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Present and Future Trends of Electric Vehicles in India

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ABSTRACT

The electric vehicles market in India is making significant progress in terms of environmental sustainability. Various new car companies are revolutionizing the industry by introducing innovative models. The interest in electric vehicles is rapidly growing, and with the introduction of new pricing models, the market is expected to expand even further. Recognizing this shift, existing car manufacturers are striving to unveil new hybrid or electric vehicle models. Developed countries such as the UK and France have already announced plans to ban the sale of diesel and petrol cars by 2040. Experts predict that Europe will witness a complete transition to electric vehicles five years prior to the deadline. This transformation has led to increased commitments and competition among leading car manufacturers and businesses in the automotive industry. Norway, for instance, is experiencing remarkable progress in the electric vehicles market, with nearly 30% of new car sales in December 2017 being electric battery-powered vehicles. Energy experts anticipate that China and India will drive the demand for electric vehicles, as these countries prioritize the development of low-carbon emission transportation solutions. In response to the growing industry, many companies are planning to introduce electric vehicle charging points to support the increasing demand for electric vehicles.

Keywords : Electric Vehicles, Developing Economy, India, Transportation.

I. INTRODUCTION

Fuel conservation and ecological protection concerns are on the rise worldwide, leading to a rapid acceleration in the research and development of electric vehicles. The automotive industry is currently undergoing a disruptive phase due to digitization, with increasing automation revolutionizing the sector and paving the way for a new era in the 21st century. India's automobile industry is also feeling the effects of this transformation. However, it is important to note that the Indian EV market differs significantly from other global markets due to the unique dynamics of the Indian economy, market requirements, and consumer preferences. In order to effectively navigate the future changes in this sector, it is crucial to understand and

reinvent existing strategies. These emerging trends will not only reshape mobility behavior but also create new opportunities for competition and collaboration. The growth potential in this industry lies in providing the necessary services that are expected to witness a significant increase in demand. It is worth mentioning that thirteen out of the twenty cities with the highest air pollution levels in the world are located in India, making it imperative to address the issue of growing vehicle pollution. The automotive industry worldwide is experiencing the impact of electrification, and by 2030, electric vehicles, including battery electric vehicles and plug-in/hybrid vehicles, are projected to account for up to 50 percent of new vehicle sales globally. India will be greatly affected across the entire automotive value chain, including manufacturers. The electric transportation industry is experiencing rapid growth and development. India, being one of the top ten automotive markets globally, has a significant middle-class population with increasing purchasing power and a steadily growing economy. However, India's road transport sector is responsible for consuming 25 to 27 percent of the country's crude oil, and vehicular emissions are a major contributor to urban pollution, as stated by the National Green Tribunal (NGT). Therefore, it is crucial for India to adopt low-emission transport solutions such as electric vehicles (EVs). To promote the adoption of EVs, the government has recently announced phase-II of the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles scheme (FAME II), which will be implemented from 2019 to 2022. Additionally, road tax and registration charges for hybrids and EVs have been exempted, which will significantly contribute to the growth of the EV market in India. However, the availability of EV charging infrastructure is essential for the widespread adoption of EVs.

Furthermore, advancements in battery technology and the decreasing cost of batteries will further enhance the market penetration of electric vehicles. Additionally, as emissions regulations become stricter, automobile manufacturers will be compelled to shift their focus towards the production of electric vehicles. Despite the numerous benefits that EVs offer in terms of environmental impact, customer satisfaction, energy grid stability, and national security, there are still various technical, social, and economic barriers that need to be overcome for large-scale adoption of EVs.

II. TYPES OF ELECTRIC VEHICLE

EVs can operate using electric propulsion exclusively or they can incorporate an internal combustion engine (ICE) in conjunction with it. The fundamental type of EV relies solely on batteries as its energy source, but there are also variations that can utilize alternative energy sources. EVs can be classified into different categories based on these characteristics.

