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Issues & Challenges in adoption of Electric Vehicles in India: An Empirical study using Data Analytics

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ABSTRACT

Purpose: Electric Vehicles (EVs) are becoming more and more popular in India, partly due to the government's ambitious goal of moving to 100% electric transportation by 2030. The purpose of this study is to analyze consumer preference and attitudes towards EVs and also identifying current infrastructure facilities that support adoption of EVs in India.

Design/Methodology/Approach: The study deploy both primary and secondary data. The primary data is collected through online survey across different geographic region and different age group. Secondary data include past literature, different industry report, and companies' reports.

Findings: Through critical analysis of the dataset using various IT analytical tools, study of EV market dynamics and trends in India and the factors driving/hindering growth of EV market has been examined. The energy demand has been also assessed for Transport in BAU, EV & EV + 2°C scenarios including PM 2.5 Emissions from Transport in BAU, EV & EV + 2°C scenarios using data analytics tools and the results have been exhibited as charts with critical analysis and inferences.

Originality/Value: In 2013, India unveiled the National Electric Mobility Mission Plan (NEMMP), aiming to position itself as a prominent player in the global electric vehicle (EV) market. As the nation witnesses a surge in the adoption of electric vehicles, the need for effective charging infrastructure deployment strategies becomes paramount. This paper delves into several key challenges hindering the widespread adoption of EVs in India and offers insights into potential solutions to enhance their uptake.

Paper Type: View Point.

KEYWORDS: Electric Vehicle | Compound Annual Growth Rate | Government's Strict Green House Gas | SDG

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Introduction

India is one of the fastest-growing automobile markets across the globe with potential to become the third-largest automobile market globally by 2025. India's booming transport sector has come with environmental costs: rising greenhouse gas emissions, air pollution, and energy needs.

To address these issues, the Government of India has set an ambitious target for the adoption of electric vehicles in the country. The roots of electric vehicles are found in the invention of electric battery which led to the development of early electric vehicles in 1835. Early in 20th century, the rise of the internal combustion engine and the mass production of gasoline-powered vehicles by companies like Ford made electric vehicles less common. Electric vehicles experienced surge in the late 20th century due to growing concerns over air pollution, emission of greenhouse gases, and the finite nature of fossil fuel resources. The oil crises of the 1970s highlighted the vulnerability of petroleum-based transportation systems, prompting governments and researchers to revisit electric vehicles as a viable alternative. In late nineteens, advancements in battery technology and adoption of lithium-ion batteries, which offer higher energy density and longer range, has significantly improved the viability of electric vehicles. Major automakers, including Tesla, Nissan, and BMW have introduced all-electric models with longer ranges and faster charging capabilities, making electric vehicles more appealing and practical to a broader range of consumers.

Overview of Electric Vehicle market in India

The Faster Adoption and Manufacturing of Electric (FAME) Cars scheme introduced in 2015, provides cash incentives to electric car makers and purchasers that ranges from INR 10,000 for electric two-wheelers to INR 15 lakhs for electric buses. This plan is intended to reduce the country's reliance on fossil fuels, reduce pollution and foster development of a robust EV ecosystem. The government's ambitious objective for transitioning to 100% electric transportation by 2030 is a major influence in the growth of the EV sector (Kumar et al., 2018). The various Indian states have also implemented their own policies and incentives to accelerate the adoption of electric vehicles. These measures include exemptions from road tax and registration fees, priority lanes for EVs, and installation of charging infrastructure (Khan et al., 2018). Furthermore, the decreasing cost of battery production have resulted in more affordable electric vehicles, further driving their adoption in the Indian market. Several domestic and international automotive manufacturers like Tata Motors, Mahindra & Mahindra, and Hyundai have introduced EVs in different segments, catering to the diverse needs and preferences of the consumers. The Mahindra eVerito and Tata Nexon EV are the most popular electric car models in India. Additionally, various Startups and technology companies have emerged, focusing on electric mobility solutions and providing innovative products and services.

