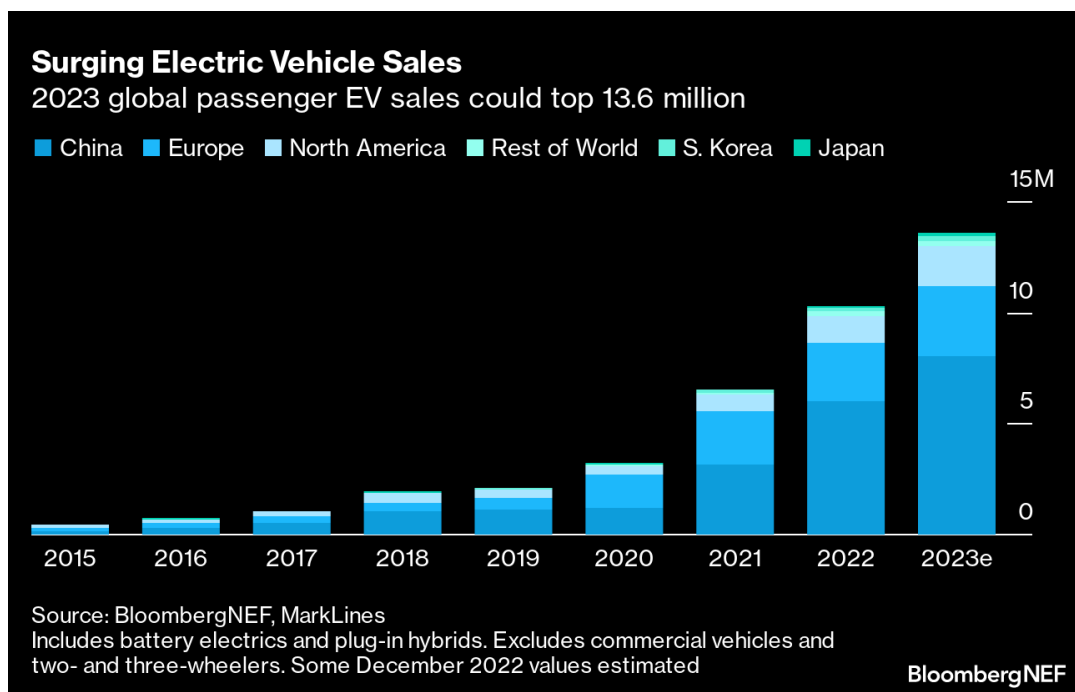


Figure 9: Increase in the number of EVs since 2015

Source: Bloomberg NEF

2.4 Impact of increasing EVs on the grid system of the economy

To avoid voltage fluctuation, especially in India, there are voltage stabilizers within the charging station. EVs are dependent on the local electric supply, and in India, there are both Tier 1 and Tier 2 cities. The emphasis on EVs is predominantly in Tier 1 cities, where the electric systems have largely stabilized. In rural areas where there is a single - phase electric supply, the situation can be erratic. Manufacturers have tried to circumvent the system, especially in lower power systems, by adopting alternating

current (AC) and Direct current (DC) conversions. The power control unit, which delivers a variable DC voltage to the battery, requires filtering functions that are carried out in the charger and can be implemented at a relatively low cost. To avoid the impact of voltage fluctuations, there is a battery management system (BMS) that is tightly integrated with the battery monitoring parameters like Voltage, current, and temperature such that the required constant current at a constant voltage is provided at the charging point. There are several protection circuits within the battery in case the battery's operating limits are exceeded, isolating the battery if needed