Battery Electric Vehicle (BEV)

EVs can operate using electric propulsion alone or in conjunction with an internal combustion engine (ICE). The most basic type of EV relies solely on batteries as its energy source, known as a Battery Electric Vehicle (BEV). BEVs are dependent on the energy stored in their battery packs, meaning their range is directly determined by the battery capacity.

Hybrid Electric Vehicle (HEV)

Another category of EV is the Hybrid Electric Vehicle (HEV), which utilizes both an ICE and an electric powertrain to propel the vehicle. The specific combination of these two power sources can vary. HEVs primarily rely on the electric propulsion system when power demand is low.

Plug-In Hybrid Electric Vehicle (PHEV)

A Plug-In Hybrid Electric Vehicle (PHEV) operates initially in an "all electric" mode, running solely on electricity. When the battery charge becomes depleted, the PHEV switches to the ICE to either provide a power boost or recharge the battery pack. In this case, the ICE is utilized the Present and Future Trends for Electric Vehicles in India.

Fuel Cell Electric Vehicle (FCEV)

Fuel cell electric vehicles (FCEVs) utilize fuel cells that employ chemical reactions to generate electricity as their primary energy source. FCEVs, commonly referred to as 'hydrogen fuel cell vehicles', rely on hydrogen as their preferred fuel. To store the hydrogen, FCEVs employ specialized high-pressure tanks. Additionally, oxygen, obtained from the surrounding air, serves as another essential component for the power generation process. The electricity produced by the fuel cells is then directed towards an electric motor, which in turn propels the vehicle's wheels.

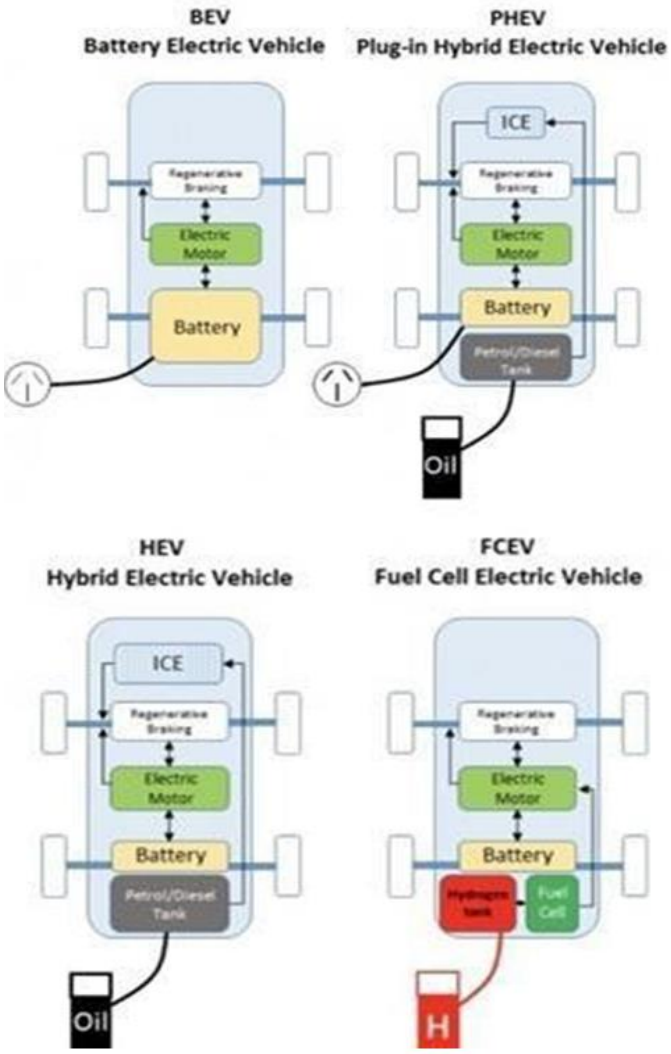


Fig. 1 Types of Electric Vehicles

III. REVIEW OF LITERATURE

The primary focus of the literature search revolved around Electric and Hybrid cars, delving into various related topics. Through an extensive review of publications and research work, valuable insights were obtained, shedding light on the fundamental guidelines and positive outcomes that can be expected. These outcomes are in favor of society, as they contribute to the preservation of fossil fuel resources and the reduction of environmental pollution.