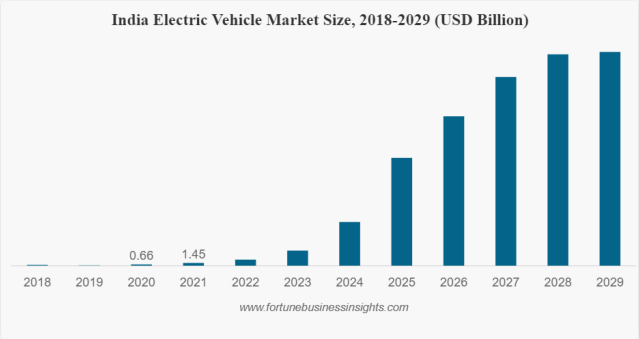

Figure 1: Market size of Electric Vehicles in India
Source: www.fortunebusinessinsight.com

In 2020, the market had a value of USD 220.1 million and a compound annual growth rate (CAGR) of 94.4% is expected for the Indian EV market between 2024 and 2030 (Kar et al., 2021). Over the course of the forecast period, market growth is expected to be fuelled by the alluring incentives offered by the Government of India on manufacture and purchase of electric vehicles. It is expected that the Government's strict Green House Gas (GHG) emission standards, such as Bharat Stage (BS) VI emission limits by M/o Road Transport and Highways will greatly contribute to market growth. Between April 2019 and March 2020, only 0.15 percent of new passenger cars were BEVs. Indian electric vehicle (EV) market had eight electric vehicle models in the start of 2021, giving Indian consumers several choices. Despite a significant drop in overall passenger and commercial vehicle sales, the epidemic had no negative impact on electric car sales in India. According to the Society of Manufacturers of Electric Vehicles (SMEV), electric vehicle sales in India increased by 109% over the course of the year, from 2,814 units in 2019 to 5,905 units in 2020.

The Tata Nexon EV accounted for more than 64% of all sales in 2020, with 3,805 units sold (Bhalla et al., 2018). India is now recognized on a global scale as one of the key nations in the automobile sector. India is currently home to a number of corporations establishing manufacturing operations (Salkuti, 2020). For instance, Dana TM4 Inc. has started a manufacturing facility in Pune, India, in September 2020. The Dana TM4 low- to high-voltage inverters, vehicle control systems, and electric motors is being manufactured at the new 4,600 square meter facility. The Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme, which is in its second phase, aims to accelerate the adoption of electric mobility and also fostering expansion of nation's manufacturing eco-system, promoting sustainable and clean mobility (Preetha & Poornachandran, 2019)

Types of Electric Vehicles

There are various types of Electric Vehicles:

(a) Battery Electric Vehicles (BEVs): which are fully electric vehicles that run solely on electricity. They are powered by rechargeable batteries, typically lithium-ion, which store electricity and provide power to the electric motor. BEVs do not have an internal combustion engine, fuel tank, or exhaust system. They offer zero tailpipe emissions, making them environmentally friendly. Notable examples of BEVs include Tesla Model S, Nissan Leaf and Chevrolet Bolt.

(b) Plug-in Hybrid Electric Vehicles (PHEVs): They pair an internal combustion engine with an electric motor. They can be charged through an external power source and feature larger battery packs than typical hybrid vehicles. Before switching to the internal combustion engine, PHEVs can run exclusively on electric charge for a limited amount of time. Flexibility and a longer range are provided by these dual power capabilities. PHEVs use less fossil fuels than other types of vehicles but still produce some emissions. The Toyota Prius Prime, Mitsubishi Outlander PHEV and BMW i3 REx are some of the PHEVs.

(c) Hybrid Electric Vehicles (HEVs): A combination of an internal combustion engine and an electric motor is used in HEVs. For better fuel economy and reduced emissions, HEVs leverage electric motors that assist with low-speed driving and acceleration. These self-charging motors (powered by the engine and regenerative braking) set HEVs apart from plug-in hybrids. Popular HEVs like the Toyota Prius, Honda Insight, and Ford Fusion Hybrid offer superior fuel efficiency compared to traditional gasoline vehicles.

