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Review of Green Mobility in India: The Journey and the Future Forecast

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ABSTRACT

Electric vehicles have fast become more commonplace around the globe over the years, and the fact that they have the ability to extensively decrease greenhouse gas emissions and provide an alternative to the long-standing fossil fuel-based IC engines does help. While a developing country like India is sure to have its unique set of barriers that hinder the adoption of green mobility across the country, and while there is a lot of apprehension amongst the end-users with regards to factors like charging infrastructure, driving range and the associated costs, there have also been a number of positive steps in the right directions, in terms of closing the technological gap, as well as giving the right incentives to the users. This paper is focused on reviewing the overall scenario of India's position with respect to green mobility and provides insights into where we currently stand.

Keywords: *Electric Vehicle; Green Mobility; Infrastructure; Charging Station; Battery; Energy Storage; Engines.*

1.0 Introduction

In recent times, electric vehicles have gained immense popularity due to their environment-friendly characteristics. Their defining advantages is that they massively reduce carbon emissions [17]. Electric vehicles are quieter, easier to use, and reduce the fuel cost which plagues conventional IC engine vehicles. They do not produce smog and air pollutants. Intelligent network integration through V2G (Vehicle to Grid) provides financial benefits to customers through two-way charging. Charging the battery of the vehicle involves integrating it with a renewable source of energy. The main challenges that hinder the adoption of electric vehicles are the high acquired costs due to batteries and fuel cells, limited range due to the speed of the vehicle and the capacity of the battery, long charging times depending on the type of battery and the charging setup, and lack of charging stations [17]. Subsequent future developments are aimed at developing an improved battery life and charging infrastructure that will significantly reduce charging standby times, increase flexibility and reduce the use of permanent magnet motors which contain rare earth metals [17]. Other options include wirelessly enabled power transfer mechanisms and vehicles utilizing solar power, alongside parallel research into compact, durable and inexpensive sensors and electronic devices.

2.0 Electric Vehicle Scenario in India: A Glance

Already about 300 million conventional vehicles are growing pacily at the rate of nearly 60,000 new registrations per day. Conventional gas stations across the country are 70,799, whereas just 221 for EVs[14]. Recently, Tata Motors won a bid to supply 10,000 EVs which would replace government vehicles, along with 4,000 electric vehicle chargers. FAME (Faster Adoption & Manufacturing of Electric Vehicles) was designed in 2015 to promote the production of environmentally-friendly electric vehicles [2]. Some of the planned incentives on the roadmap are the provision of free charging points for electric vehicles, public charging stations, controlled

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power rates for charging vehicles and convenient battery replacement. A stable power supply for EV charging stations and providing alternative energy sources for EV charging infrastructure are important elements that will play a critical role in the growth of the EV industry, with the conversion of microgrids and renewable energy storage devices into proper EV charging infrastructure [2]. Reducing CO2 emissions will also enable India to deliver on its commitments under the Paris Climate Agreement. India is aiming to increase the capacity of renewable energy sources to 185 GW by 2022 as part of building a green economy [6]. The Bangalore Municipal Transport Corporation recently introduced electric transport on a dense corridor in the city. A survey was carried out in Ludhiana city, which demonstrated that 36% of the existing car and two-wheeler owners were enthusiastic about shifting to the electric vehicle [75]. Hyderabad metro rail was the first metro rail in the country to have EVs charging stations to be monitored and operated by the power grid [9]. In November 2018, the Delhi Govt.

Released a draft policy that is aiming to convert 25% of their vehicles to EVs by offering various incentives and by setting up charging infrastructures in both residential and non-residential areas. In Mumbai-Pune highway, a Private firm named Magenta Power is also working to set up EV charging infrastructure [10].

1.1 Covid-19 influence on India's clean energy transition

The COVID-19 pandemic has caused unprecedented damage to businesses, the global economy, and human lives. The economy bears the worst contraction so far in history and the ruckus it would bring was beyond the imagination [13]. The automotive industry, in sync with the Indian economy, has already been a victim of the low demand, high cost of production, and idle capacity. According to the Industry body of The Society of Indian Automobile Manufacturers, the estimated production loss due to the 21 days lockdown period (first phase) is around INR 2300 crores [13].