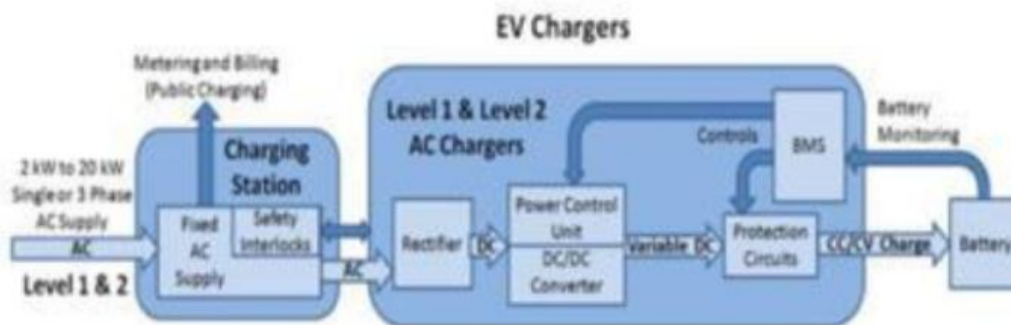


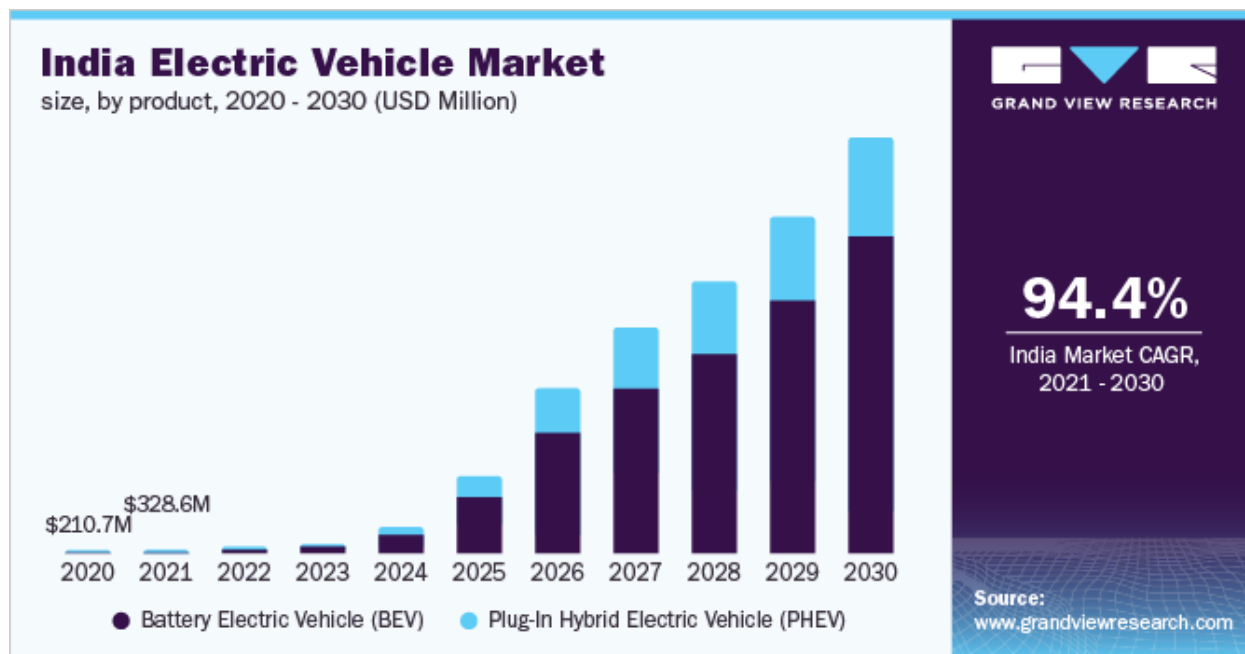
Figure 10: Battery systems of EVs that safeguard against voltage fluctuations

Studies have indicated that an increase in EV sales is unlikely to cause a significant increase in total power demand. At best, it is likely to reshape the electricity load curve. The load factor in the evening is likely to be at its peak as people will plug in their EVs when they return home from work.

Some studies indicate that EVs, in the long run, can improve the resilience and reliability of the grid. This requires encouraging EV owners to charge when electricity is plentiful and cheap and deploying technology so that the batteries of EVs can provide backup power to homes or supply it back to the grid during times of severe stress.

EVs can run on solar and wind generation when it is abundant and could be programmed to avoid peak hours when the grid may be strained. Policy measures advancing EV adoption are not in conflict with efforts to adopt renewable energy but are a means to achieve those goals and improve reliability.

At this point, the number of EVs on the road is minuscule compared to the number of internal combustion vehicles. Pure electric cars in India in 2022 accounted for nearly 1% of the 3.3 million car registrations. Besides the four-wheeler section, several two-wheeler and three-wheeler are using battery electric vehicles (BEVs).



**Figure 11:** Indian Electric Vehicle Market Expansion  
Source: www.grandviewresearch.com

At this point, the impact on the grid in India is negligible as the number of vehicles is minuscule, and thus the existing grid system is in a position to adequately handle the demand from EVs.

#### Increasing EVs: Is it a viable alternative?

EVs are the need of the hour, as the impact of climate change is immense and extremely apparent. The heat wave, floods, and strange weather phenomena at unusual points in time are all a result of huge carbon emissions that have occurred throughout the years and are still occurring. Greenhouse Gases (GHG) have reached extremely high levels, and all economies, developed or emerging, have realized that something urgent has to be done to save future generations. All the countries have finally decided that the temperatures have to reduce by at least 1.5 degrees every year. For this to happen, the economies have collectively decided to reduce their emissions of GHG.

China has become the country with the largest number of electric vehicles per person. In the US, it is 1: 7; in China, it is 1: 4, and in Europe, it is 1: 8. The use of these vehicles seems to be one of the most important ways to curtail greenhouse gas emissions.

