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Green Mobility: Promoting Electric Vehicles for a Sustainable Future in India

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Abstract

In order to achieve environmental sustainability, green transportation is essential, and electric vehicle (EV) marketing in India is a key component of this shift (Rehman et al., 2023). Adoption of EVs offers an environmentally suitable substitute for traditional automobiles in light of growing pollution levels and a growing reliance on fossil fuels (Tilkar et al., 2024). The transition to electric mobility has been sped up by government programs including the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, subsidies for taxes, and the development of charging infrastructure. The viability of EVs is also being improved by developments in the battery technology and the incorporation of renewable energy. But issues including exorbitant upfront costs, a shortage of charging points, and battery disposal issues must be resolved. Promoting EV adoption requires a cooperative strategy combining consumers, businesses, and legislators. Electric mobility is a key component of a better future since it may help India cut carbon emissions, import less oil, and stimulate economic growth.

Key words: - Electric mobility, sustainability, EV Ecosystem, Technology and inovation

Introduction

Vehicle emissions have significantly increased as a result of India's fast industrialisation and urbanisation, which has exacerbated air pollution and accelerated climate change. One sustainable way to lessen these environmental issues is through green mobility, especially the use of electric cars (EVs) (Iflah Aijaz & Aijaz Ahmad, 2021). EVs have many advantages, including as decreased carbon emissions, less reliance on fossil fuels, and improved energy efficiency (Ghosh, 2020). The Indian government has seen the promise of electric mobility and has implemented a number of programs to encourage the use of EVs, including the Faster use and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, tax breaks, and subsidies (Arora & Gargava, 2023; Sreeram et al., 2019). The transition to sustainable mobility is also being accelerated by developments in battery technology, the development of charging infrastructure, and the incorporation of renewable energy sources (D'Adamo et al., 2022). High upfront prices, a lack of adequate charging infrastructure, and problems with battery recycling continue to be major obstacles in spite of these efforts (Alanazi, 2023). To overcome these obstacles and guarantee a more sustainable and environmentally friendly

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future for Indian transport sector, a cooperative strategy involving consumers, businesses, and politicians is essential (Ramanathan, 1996).

Objective

- To evaluate how electric vehicles (EVs) will help India achieve a sustainable future and encourage green mobility.
- To Examining the state of EVs now and contrasting India's development with that of world leaders like Europe and China,
- To provide suggestions for quickening the adoption of EVs in India, the study incorporates insights from China and Europe.

The EV Ecosystem: India, China, and Europe

Globally, the EV (electric vehicle) ecosystem is changing quickly, and Europe, China, and India are becoming important hubs in the shift to sustainable mobility. Driven by infrastructural development, regulatory support, and technology breakthroughs, each region has implemented distinct tactics to encourage the use of electric vehicles (Altenburg et al., 2016).

China: The Global Leader in EV Adoption

With more than half of all EV sales worldwide, China is the market leader. The nation has made significant investments in domestic EV manufacture, charging infrastructure, and battery technologies (Yessaulkov & Gondal, 2024; Wu, 2024). The growth of EVs has been pushed by policies like the New Electricity Vehicle (NEV) requirement, strict emission standards, and government subsidies. Big Chinese automakers such BYD and NIO have been instrumental in lowering the cost and increasing the accessibility of EVs(Fu, 2023).

Europe: Driving Green Innovation

Europe is leading the world in EV adoption thanks to stringent environmental laws and emission standards. Large-scale EV subsidies and the growth of charging networks are the results of the European Union's (EU) strict CO2 emission targets (Chen Tang et al., 2022). With robust legislative backing, tax breaks, and growing investments in battery manufacturing, nations like Germany, Norway, and Netherlands are spearheading the shift (Dijk et al., 2020).

India: An Emerging EV Market

Although it is still in its infancy, India's EV ecosystem is expanding gradually with the support of the government. EV adoption is being aided by state-level subsidies and incentives as well as the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) program (Vyas & Kushwah, 2023). But there are still issues that need to be resolved, like a lack of adequate charging infrastructure, expensive batteries, and customer awareness. Notwithstanding these challenges, long-term growth is anticipated as a result of India's

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emphasis on domestic EV manufacture, integrated renewable energy, and localised battery production. A graph displaying important indicators including EV market share, government subsidies, and charging infrastructure is shown to give a comparative study of the EV ecosystems in China, India, and Europe (Habib et al., 2017).

Do the largest auto markets outperform or underperform the global average?