Towards a Clean Energy Economy: Post-Covid-19 Opportunities in India's Energy and Mobility Sectors, a report by Niti Aayog and Rocky Mountain Institute, the market may experience a shift as consumers seek affordable products amid the pandemic which could make manufacturers resume production for conventional vehicles. It also said that the tendency towards cash saving led to lower disposable income will lead to contracted demand for Electric Vehicles in the short term [8].

Covid-19 will lead to new challenges for India's clean energy transition, including liquidity and financing constraints, supply chain shortages, job losses and reduced workforce. Emerging challenges In the transport sector include private vehicle ownership versus shared, non-motorized and public transport; inefficient supply chains versus clean, optimized logistics; internal combustion engines versus electric vehicles; demand rebound versus sustained behaviour change; and short-term supply disruptions versus long-term resilient supply chains [13].

2.0 EV Industry's Response on Budget 2021

The Budget 2021 saw a mixed response from the EV industry. Even though there wasn't any direct benefit for the sector, there are certain indirect benefits the sector would enjoy. The voluntary scrappage policy will boost the EV demand for electric vehicles. But the increased customs duty on certain auto components to boost domestic manufacturing will hurt the electric vehicle manufacturers as it will increase their cost in India [16]. The extension of tax holidays for startups for another year was cheered by the new-age companies and startups [16]. The FM also declared the highest ever capital expenditure of Rs. 1.08 trn for the Ministry of Roads. This would strengthen the infrastructure of the country which is a welcoming move [16]. Furthermore, the PLI schemes covering 13 sectors saw a commitment of Rs. 1.97 lakh crore, which is also cheered by the industry [16]. However, the increase in customs duty on certain auto parts may lead to a higher cost of production [7].

2.1 Barriers for EV: Indian market

The barriers for Electric vehicles in Indian markets can be analysed through various lenses such as Policy barriers, lack of infrastructure, and technical barriers.

2.2 High capital cost

Electric vehicles when compared to ICE vehicles are expensive as they require frequent replacement of expensive batteries.

2.3 Consumer perception

Retention of customers is a vital aspect for stable growth of any product or market and thus customer perception plays an important role. Even after growing market share for EV in the auto industry, people's choice to buy an electric vehicle is stagnant and is expected to remain the same over time. Government schemes and incentives can help to overcome this barrier. [3]

2.4 Driving range of electric vehicle

This is one of the main barriers to the adoption of EV because EVs driving range in one charger is shorter as compared to conventional vehicles. Thus it is considered the most important drawback. Most of the EV offers a driving range of not more than 250 km per charge. However, the latest EVs can offer up to 450 km per charge [11]

2.5 Charging time

This barrier is closely related to the driving range issue depending on the battery size. It is directly proportional, hence the larger the battery size, the longer is the time before recharge and the longer is the driving range. EVs can take up to 7 hours to be fully charged which again is a major drawback.

2.6 Charging infrastructure

Without an effective and efficient charging infrastructure, the EV market would not be able to sustain itself. As fast as EV adoption increases, the charging infrastructure needs to get wider, hence leading to higher electricity demand. The lack of the same in India is the prime reason for the low sale of electric vehicles [5].

3.0 Electric Vehicle Technology: An Overview

Electric Vehicles, top-down, can be mainly classified into four categories. The vehicles using only batteries to deliver electric power are termed Battery Electric Vehicles (BEV). The Hybrid EVs use a conventional engine alongside an electrical motor, which drives the power train. Plug-in Hybrid Electric Vehicles (PHEV) utilise larger capacity batteries than HEVs and function solely on electric power and only utilize a traditional engine to give an enhancement and increase the range during a small battery charge [11]. PHEVs directly charge the batteries by utilizing the power grid. Fig. 1 shows the overall view of an EV.