(d) Extended Range Electric Vehicles (EREVs): These function similarly to PHEVs but have a larger battery and a longer range on electricity alone. When the battery is empty, EREVs switch to an internal combustion engine to produce energy. Electric motors are used as vehicle's primary means of propulsion. This enables an increased driving range without relying on the infrastructure for charging, example Chevrolet Volt.

(e) Fuel Cell Electric Vehicles (FCEVs): It uses hydrogen fuel cells to generate electricity, which powers the electric motor. FCEVs are powered by a clean reaction between hydrogen and air oxygen. This process generates electricity and emits only water vapor. While offering long driving ranges and quick refuelling times, FCEVs face a hurdle: a limited network of hydrogen fuelling stations. Examples include the Toyota Mirai and Hyundai Nexo.

(f) Neighbourhood Electric Vehicles (NEVs): These are small, low-speed electric vehicles designed for local commuting. They typically have limited top speeds ranging from 20 to 45 mph, and are used in neighbourhoods, gated communities, resorts and industrial complexes.

(g) Electric Bicycles (e-bikes): Electric bicycles, or e-bikes, are bicycles equipped with an electric motor and battery. The motor assists pedalling and provides additional power, making cycling easier, especially on uphill terrains or longer distances. E-bikes come in various configurations, including pedal-assist (where the motor activates when the rider pedals) and throttle-based (where the motor activates with a twist or push of a button).

In a push for clean transportation, the Indian government set an ambitious target in 2018: 30% of all new vehicle sales to be electric by 2030. This goal aligns with India's commitment to the Paris Agreement and aims to reduce dependence on imported oil. Electric vehicles, beyond boosting energy security, have the potential to significantly cut India's greenhouse gas emissions and air pollution.

Literature Review

Kumar K et al., (2022), compares Indian electric vehicle charging stations(EVCS), its types, charging methods, connector guns, charging modes, testing and certification with respect to international standards such as European Union, China, Japan, Germany, United States and the International Organization for Standardization (ISO). The larger recommendation is to use combined charging system (CCS) as it requires a single connector support for both AC and DC charging, high power capacity and widely accepted by international EV manufacturers.

Bhattacharyya & Thakre, (2021), highlighted the shift from gas-powered cars to cleaner, more eco-friendly electric vehicles (EVs) powered by batteries in Indian auto sector. The authors analysed consumer preference for EVs by analysing six key parameters: charging duration, charging station accessibility, cost, model variety, rebates, and warranty. Notably, the study found a strong correlation between the time it takes to fully charge an EV and the closeness of charging stations. This suggests that charging speed and station availability are crucial factors influencing consumer decisions.

Goel et al., (2021) discussed the difference between the modelling approaches and optimization strategies for pure electric vehicles, hybrid electric vehicles, plug-in hybrid electric vehicles and battery electric vehicles. What sets this study apart is its focus on resolving issues specific to developing nations like India, such as fundamental obstacles and inadequate charging infrastructure. Vehicle-to-grid is a novel concept that can be used to supplement the power grid in the event if renewable energy sources are not accessible.

Rajper & Albrecht, (2020), conducted systematic study of data of (2010-2020) on viability of rampant use of EVs in developing countries has been undertaken by analysing

statistics from 35 papers in Google Scholar and Web of Science using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) criteria. The study concluded that electric four-wheelers are not absolute viable alternative in developing countries due to infrastructural deficiency and exorbitant pricing of EVs.

Ahmad et al., (2020) discusses the merits of Intelligent Battery Swap Station (BSS) architecture that can support widespread deployment of hybrid and electric vehicles (i.e. xEVs) which would follow the same procedure as used in extant gasoline refuelling stations wherein the entirely drained batteries are swapped with partially/fully charged ones. The BSS method has emerged as an attractive alternative to the conventional EV charging station method since it opens up more economic opportunities for the relevant parties. Finally, S34X-smart switching station for EVs has been highlighted and recommended.