Electric vehicles utilize an electric motor for propulsion, along with various energy storage systems such as chemical batteries, fuel cells, ultra-capacitors, and flywheels. These vehicles offer several advantages, including reduced emissions, high efficiency, and smooth operation (Mehrdad Ehsani, Yimin Gao, Stefano Longo, Kambiz M. Ebrahimi, 2018).

A study conducted in China examined the energy consumption and emissions of plug-in hybrid electric vehicles, comparing them to gasoline vehicles. The findings revealed a significant reduction of 37.5% in energy consumption and 35% in greenhouse gas emissions for plug-in hybrid electric vehicles when compared to their gasoline counterparts (Liu and Santos, 2015).

IV. BENEFITS OF ELECTRIC VEHICLES

EVs provide major benefits for the environment, for customers, for the nation's energy grid, and for national security.

Environmental Benefits

EVs can reduce the emissions that contribute to climate change and smog, improving public health and reducing ecological damage. Charging EV on renewable energy such as solar or wind minimizes these emissions even more.

Customer Benefits

EVs are cheaper to operate than gasoline vehicles, primarily due to the lower cost of electricity on an equivalent cost basis and also due to lower maintenance costs.

Energy Grid Benefits

EVs coupled with managed charging, result in more efficient utilization of the energy grid, which lowers the average cost.

National Security Benefits

When EVs plug in, they are 100 percent powered by a domestic mix of energy sources, including natural gas, coal, nuclear, hydropower, wind, and solar. This is in stark contrast to gasoline-fueled vehicles, which depend solely on oil which is imported.

BARRIERS TO ADOPTION OF ELECTRIC VEHICLES

Electric Vehicles (EVs) are widely advocated as a feasible vehicle technology in the near future, aiming to diminish reliance on fossil fuels and mitigate the consequential greenhouse gas emissions linked to traditional vehicles. Despite the numerous advantages that EVs offer, there exist certain socio-technical and economic obstacles that hinder the widespread acceptance and adoption of these vehicles by consumers.

Technological problems

The adoption of electric vehicles (EVs) is hindered by various drawbacks associated with technology. One major barrier is the significant impact of batteries on the weight of the car. This weight contribution raises concerns regarding the overall performance and efficiency of EVs.

Limited range

One of the technological barriers is the limited range of EVs, which is directly linked to the capacity of their batteries. The distance an EV can travel is determined by the amount of stored energy in the battery. Additionally, factors such as the vehicle's speed, driving style, cargo load, terrain, and energy-consuming services like air conditioning also affect the range. This limitation often leads to "range anxiety" among users, despite the fact that current battery electric vehicles (BEVs) can cover equivalent or even greater distances than conventional vehicles with a full tank of fuel. Overcoming this range anxiety remains a significant challenge for the widespread adoption of EVs.

Another drawback is that not all EV batteries can be fast charged, and the charging rate, known as the C-rate, plays a crucial role in this regard. The C-rate refers to the time it takes to fully charge a battery. For instance, a 1C rate means the battery can be fully charged in one hour, while a 2C rate indicates a 30-minute charging time. On the other hand, a 10C rate allows for full charging in just 6 minutes, whereas C/2 requires two hours for a complete charge. The maximum charging rate varies depending on the type of battery used.

In conclusion, the drawbacks related to technology, particularly concerning batteries, pose significant challenges to the widespread adoption of EVs. The limited range and the inability of all batteries to be fast charged are key technological barriers that need to be addressed in order to overcome the obstacles hindering the acceptance of EVs.