Fig. 1:Top Level Perspective of an Electric Vehicle

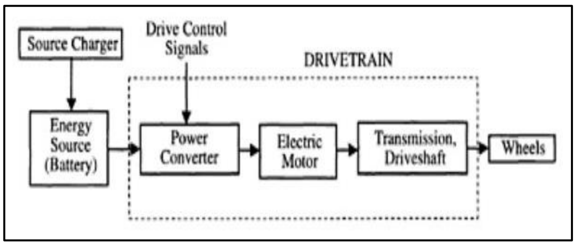


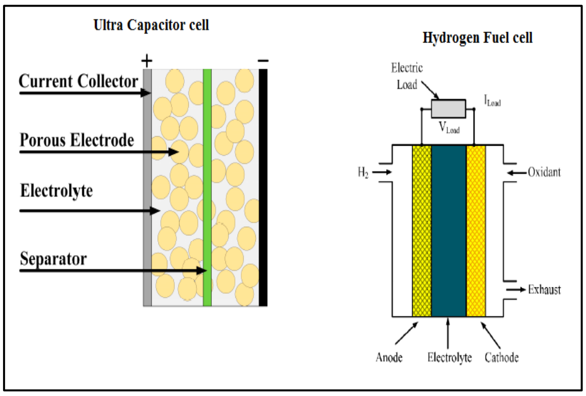
Table 1: Commonly Used Batteries in EV

Battery Type	Material	Merits	Demerits
Lead Acid	Negative active material: Spongy Lead	Easy access in production volume	Cannot be discharged over than 20% of its capacity
	Positive active material: lead Oxide	Reasonably inexpensive	Short life
	Electrolyte: diluted Sulphuric acid	Highly abundant	Heavier with low energy and power density and requires maintenance
NiMH (Nickel-Metal Hydride)	Positive electrode: Nickel Hydroxide	High energy density and environment friendly	When subjected to rapid discharge due to large current, life cycle is limited to ~300 cycles
	Negative electrode:A mixture of Nickel, Titanium, Vanadium alloys etc	Large range of operating temperature and resistance to discharging and over-charge	
	Electrolyte: alkaline solution	Safe to operate at high voltage, recyclable and has a long cycle life	Memory effect cause low operating power
Li-Ion (Lithium ion)	Positive electrode: Oxidized Cobalt Material	High energy density and efficiency, even at large temperatures	Expensive
	Negative rod: Carbon Material	High specific power and energy and average lifespan of around 1000 cycles	Takes a long time to recharge
	Liquid electrolyte: Lithium salts in an organic solvent	The recyclable	

Coming to the energy-storing systems (ESS), some of the critical features that define a good ESS, the element of an EV that is responsible for providing the power to start an electric vehicle, are rapid charging, high specific energy to enable longer distance travels, high specific output to provide good acceleration, extended service life, as well as low price as well as maintenance required. In Table I are some of the common batteries deployed in EVs, with Lithium-ion batteries being the most abundant [11].

As shown in Figure 2, another type of energy storing system is an Ultra Capacitor (UC), which provides a large power density, at the cost of a low energy density. UCs are capable of generating large amounts of power for small time frames and help with regenerative braking. Integrating a battery with a UC assist in nullifying the flaws of both the devices and provides the best of both worlds by offering a competent, as well as a consistent source of energy. Other alternatives include a Hydrogen fuel cell, which generates electricity by the means of an electrochemical reaction in which electricity is a result of the electrons generated through oxidation at the anode.