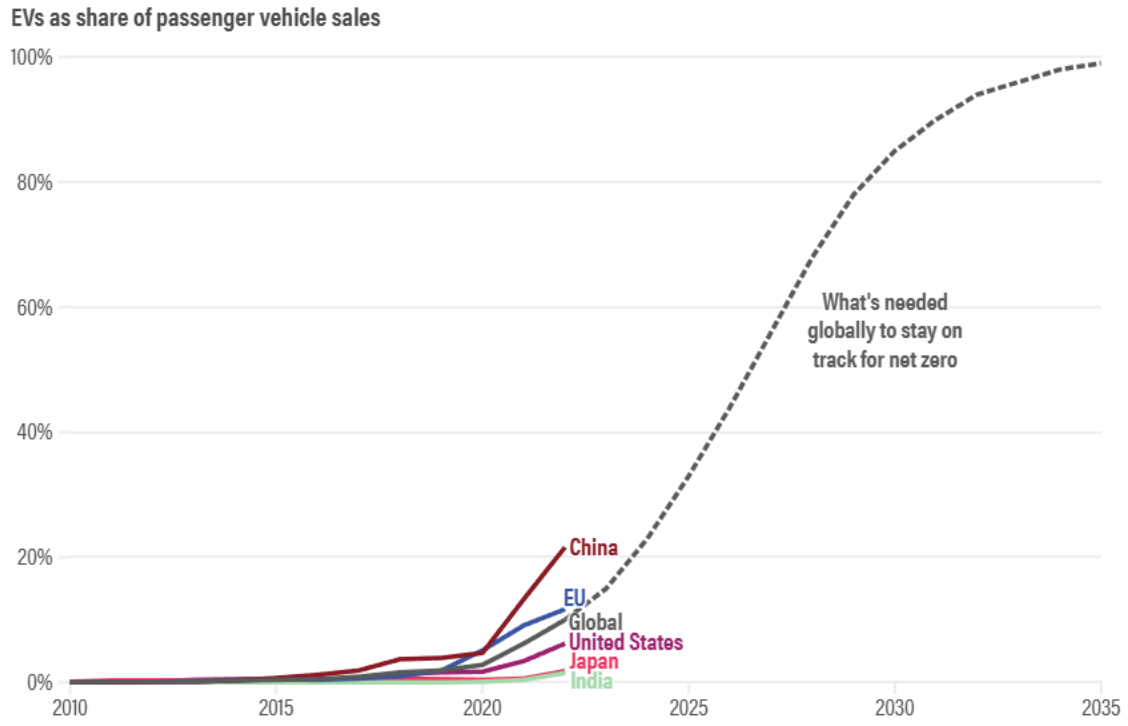

Figure 1 IEA Report

The success of the three largest auto markets—China, Europe, and the United States—which together account for 60% of all worldwide auto sales, will have a significant impact on the global shift to electric vehicles. In recent years, EV sales have increased significantly in all three areas (Borucka et al., 2024). At the moment, China's percentage of EV sales is double the global average. Europe's share of EV sales is somewhat higher than the global average. With a 6.2% EV sales share in 2022—exactly the same as the global average in 2021—the United States lags behind the global average by roughly a year. Japan and India, which are the fourth and fifth largest auto markets, respectively, continue to have low car sales. They are, nevertheless, at last starting to pick up speed, and as the latest sales data has demonstrated, late-adopting nations frequently see higher growth than early adopters.

Policy Interventions and Incentives

China's EV Policies

Thanks to aggressive government policies and well-timed interventions, China has become a global leader in the adoption of electric vehicles (EVs). The nation's New Energy Vehicle

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(NEV) policy encourages mass production and sales by requiring automakers to satisfy certain EV production goals. Furthermore, China has given EV buyers substantial tax breaks and subsidies, albeit these benefits are being phased out as the industry develops. With more than 2.5 million charging points spread across the country, China's investment in electrical infrastructure for charging has been a major factor in its success and has made using EVs more convenient. To ensure scientific breakthroughs and cost reductions, the government has also implemented strict emission rules and provided research and development (R&D) funding for battery technology. Additionally, by offering incentives, priority lane access, and reduced registration costs, local governments aggressively encourage the use of EVs. Because of these all-encompassing policies, China is now the market leader for EVs worldwide, propelling innovation, affordability, and widespread adoption.