By 2030, studies indicate that 90% of cars will be EVs in China. Both buyers and manufacturers of these vehicles are experiencing boom conditions. The main reasons are:

- 1) Sufficient infrastructure
- 2) Consumer subsidies
- 3) Tax Breaks
- 4) Manufacture subsidies
- 5) Infrastructure
- 6) Avoiding Gas hurdles: This means buying and owning gasoline-powered cars is less appealing. To fight congestion on the road, the government has limited the number of cars. Besides this, there are lotteries to obtain new license plates. On the other hand, EV drivers can easily get a green license plate showcasing their environmentally friendly credentials.
- 7) Production Penalties: China introduced a dual credit system for the automobile industry in 2017, which awarded points for making clean cars and penalties for those with high fuel consumption
- 8) Government Purchases: Some local governments have converted their public transport and taxi fleets to 100% electric, encouraging the buying of electric hybrids, resulting in steady business for EV producers.

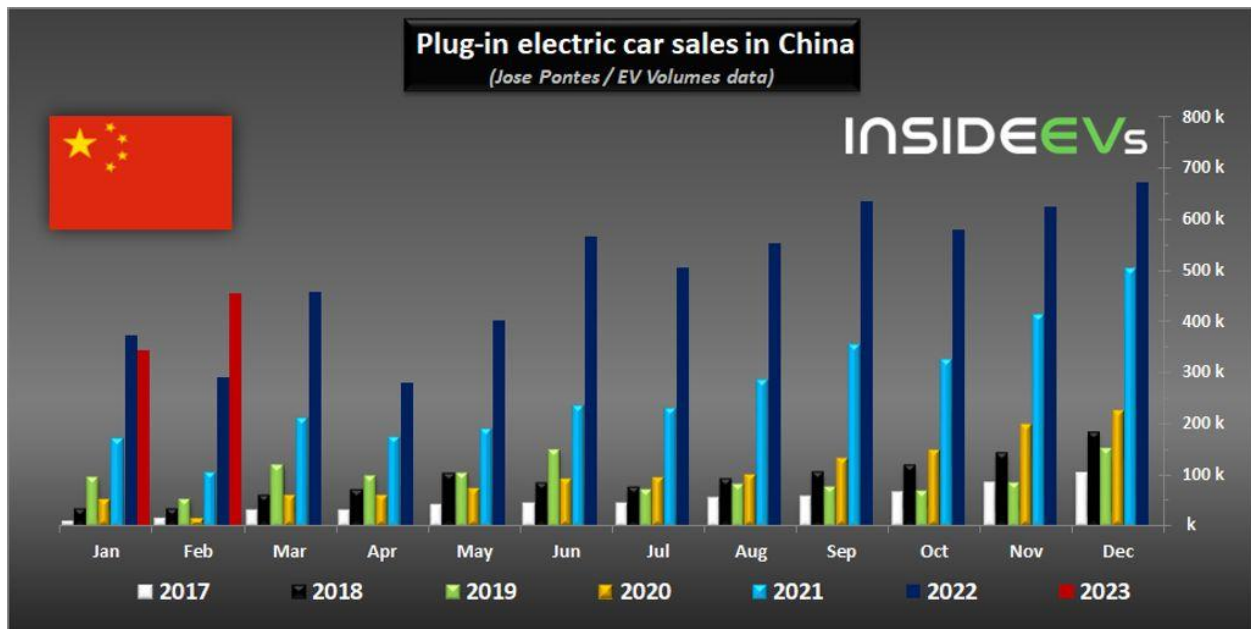


Figure 12: EV sales in China

Source: Google Image

EVs are an efficient and cheaper alternative to operate, given the subsidies that have been negotiated by various governments. As with all new technology, development is required to make EVs more affordable. The biggest obstacle in the path of EVs is the existing electricity infrastructure. In the short term, due to the limited number of vehicles, it will be able to handle the additional demand. As the number of electric cars increases along with the increased power demands from homes, it is possible that the power grid may not be able to accommodate the extra load, especially during peak power consumption.

Though EVs are popular due to their eco - friendly reputation, in reality, they are not as carbon neutral as they might seem, as the electricity they require to charge their cars comes from burning fossil fuels.

According to Professor Ginn, a professor of electrical engineering at the University of Southern California, "You are just shifting the fossil fuel burning from the local car engine to a giant power plant somewhere where you don't see it." Besides this, super capacitors and energy storage devices are not sophisticated enough to allow EVs to travel great distances on just one charge. As demand grows, technology will try to keep up with it and reduce the problems that EV owners face. The costliest portion of the car is the cost of the battery. Given the fact that Lithium is also required in the production of such cars, a worldwide shortage has impacted all car and battery manufacturers, including EVs. Lithium is an important element in batteries. China has a large supply and will be able to meet targets, but the European and American economies will have to face higher battery prices and thus a reduction in profits.