Fig. 2: Ultra Capacitor and Hydrogen Fuel Cell



Charging circuits are classified based on their usage of uni or bidirectional flows of energy (which helps return battery energy to the grid), into external and built-in circuits (conductive and inductive). Built-in chargers limit the power flow due to constraints over budget, space and pressure. Charging infrastructure reduces the onboard storage and costs of energy. Battery charging systems must have adequate efficiency and reliability, along with a high power density, low cost and a small volume and weight [15]. Electric vehicle charging systems need to operate at a high power factor to reduce the distortion from mains and maximize the actual usable current to minimize its impact on power quality. EV battery chargers contain a boost converter to aid the process of active power factor correction [15], [1]. Car charging systems allow the electric vehicle owners to charge the right power source for their vehicle [26]. Due to limitations over the size, budget and bulk nature, generic onboard chargers have a limit to restrict the power. On the other hand, off-board charging setups are set back by extensive circuitry as well as higher expenses, which may lead to a lot of clutter in the metropolitan area. [21].

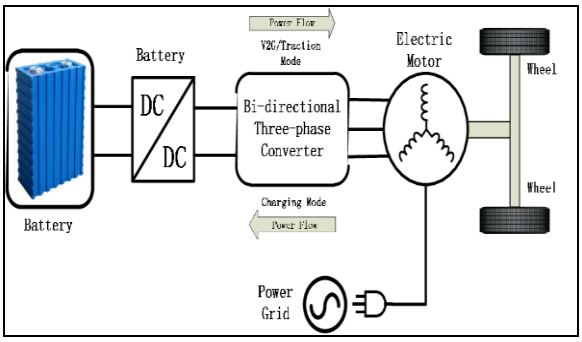
A variety of electric vehicles are available in the Indian market, as listed in table IV, along with their main characteristics. The advantage provided by a wireless charging setup is that there is no physical connection between the car and the charging cable. Inductive power transfer (IPT), while has no physical contact, is not wireless [18]. Some of the known wireless power transfer techniques include Capacitive power transfer (CPT), Permanent magnet coupling power transfer (PMPT), Resonant inductive power transfer (RIPT) and Online inductive power transfer (OLPT).

Table 2: Electric Cars Available in India

Manufacturer	Mahindra e2o/ Sun2Car	Mahindra Verito	Tata Tiago Electric
Motor used	3 Phase Induction Motor	72V induction motor	Three-phase induction motor
Recharging time	5 hours	Less than 2 hours (fast charging)	40% in an hour
Battery used	11 to 16 kWh Lithium-ion	Lithium-ion battery	Lithium-ion and motor comes paired to an Automatic transmission
Range and Maximum speed	120 km and 9 km/hr	110 km and 86 km/hr	100 km and 75 km/hr
Shortcomings	Expensive, top speed of 85km/hr, range restriction	Battery charging Point availability, High price	High cost, Poor performance and low range, lack of sufficient charging ports

Then, there are a variety of techniques for power conversion. After the conversion of energy from the AC grid, energy reservoirs store this energy in the form of a DC charge, which is then used to deploy the motors after getting converted again into AC using power electronic converters. These converters are also built to allow flow in the opposite direction, i.e., when the power is fed back up to the batteries (regenerative braking), or whenever the vehicle is in an idle state, supplying power back to the utility (Vehicle to Grid: V2G) [19. A generic bidirectional electric vehicle drive is showcased in Fig. 4.

Fig. 3: Typical Bidirectional Electric Vehicle Drive



Integrating the smart grid with the EVs provides a way to coordinate the regulating mechanism and enables charging technologies like V2G, along with the integration of renewable energy. V2G provides a means to the vehicle to provide power to the grid in a bidirectional flow of electrical energy [23]. Renewables are the primary source of charge in green charging, with the grid providing standby support in case of emergencies, a case in point of which is a unified, solar-based model of a Lithium-ion battery and a supercapacitor, which in turn is an example supercapacitor energy storage systems (HESS) and is characterized by subsequent charging and discharging of the energy storage source used, hence increasing the effectiveness and functioning of the storage. [22]

Electric vehicles also significantly reduce the impact of the greenhouse effect . Traditional cars are responsible for high carbon dioxide and carbon monoxide emissions, amongst other harmful pollutants. On the contrary, electric vehicles emit much less than conventional vehicles, at the same time, help reduce noise pollution. While the efficiency of an internal combustion engine lies between the range of 60-70%, electric vehicles offer low operating costs and high efficiency upwards of 90%.