Europe's EV Policies

With strict environmental laws and robust policy backing, Europe has become a leader in the adoption of electric vehicles (EVs). Automakers are forced to switch to EV production or risk severe penalties due to the European Union's (EU) stringent CO2 emission limits. To entice people to convert to electric vehicles, several European nations provide subsidies, tax reductions, and buying incentives. For example, Norway offers significant tax breaks and subsidies, which cause EVs to make up more than 80% of sales of new cars. Financial subsidies are also available in France, Germany, and the Netherlands, which lowers the cost of EVs. With EU-backed initiatives financing the construction of high-speed charging networks around the continent, infrastructure development is a top priority. The adoption of EVs is further accelerated by the European Green Deal's goal of becoming carbon neutral by 2050. Automakers are also being pressured to make significant investments in electric mobility by rules like the EU's 2035 prohibitions on the sale of new petrol and diesel vehicles. Europe's strategy is establishing a global standard for environmentally friendly transport thanks to stringent laws, funding, and infrastructure development.

India's Policy Landscape

Government efforts to lessen reliance on fossil fuels and reduce pollution are driving a rapid evolution in India's EV (electric vehicle) policy environment. The foundation of India's EV policy is the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) program. When FAME-I was first introduced in 2015, its primary goal was to offer financial assistance for electric bikes, three-wheelers and public transportation vehicles. ₹10,000 crore is allotted by the current FAME-II (2019–present) to encourage the use of EVs, with a focus on commercial fleets, electric bus subsidies, and the construction of charging infrastructure. The Production-Linked Incentive (PLI) Scheme encourages investments in lithium-ion batteries battery production by providing financial incentives to EV and battery producers in

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order to increase domestic manufacturing. In order to encourage local adoption, a number of governments have implemented state-specific EV laws that provide extra subsidies, exemptions from road taxes, and waivers of registration fees. The government has also introduced tax breaks, including as income tax deductions for EV loans and lowered the rate of GST on EVs (from 12% to 5%). A sustainable EV ecosystem is also being shaped by programs like the National Electric Mobility Mission Plan (NEMMP) and laws that encourage the incorporation of renewable energy. India's legislative framework seeks to establish a strong EV industry through financial incentives, industrial support, and infrastructure expansion, despite ongoing obstacles including high battery costs and inadequate charging infrastructure.

Market Growth and Consumer Behavior

The market for electric vehicles (EVs) is expanding quickly in Europe, China, and India due to a variety of factors, including customer preferences, infrastructural development, and governmental regulations. India is becoming a high-potential marketplace for electric mobility, Europe is a leader in policy-based adoption, and China is the world leader in EV sales and manufacture.

1. China: The World's Largest EV Market

With more than 50% of all EV sales occurring in China, the country leads the global EV market. It is anticipated that the Chinese EV industry would keep growing because to active government initiatives, domestic manufacture, and a sophisticated charging infrastructure. Leading innovators like BYD, NIO, and XPeng are advancing the technology and lowering the cost of EVs. high adoption of EVs as a result of reduced operating costs, city fuel vehicle limits, and government subsidies. Because local products are more affordable and use cutting-edge battery technology, consumers like them over those made in other countries. All vehicle sections, including automobiles, business fleets, and two-wheelers, are driving growth.

2. Europe: Policy-Driven EV Adoption

With nations like Germany, Norway, and the Netherlands spearheading the shift, European is the second-largest EV market. EV adoption is being accelerated by stricter CO2 emission regulations and 2035 ICE car prohibitions. Demand has been further stimulated by the European Green Deal and benefits such as tax breaks and purchasing subsidies. EV adoption is encouraged by European customers' strong environmental sensitivity. Premium and high-performance EVs are preferred by consumers, and sales of these vehicles are dominated by companies like Tesla Motors, Volkswagen, and Renault. Large investments have been made in high-speed charging networks throughout Europe as a result of consumer preference for charging convenience.

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3. India: An Emerging EV Market

With electric motorcycles (E2Ws) and three-wheelers accounting for over 60% of all EV sales, India's EV sector is still in its infancy. Local EV manufacturing is being stimulated by government programs such as FAME-II and PLI subsidies. By 2030, the industry is expected to reach $150 billion because to growing investments from indigenous companies including Ather Energy, Ola Electric, and Tata Motors. Given the high initial cost of EVs, price sensitivity continues to be a significant issue driving EV adoption. Despite ongoing advancements, range anxiety and a lack of charging facilities influence purchasing decisions. With a greater demand for bicycles with electric power and last-mile delivery vehicles than for passenger automobiles, the Indian market is distinct.