Research Objectives

The main objectives of study is to exhaustively analyse the following using IT analytical tools:

a) Analysis of market dynamics and trends in EV market in India, including the factors driving and hindering the growth of EV market.

b) Identification of the policy interventions required to accelerate the growth of EV market in India, including incentives, subsidies, and regulatory measures.

c) Analysis of the infrastructure investments required to support the growth of EV market in India, including charging infrastructure, battery manufacturing and recycling facilities.

d) Understanding of the consumer preferences and attitudes towards EVs in India through surveys and focus groups.

e) To analyze the Final Energy Demand (in Mtoe) for Transportation across scenarios including Business-As-Usual (BAU), Electric Vehicle (EV), and EV + 2°C scenarios.

f) To assess the PM 2.5 Emissions (in tonnes) originating from Transportation under different scenarios: Business-As-Usual (BAU), Electric Vehicle (EV), and EV + 2°C scenarios.

Research Methodology

Exhaustive Online surveys through Google forms comprising of fields that influence the adoption of EVs in India, such as government incentives, fuel prices, environmental concerns, charging stations, battery manufacturing etc. have been utilised to collect data from a large pool of respondents. The dataset has been divided in different age bracket of 18-24, 25-34 and remaining above the age of 34 years. The population is stratified by geographic region, age, gender, income, infrastructure and other relevant factors.

Secondary data sources, such as government reports, industry publications and academic journals have been used to gather data on the current state of EV adoption in India as well as the factors that may influence future adoption of EVs in the country.

Data Analytics and Observations

The study and analysis of the data exhibits the following critical results as discussed below:

Factors influencing individuals' decision regarding adopting EVs: Out of the entire respondents, 44 respondents expressed their affirmation towards purchasing an electric vehicle in next 5 years whereas 26 expressed disagreement and 10 were unsure about their preference. The following chart represents the factors that influence individuals' decisions regarding adopting electric vehicles (EVs).Out of the total, 21 individuals cited lower fuel/operating costs as a motivating factor for considering an EV. This suggests that they are attracted to the potential cost savings associated with EVs compared to traditional fuel-powered vehicles. Environmental concerns were mentioned by 19 individuals, indicating that they prioritize the reduction of carbon emissions and are driven by the desire to make a positive impact on the environment.

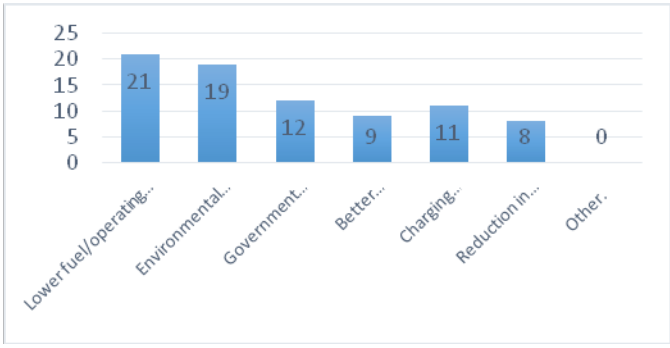

Figure 2: Factors Influencing Individuals' Decisions regarding adopting EVs (Source: Author)

Government incentives or subsidies were identified as a factor by 12 individuals. This suggests that they are influenced by the financial support or incentives provided by Government to encourage the adoption of EVs, which can include tax credits, rebates or other monetary benefits. A smaller number of individuals, (9 in number), mentioned better performance/features as a reason for considering an EV. This suggests that they are attracted to the technological advancements and benefits that EVs offer in terms of

performance and additional features. Charging infrastructure availability was highlighted by 11 individuals, indicating that they consider the accessibility and availability of charging stations as an important factor in their decision-making process. This suggests that the availability of a reliable and convenient charging network is crucial for the widespread adoption of EVs.

Factors hindering individuals' decision regarding adoption of EVs: The following chart depicts the factors that may hinder respondent's adoption of EV and its associated technology. Out of the entire dataset, 18 individuals identified high upfront cost as a significant factor. This suggests that the initial investment required to purchase an EV is perceived as a barrier for potential buyers. Limited charging infrastructure was mentioned by 12 individuals, indicating that the availability and accessibility of charging stations are seen as a potential obstacle. The need for a reliable and widespread charging network is crucial. Insufficient driving range was highlighted by 10 individuals, suggesting that the distance an EV can travel on a single charge is a concern for them. The lack of vehicle options/models was mentioned by 15 individuals, indicating that they feel that there are limited EV models available in the market. This suggests that individuals may deter from buying an EV if they perceive lack of variety in terms of vehicle types, sizes or features that align with their preferences and needs.