Safety concerns

Safety concerns surrounding FCEVs have become a prominent issue in recent times. The potential dangers associated with hydrogen leakage have raised alarm, given its highly flammable nature. Moreover, the fact that hydrogen is colorless makes it difficult to detect leaks. Additionally, collisions pose a risk of the hydrogen tanks exploding. In response to these concerns, automakers have implemented measures to ensure the tanks' integrity. For instance, the Toyota Mirai incorporates carbon fiber wrapping for added prot'ction. Furthermore, the hydrogen handling components are positioned outside the cabin,

facilitating the dispersion of gas in the event of a leak. Additionally, precautions have been taken to seal the tank outlet in case of high-speed collisions.

Social problems

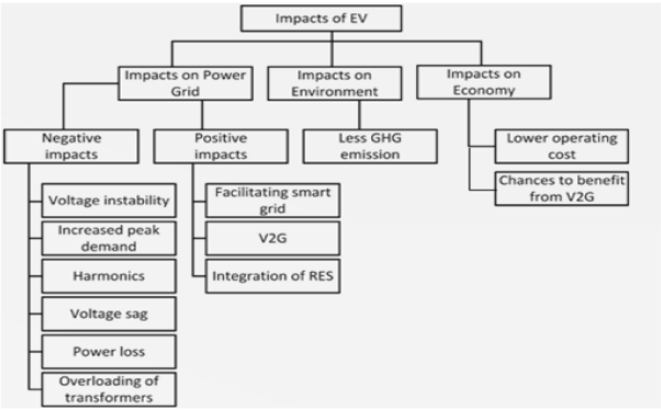
Social Acceptance: The integration of a novel and underdeveloped technology, along with its associated consequences, necessitates a considerable amount of time for societal acceptance due to the need for individuals to modify their established habits. Opting for an electric vehicle (EV) instead of a traditional automobile entail altering driving patterns, refueling routines, and being prepared to utilize alternative modes of transportation in the event of a low battery. These adjustments are not easily embraced by individuals, making the process of adopting EVs challenging.

Insufficient Charging Stations: Despite a significant increase in the number of public charging stations, their availability remains inadequate. This, coupled with the lengthy charging duration, serves as a significant deterrent to the widespread adoption of Evs. Furthermore, not all public charging stations are compatible with every type of electric car, posing a challenge in locating a suitable charging point when battery replenishment is required. However, manufacturers are actively addressing this issue. Companies like Tesla and Nissan are expanding their own charging networks, as it allows them to sell more of their EVs. Additionally, the scarcity of hydrogen refueling stations poses a similar obstacle in promoting the adoption of fuel cell electric vehicles (FCEVs).

Economic problems

The cost of electric vehicles (Evs) is considerably higher in comparison to their internal combustion engine (ICE) counterparts. This discrepancy can be attributed to the expensive nature of batteries and fuel cells. In order to mitigate this issue, various governments across different nations are offering incentives and tax breaks to encourage the purchase of Evs, thereby providing subsidies to buyers. As mass production and technological advancements continue to progress, it is anticipated that the prices of batteries and fuel cells will gradually decrease.

V. IMPACT OF ELECTRIC VEHICLES



IMPACT ON THE POWER GRID

The impact of electric vehicles (EVs) on the power grid can be both positive and negative. On one hand, EVs are considered high power loads that directly affect the power distribution system. This means that the distribution transformers, cables, and fuses are most affected by the increased demand from EV charging. If charging is done during peak hours, it can lead to overload on the system, damage to equipment, tripping of protection relays, and ultimately an increase in infrastructure costs.

To mitigate these effects and ensure efficient charging with the existing infrastructure, coordinated charging, also known as controlled or smart charging, needs to be implemented. This involves charging EVs during periods of low demand, such as after midnight. Such schemes have multiple benefits. They not only prevent the addition of extra load during peak hours but also increase the load during off-peak hours, optimizing the use of power plants and improving overall efficiency.