4.0 Green Mobility: Policies and Incentives

The Government of India has also launched a plan on Faster Adoption and Manufacturing of Electric Vehicle (FAME II) to empower and speed up the process of EV adoption, by providing a bunch of incentives and laying out concrete plans for setting up the charging infrastructure. In February 2019, the cabinet cleared 10,000 crores for FAME II for its implementation from April 1st 2019 for three years [4]. The EV manufacturers have been waiting for this policy to be implemented for creating a roadmap of the EV ecosystem together with charging infrastructure and manufacturing incentives.

Similarly, a roadmap has been set by NITI Aayog's transformative mobility report of 2017 for the usage of pure electric vehicles following the development of the EV technology and the necessity developed in the automobile sector to decrease the demand of energy. By NITI Aayog, Kerala is the fifth state after Telangana, Madhya Pradesh, Andhra Pradesh and Karnataka to encourage and implement e-mobility, as well as execute the e-portability desired by the policy. It has been forecasted that if India adopts a transformative solution of shared connected electric mobility,100% public transport vehicle and 40% private vehicles, then it can become all-electric by 2030 [28].

With concrete plans to localise the production of electric vehicles as well as components by encouraging the manufacturing facilities, the government of Kerala proposed a manufacturing unit to produce e-Autos, as a joint venture between the private sector and the Kerala Automobiles Ltd (Public Sector). Under the government's IT policy, the EV manufacturing facilities which would be set up under the policy framework would be provided with adequate financial and regulatory benefits, such as the ability to acquire electric power at low prices and tax relaxations [12]. As planned in the policy, high capacity optical fibre cables would be fitted across the mobility corridor, which would connect various road infrastructure.

4.1 Trends and future developments

The emergence of electric vehicles has raised huge concerns about mileage due to a significant lack of charging infrastructure across the country. The lack of an adequate and efficient EV charging infrastructure is the defining factor that currently hinders the adoption of EVs in India. The latest battery charging technology uses extensive urban space and external charging stations that require significant investments. Even with the provisions for onboard charging, charging times are usually lengthy. The main drawbacks of charging stations are the charging time, the required proximity to electric vehicles, potential obstacles and queues at the charging station. A physical connection is necessary between the electrical system and the electric vehicle and includes a rectifier, a DC-DC converter, or a low-frequency AC-to-high converter with PFC [25].

Wireless charging has the potential advantages of being safe and highly convenient when your vehicle is resting or on the go. High-performance chargers and streamlined circuitry are essential requirements waiting for electric vehicles. On the device side, there is a high scope of research on devices that use BLDC and PMSM motors as well as SRM motors.

Increasing the number of electric vehicles and charging points affects the quality of voltages and harmonics and can potentially degrade the performance of integrated renewable energy and smart grids. The future development from electric vehicle dissemination to smart grid will be a test but at the same time a significant opportunity for the electric grid. Careful handling will be able to reduce the peak load on the network. When integrated with electric vehicles, it is necessary to address energy quality issues that affect the integrated operation of renewable energy and smart grids.

5.0 Conclusions

With a mission to shape the future of the transportation sector by promising to reduce the carbon footprint produced by a long drawn history of conventional vehicle usage, Electric vehicles are here to stay. Being a viable alternative to traditional IC Engine vehicles that are directly responsible, as well as dependent on the ever diminishing fossil fuel reserves, they hold to put forward a greener energy system by collaborating with technologies like smart grid and facilitating the integration of renewable sources. The ever-changing effects of the technical features of EVs are therefore quintessential for researchers, policymakers, and manufacturers alike as they can directly lead to an improvement in popularity and marketing strategies pertaining to EV and the subsequent mitigation of consumer doubts. To be able to promote a culture that can encourage the application of appropriate governance policy, future research should concentrate on methods to lead customers to EVs, as well as psychological variables, which play a critical role in the process of green mobility adoption.

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