Battery life and degradation were cited by 12 individuals as a potential concern. This suggests that they have reservations regarding longevity and performance of EV batteries over time, including concerns about degradation and the cost of battery replacement. Uncertainty about maintenance and repairs was mentioned by 9 individuals, indicating that they are unsure about the maintenance requirements and associated costs of owning an EV. This highlights the need for awareness and education regarding EV maintenance, servicing and repair options.

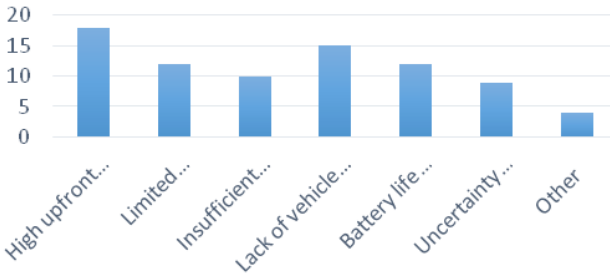

Figure 3: Factors hindering Individuals' Decisions regarding adopting EVs

(Source: Author)

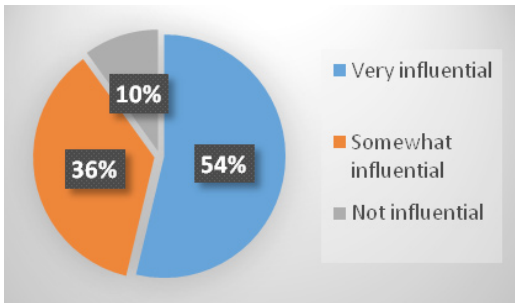

Figure 4: GoI Policies Influencing Adaptation of EV

(Source: Author)

Influence of Government of India's Policies: The following chart depicts that majority of the respondents find government incentives and policies "Very influential" in their decision to purchase/consider an EV. This indicates that Government incentives and policies play a significant role in shaping their choices. Additionally, 29 respondents stated that Government incentives and policies are "Somewhat influential". A smaller group of respondents indicated that Government incentives and policies are "Not influential" in their decision in EV adaptation. However, the majority of respondents find Government incentives and policies influential or somewhat influential in their decision to purchase or consider an electric vehicle, highlighting the importance of such measures in promoting the adoption of electric vehicles in the country.

Analysis of Energy Demand (Mtoe) for Transport in BAU, EV & EV + 2°C Scenarios The following chart depicts rise in widespread adoption of electric vehicles. A "business-as-usual" approach (BAU) for transportation predicts a significant rise in final energy demand. This is driven by population growth, urbanization, and a surge in vehicle ownership. Under this scenario, fossil fuels like gasoline and diesel are likely to remain dominant, potentially leading to a substantial increase in overall energy consumption for transportation.

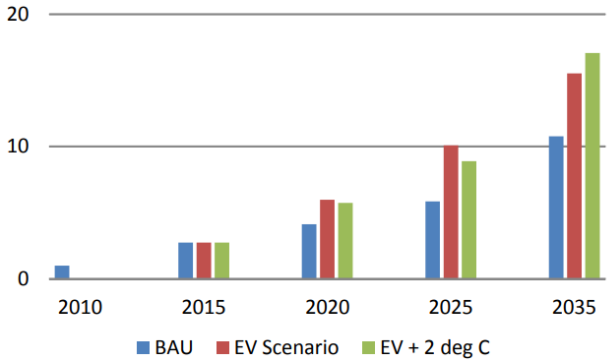

Figure 5: Final Energy Demand (Mtoe) for Transport in BAU, EV & EV + 2°C Scenarios

(Source: Author)

In an EV scenario, the adoption of electric vehicles can significantly impact the final energy demand for transport. Electric vehicles are more energy-efficient compared to internal combustion engine vehicles and their usage can reduce the demand for petroleum-based fuels. The shift towards electric vehicles would increase the demand for electricity to power these vehicles but it would also lead to reduction in the demand for fossil fuels in the transport sector.