Voltage Instability

However, there are also challenges that arise in power systems due to EVs. One major problem is voltage instability. Power systems are typically operated close to their stability limit, and the nonlinear characteristics of EV loads, which differ from general industrial or domestic loads, can cause significant voltage instability. If the EVs have constant impedance load characteristics, the grid can support a large number of vehicles without instability. However, since the power consumption of EVs is unpredictable, the addition of a large number of EVs at once can violate distribution constraints and lead to voltage instability.

Harmonics

Another issue is harmonics. The nonlinear characteristics of EV chargers result in high-frequency components of current and voltage, known as harmonics. These harmonics distort the voltage and current waveforms, reducing the power quality of the system. It also causes stress in the power system equipment like cables and fuses.

Voltage sag

Voltage sag refers to a decrease in the RMS value of voltage for a half cycle or one minute. This phenomenon can occur due to overload or during the starting of electric machines. A simulation that involved an EV charger and a power converter revealed when the penetration of EVs reaches 20%, it can exceed the limit of voltage sag. However, the application of a smart grid can greatly help in mitigating this issue.

Power Loss

Another concern is power loss, which can increase by as much as 40%. Uncoordinated charging of EVs can further exacerbate this power loss.

Overloading of Transformers

Furthermore, the overloading of transformers is directly impacted by EV charging. The additional heat generated by EV loads can accelerate the aging rate of transformers, although this also depends on the ambient temperature. In regions with generally cold weather, the aging due to temperature is negligible.

Power Quality Degradation

Massive scale EV penetration can also lead to power quality degradation. This is characterized by an increased number of harmonics and voltage imbalance, which negatively affects the overall power quality of the grid.

Smart Grid System

Despite these challenges, EVs can prove to be beneficial to power systems in various ways. One such advantage is the implementation of a smart grid system. The smart grid incorporates intelligent communication and decision-making into the grid architecture, offering reliable power supply and advanced control. Coordinated charging, which is highly desirable, becomes easily achievable in a smart grid system. The interaction between EVs and the smart grid also enables opportunities like vehicle-to-grid (V2G) technology and better integration of renewable energy. In fact, creating an efficient smart grid is one of the priorities listed for the successful integration of EVs.

V2G

V2G, or vehicle-to-grid, is a method where EVs can provide power to the grid. In this system, EVs act as loads when they draw energy from the grid, but they can also become dynamic energy storages by feeding back energy to the grid. EV loads are strategically applied during the valley points of the load curve in V2G systems. ; EVs can act as power sources during

peak hours. V2G is realizable with the smart grid system.

Integration of Renewable Energy Sources

The integration of electric vehicles (EVs) into the energy landscape enhances the prospects of renewable energy utilization. EV owners have the opportunity to harness Renewable Energy Sources (RES) for local power generation, specifically for charging their EVs. The roofs of parking lots hold significant potential for the installation of photovoltaic (PV) panels, which can not only charge the vehicles parked beneath them but also contribute surplus energy to the grid. This dual functionality serves to promote the wider adoption of commercial RES deployment.

IMPACT ON ENVIRONMENT

The surge in popularity of electric vehicles (EVs) can be attributed to several key factors, one of which is their significant contribution to reducing greenhouse gas (GHG) emissions. Unlike conventional internal combustion engine (ICE) vehicles that burn fuels directly and release harmful gases such as carbon dioxide and carbon monoxide, EVs, including hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs), emit fewer emissions. However, there are concerns that the increased demand for electrical energy by EVs may lead to GHG emissions from power plants, which must generate more electricity to accommodate the additional load from EVs. This theory is supported by the fact that peak load power plants often rely on ICE technology or use gas or coal for power generation. If EVs contribute to excess load during peak hours, it will result in the operation of such power plants and an increase in CO2 emissions. Nevertheless, it is important to note that not all power is generated from these resources, as there are alternative power generation technologies that produce fewer GHG emissions. Taking these factors into account, the GHG emissions from power plants due to EV penetration are still lower than the emissions produced by equivalent power generation from ICE vehicles. Furthermore, power plants have the advantage of producing energy in bulk, which minimizes the per unit emission. By integrating renewable energy sources effectively, which EVs can strongly support, both the power generation and transportation sectors can achieve reduced emissions. Over the lifetime of an EV, it emits less greenhouse gases compared to conventional vehicles. Denmark serves as a successful example, having managed to reduce transportation-related CO2 emissions by 85% through the combination of EVs and electric power. Additionally, EVs contribute to a significant reduction in noise pollution, particularly in urban areas. However, the recycling of lithium-ion batteries used in EVs remains a serious concern, as there are limited organizations capable of fully recycling them.