Eventually, it depends on the pace of technology to reduce prices, especially for batteries, making EVs a viable option.

#### Economic cost - benefit analysis on the adoption of EVs

Researchers have used various models that take into account the following:

- Battery cost
- Purchase Price
- Driving range
- Charging Time

All of the above are internal factors concerning the vehicle. The external factors are:

- Fuel Prices
- Policy Incentives by the Government
- Consumer Characteristics
- availability of charging stations
- Travel Distance
- Vehicle Diversity

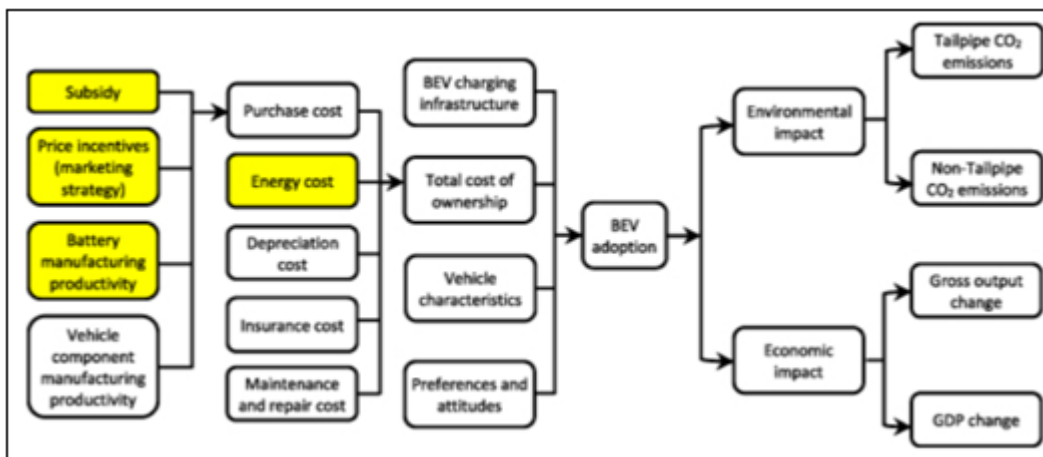
Incentives are important to promote B - EVs and are necessary for the vehicles to be cost - competitive. It was found that increased levels of subsidies led to higher B - EV adoption.

Eventually, the four main important economic factors are:

- Relevance of B - EV charging infrastructure
- Total cost of ownership (TCO)
- Vehicle characteristics
- Preferences and attitudes of consumers

TCO is further driven by the following factors:

- Purchase cost
- Energy Cost
- Depreciation cost
- Insurance
- Maintenance and repair costs



**Figure 13:** Conceptual Framework of the Impact Evaluation of BEV Adoption

Source: <https://iopscience.iop.org/article/10.1088/1748-9326/abe2d0>

According to most researchers, subsidies have a greater impact on GDP and B - EVs than changes in fuel prices. The subsidy element should continue until the industry's transition to greener products is completed. A combination of subsidies and rising productivity and fuel price trends will increase the positive impact of the subsidies.

**Disadvantages of Electric Vehicles (Lithium)**

Lithium, which is an important component for making batteries for electric vehicles, is a non - renewable mineral, and its extraction is comparable to fossil fuel mining, which results in soil degradation, water shortages, biodiversity loss, damage to ecosystem functions, and global warming. A lot of water and energy are consumed in its extraction, and the mining itself pollutes the air and water with chemicals and heavy metals. But it is still more environmentally friendly than fossil fuels. The disposal of the batteries used in EVs can pose a threat to the climate, though they contain less toxic waste than any other kind of battery. It has been seen in Australia that a large number of these batteries end up in landfill sites, leading to the likelihood of fires that can burn for years to come.



**Figure 13:** Lithium - Ion Battery

Source: <https://caryvolt.com/>

**3. Conclusion**

EVs are an important cog in the wheel in an attempt to reach sustainable development goals that have been adopted by the UN and almost all countries in the world. The urgency to save the environment has necessitated the use of fuels that are alternatives to fossil fuels. Fossil fuels are known to be the most polluting elements and are mainly responsible for increasing Greenhouse Gases and, subsequently, carbon imprints, as well as huge variations in global temperatures. To bring this under control without necessarily reversing the process, it is essential to use alternative fuels, of which EVs are the most efficient. The disadvantage of this type of technology is the use of lithium of batteries, which, though not as polluting as other fossil fuels, are still not environmentally friendly. The need of the hour is to continuously improve and improvise on the technology that



EVs adopt to maintain the environment for all future generations.

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