The EV + 2°C Scenario is aimed at limiting global warming to 2 degrees celsius above pre-industrial levels for smooth transition to EVs and other low-carbon transportation options. Curbing greenhouse gas emissions necessitates a significant transition to low-carbon and renewable energy sources. This scenario outlines a future with a dramatic rise in renewable energy generation, particularly solar and wind power. It would also see a decline in reliance on fossil fuels. Nuclear power could potentially play a significant role in reducing emissions, but its inclusion depends on regional policies and government stances.

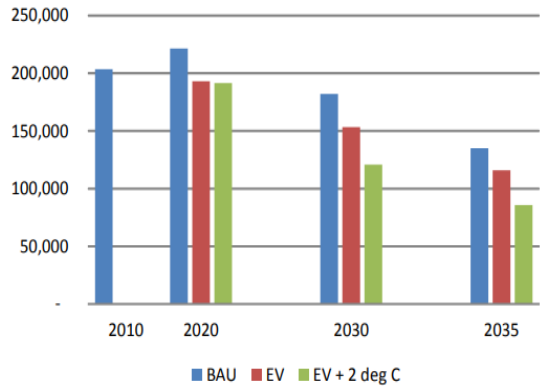

Figure 6: PM2.5 Emissions (tonnes) from Transport in BAU, EV & EV + 2°C Scenarios

(Source: Author)

PM2.5 Emissions (tonnes) from Transport in BAU, EV & EV + 2°C Scenarios: PM2.5 refers to fine particulate matter with a diameter of 2.5 micrometres or less. Transport-related emissions, such as exhaust emissions and tire wear, contribute to the overall PM2.5 pollution in urban areas. PM2.5 emissions from transport can vary depending on the number of vehicles, type of vehicles (e.g., gasoline, diesel, electric), driving patterns, fuel quality, emission control technologies, and traffic congestion. Additionally, regional and local factors, such as topography, climate conditions, and urban design can also influence PM2.5 emissions from the transport sector. To reduce PM2.5 emissions from the transport sector, various measures can be implemented including improving fuel quality and vehicle emissions standards, promoting use of cleaner fuels (e.g., low-sulphur diesel, biofuels) encouraging adoption of electric vehicles, implementing vehicle inspection and maintenance programs, promoting public transportation and active transportation modes (e.g., walking, cycling), and implementing traffic management strategies to reduce congestion.

The transition to electric vehicles (EVs) and the implementation of low-carbon transportation strategies in the EV and EV + 2°C scenarios would likely have positive effects on reducing PM2.5 emissions compared to the BAU scenario.

Conclusion

Europe and Norway were one of the early leaders in EV adoption with a significant number of EVs on road. Other countries such as France, Netherlands, and Germany also have a growing number of EVs, although the overall stock is relatively small compared to conventional vehicles. The adoption and growth of electric vehicles (EVs) in India holds great significance for addressing environmental challenges, improving public health, enhancing energy security, driving technological advancements, exploring economic opportunities and shaping effective policies. EVs offer numerous advantages, including reduced emissions, energy efficiency, lower operating costs and improved air quality. India, with its vast population and rapidly growing urban infrastructure stands to benefit greatly from the widespread adoption of EVs. By embracing electric vehicles, India can reduce its dependence on imported fossil fuels, mitigate air pollution, improve energy security, create green jobs and would contribute to global efforts in combating climate change. The transition to electric mobility aligns with India's sustainable development goals and positions the country as a leader in the clean energy and transportation sector. With the announcement of the National Electric Mobility Mission Plan (NEMMP) in 2013, India set out to become a global leader in the production of electric vehicles and their parts. Several challenges, including the high upfront cost of electric vehicles, limited charging infrastructure and consumer awareness and acceptance have hindered the growth of the electric vehicle market in India (Gujarathi et al., 2018). However, Electric vehicles require a different set of technologies, components and supply chains compared to traditional internal combustion engine vehicles. Understanding the challenges and opportunities associated with electric vehicle manufacturing and supply chains will be critical for India's automobile industry to remain competitive in the global market (Husain et al., 2021). India has made commitments to reduce greenhouse gas emissions under international agreements such as the Paris Agreement. The widespread adoption of EVs aligns with these commitments and showcases India's commitment to mitigating climate change. By embracing electric mobility, India can contribute to global efforts in reducing emissions and transitioning to a low-carbon economy, an endeavour towards Green India.