IMPACT ON ECONOMY

EV owners benefit from lower operating costs due to the superior efficiency of electric vehicles compared to internal combustion engine (ICE) vehicles. EVs can achieve efficiencies of up to 70%, whereas ICE vehicles typically have efficiencies in the range of 60% to 70%. Although the current cost of EVs is high, it is expected to decrease with mass production and improved energy policies. This reduction in cost will further enhance the economic advantages for EV owners. Additionally, EV owners can also derive financial benefits through vehicle-to-grid (V2G) technology. By providing services to the grid, EV owners can earn money from their vehicles. This allows them to not only save on operating costs but also generate income. Furthermore, power service providers also reap benefits from the integration of EVs. By implementing coordinated charging and V2G, they can optimize their peak handling strategies and effectively integrate renewable energy sources. This integration enables power service providers to

enhance their overall grid management and contribute to a more sustainable energy system.

CHARGING INFRASTRUCTURE

The growth of Electric Vehicles (EVs) heavily relies on the availability of Electric Vehicle Charging Infrastructure (EVCI). Despite the initial higher investment compared to conventional IC engine vehicles, the focus has shifted towards the environmental cost rather than the vehicle cost. To provide energy to EVs, two methods are commonly used: EV charging and battery swapping. However, for these services to be effective, standard charging protocols for EVs are necessary. In India, the government has taken various initiatives to promote the manufacturing and adoption of electric vehicles. To ensure sufficient EVCI, the Ministry of Power and Ministry of Housing & Urban Affairs have introduced guidelines and standards for its development. Additionally, existing laws have been amended, and a comprehensive framework was published in December 2018. These guidelines have been shared with all state governments and UT administrations, urging them to amend their Building Byelaws and Master Plan Regulations accordingly. The latest framework classifies EVCI into two categories: private charging facilities at residences/offices, which will be facilitated by Distribution Companies of India (DISCOMs).

Public Charging Stations (PCS)

Public Charging Stations (PCS) are an activity that does not require a license, allowing any individual or entity to establish them. However, there are certain criteria that must be met in order to set up a PCS. These criteria include meeting the technical and performance standards and protocols established by the Ministry of Power and Central Electricity Authority. These standards and protocols are periodically updated to ensure the efficient functioning of the charging stations. In addition, charging stations have the option to obtain electricity from any generation company through open access protocols. This provides flexibility in terms of sourcing electricity for the charging stations.

power and voltage levels: When it comes to Electric Vehicle Charging Infrastructure (EVCI), there are several characteristics that differentiate chargers. One such characteristic is the power and voltage levels supported by an EVCI. The output power range and voltage range determine the charging capabilities of the station.

AC or DC: Another differentiating factor is whether the output of the EVCI is AC or DC. If the output is AC, the vehicle must have an on-board charger to convert the AC power to DC power for charging.

Type: The type of output socket and connector used by an EVCI is also a distinguishing feature. Different vehicles may require different types of sockets and connectors for charging.

Mode: Lastly, the mode of communication between the vehicle and the charger is an important aspect. The communication protocol ensures effective communication and coordination between the vehicle and the charging station during the charging process.

FINDINGS

The automobile industry holds significant importance and plays a crucial role in the economic and industrial development of a country. Within this industry, electric vehicles have emerged as a segment of growth and innovation, contributing to improvements in various transportation infrastructure facilities and promoting ecological sustainability. Due to its strong associations with multiple industrial segments, the automobile industry has a constructive multiplier effect, making it vital for national progress.