Recommendations

As the number of electric vehicles (EVs) rises, India needs optimal charging infrastructure deployment strategies. This focus on EV infrastructure will drive advancements in several areas: more efficient batteries, faster charging solutions, and improved grid integration capabilities. These innovations extend beyond EVs, benefiting sectors like energy storage and renewable energy integration, ultimately propelling overall technological progress.

Development of indigenous battery manufacturing capabilities and potential for recycling and reuse of EV batteries should be taken up vigorously.

Synergies between EVs and renewable energy sources are required. Integration of EV charging with solar and wind energy generation, grid management and demand response programs may be explored and initiated. Assessment of environmental and economic benefits of coupling EVs with renewable energy, including greenhouse gas emissions reduction and energy cost savings may be undertaken.

To fully realize the potential of EVs in India, it is crucial to address challenges such as development of robust charging infrastructure, promoting domestic manufacturing and innovation, longevity issue of battery charging through battery technology advancements and creating supportive policies and regulations. Continued efforts are needed to build consumer awareness, provide financial incentives and encourage public-private partnerships to accelerate EV adoption.

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Annexure 16.1.6

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Reviewers Memorandum

Reviewer's Comment 1: The relevance of this topic is paramount in today's era, particularly within the Indian context, where the burgeoning transport sector has brought forth significant environmental ramifications, including escalated greenhouse gas emissions, air pollution, and heightened energy demands. This paper endeavors to explore the contemporary landscape of electric vehicles (EVs) in India, examining the prevailing trends, the state of infrastructure, and governmental initiatives. The author has conducted both primary and secondary research to delve into this multifaceted domain.

Reviewer's Comment 2: Although the author has employed both primary and secondary research methods, the primary study's sample size is less which raises concerns about its representativeness. A more extensive sample would yield more robust insights into the challenges surrounding the adoption of electric vehicles in India. However this provides a scope for future research.

Reviewer's Comment 3: A more comprehensive review of existing literature would enhance the paper's credibility and provide a stronger theoretical framework for the empirical findings. The article is well-structured and easy to follow. However, some sections could be further refined for clarity.

Citation

Namrata Agrawal and Prakhar Bisht
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Conflict of Interest: Author of a Paper had no conflict neither financially nor academically.

Editorial Excerpt

The article has 10% of plagiarism which is the accepted percentage as per the norms and standards of the journal for publication. As per the editorial board's observations and blind reviewers' remarks the paper had some minor revisions which were communicated on a timely basis to the authors (Namrata and Prakhar), and accordingly, all the corrections had been incorporated as and when directed and required to do so. The comments related to this manuscript are noticeably related to the theme "**Issues & Challenges in adoption of Electric Vehicles in India: An Empirical study using Data Analytics**" both subject-wise and research-wise. The paper presents a comprehensive examination of the challenges and opportunities associated with the adoption of electric vehicles (EVs) in India, contributing valuable insights to the discourse on sustainable transportation. However, clear articulation of the data collection techniques, sampling methods, and analysis procedures would not only strengthen the rigor of the study but also offer transparency to readers, facilitating a better understanding of the research process. The use of data visualization tools such as graphs and frequency charts for data analysis is commendable. After comprehensive reviews and the editorial board's remarks, the manuscript has been categorized and decided to publish under the "**View Point**" category.

Acknowledgement

The acknowledgement section is an essential component of academic research papers, as it provides due recognition to all those who contributed their hard work and effort towards the writing of the paper. The author/s (Namrata and Prakhar) express their sincere gratitude to all those who assisted in the research process and made this paper a possibility. Lastly, the reviewers and editors of GJEIS deserve recognition for their pivotal role in publishing this issue, without whom the dissemination of this valuable research would not have been possible.

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