In the case of India, the automobile sector plays a crucial role in the country's economy. Several demographic factors, such as increasing purchasing

power, the launch of environmentally friendly vehicles, flourishing exports, and easy access to finance, have led to a rise in automobile sales volumes. Additionally, the development of infrastructure in terms of roads, power, and testing certification facilities, along with the availability of trained manpower and supportive government policies, has made the Indian automotive industry an attractive investment destination for global auto manufacturers.

Currently, India stands as the world's second-largest manufacturer of two-wheelers and the fifth-largest manufacturer of commercial vehicles. It also holds the position of the fourth-largest passenger car market in Asia and the largest motorcycle manufacturer, indicating the immense opportunities for electric vehicles in the country. The Indian automobile market is actively promoting alternative fuels and advanced technologies, including battery-powered electric vehicles and hybrid vehicles.

To further boost the Indian automobile sector, the government has implemented various initiatives, incentives, and policies. These include the Modernization and Phase Manufacturing Programme, the Auto Policy 2002, the National Automotive Testing and Research & Development Infrastructure Project (NATRIP), and the Automotive Mission Plan 2006-2016. These measures aim to foster growth, innovation, and sustainability within the Indian automobile industry.

RECOMMENDATIONS

The present study proposes several recommendations to enhance the penetration of electric vehicles (EVs). Firstly, manufacturers should prioritize providing top-notch services and value-added features alongside product availability. This will enable companies to attract customers by offering attractive financial incentives and deals. Additionally, to stimulate sales, it is advisable for companies to collaborate with the government, banks, and financial institutions to offer vehicle loans to middle-class customers at low interest rates, thereby encouraging greater usage of EVs. Furthermore, considering the growing environmental consciousness among today's youth and their involvement in family decision-making, companies should focus on promoting and advertising their electric vehicles to this demographic. Offering additional discounts, incentives, or special offers specifically targeted at college students who plan to purchase an electric vehicle can be an effective strategy. To promote the adoption of electric vehicles, both the government and manufacturers should work towards increasing consumer awareness. In India, consumers still have concerns regarding charging infrastructure, availability of service stations, and a lack of awareness about EVs. To address these issues, companies can initiate free awareness campaigns in collaboration with their dealers. Moreover, given the continuous rise in petrol and diesel prices, customers are increasingly conscious of fuel efficiency and environmental sustainability. This presents an opportunity for companies to highlight the benefits of EVs in terms of cost savings and reduced emissions.

VI. CONCLUSION

Shifting from ICE vehicles to EVs in India can bring about numerous benefits. These advantages include a reduction in environmental pollution, decreased reliance on oil imports, enhanced national security, improved economy, and better utilization of renewable resources. The emissions from ICE-powered motor vehicles contribute significantly to air pollution in urban areas, accounting for about two-thirds of it. The current ban on older fuel cars in certain Indian cities has already demonstrated a positive impact on air quality, and this positive effect can be further amplified with the widespread adoption of EVs. Currently, ICE three-wheelers serve as the

primary mode of transportation in villages, ferrying people to bus stops and train stations. These vehicles can be swiftly converted to electric, providing clean and sustainable transportation options in rural areas. The introduction of EVs will also create opportunities in various sectors such as durable and lightweight thermoplastics, increased demand for electricity, and storage solutions, among others. Moreover, the establishment of EV battery charging and swapping infrastructure will generate a significant number of job opportunities across the country. The Indian government is actively working towards creating a conducive environment for electric mobility and has recently made significant announcements in this regard as part of the Union Budget 2019. One such announcement includes a recommendation to reduce the GST rate on electric vehicles from 12% to 5% to encourage sales in the country. Additionally, there will be an income tax deduction of ₹ 1.5 lakh on the interest paid on loans taken to purchase electric vehicles.

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