Technological Innovations and Infrastructure Development

The adoption of electric vehicles (EVs) in Europe, China, and India is primarily driven by technological advancements and the expansion of infrastructure. One of the most significant developments in battery technology is that China is now the world's top producer of lithium-ion batteries thanks to firms like CATL and BYD, which are at the forefront of solid-state and high-energy-density batteries for increased range and quicker charging. In an effort to lessen its reliance on rare earth resources, Europe is making significant investments in environmentally friendly battery manufacturing and recycling initiatives. Under the Production-Linked Incentive (PLI) program, India is concentrating on localised battery manufacturing while investigating more affordable options such as domestic lithium-ion and sodium-ion batteries (alex scott, 2022). With more than 2.5 million both private and public charging points, including incredibly quick 800V DC chargers, China has created the greatest network of charging infrastructure in the world. With the installation of superchargers along major highways by businesses like Ionity and Tesla, Europe is growing its high-speed charging networks. While still in its infancy, India is developing battery-swapping technology and interstate fast-charging facilities, specifically for electrified two- and three-wheelers. Smart transportation methods are improving EV efficiency in addition to charging. To maximise energy use, China is combining autonomous driving technologies, V2G (vehicle to grid) systems, and AI-powered battery management. In order to encourage the use of renewable energy, Europe is concentrating on EV-friendly urban planning and supporting smart electricity networks and solar-powered charging stations. AI-driven batteries monitoring systems and app-based charging networks are becoming more popular in India, where they are enhancing fleet management and maximising energy use (Senthilkumar et al., 2021). All things considered, Europe is leading the way in smart and sustainable mobility solutions, India is promoting affordable technologies, and China is leading the way in large-scale battery manufacture and quick infrastructure construction. The long-term viability of the

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global EV market will depend on sustained investment in digital connectivity, charging infrastructure, and battery technology.

Sustainability Impact of Electric Vehicles

As major markets like Europe, China, and India accelerate EV adoption, the shift is helping to reduce climate change and minimise dependence on fossil fuels. The broad adoption of battery-powered vehicles (EVs) has significant effects on sustainability, contributing to lower carbon emissions, lessen air pollution, and a shift towards renewable energy integration. One of the most significant advantages of electric cars (EVs) is that they emit fewer greenhouse gases (GHGs) than internal combustion engines. In China, the proliferation of battery electric cars (BEVs) and hybrid EVs has greatly decreased the transportation sector's carbon footprint, aided by a sharp rise in solar energy-powered charging points. Europe's strong CO_2 emission rules and Green Deal policies promote the adoption of solar- and wind-powered EV charging infrastructure, making it a leader in decarbonising transportation. India, although being reliant on coal for electricity, is incorporating solar and wind energy into its Evs ecosystem to make charging environmentally friendly (Shariff et al., 2018). EVs also help to reduce air pollution, particularly in towns and cities. Countries with strong EV adoption, such as Norway and the People's Republic have reported better air quality and lower dependency on petroleum-based fuels. India, where cities like Delhi and Mumbai have severe air pollution, is encouraging the use of electric two- and three-wheeled vehicles for last-mile connection, which will assist to reduce pollution from traditional fuel-powered cars (Vermani et al., 2020). However, sustainability issues persist, particularly in the manufacture of batteries and recycling. The extraction of nickel, cobalt, and lithium for EV batteries causes environmental concerns. To remedy this, Europe is investing in recycling battery technology, and China is developing closed-loop batteries supply chains to boost sustainability. India is also developing battery swapping and second-life battery uses to reduce waste and expenses. Overall, EVs have a positive sustainability impact, as they reduce emissions, improve air quality, and promote the use of renewable energy. However, continued developments in green battery technologies, infrastructure for charging and recycling techniques will be required to fully realise their environmental benefits worldwide (Chaudhari, 2024)

Challenges and Barriers

Despite the rapid expansion of electric cars (EVs) worldwide, a number of hurdles and barriers prevent mainstream adoption, particularly in Europe, China, and India. These issues include high initial costs, insufficient charging facilities, battery supply chain bottlenecks, and policy uncertainty. One of the greatest challenges to EV adoption is their high initial cost, which is primarily due to pricey battery technology. While battery costs are gradually falling, lithium-ion batteries remain expensive, making electric vehicles less accessible than traditional ICE vehicles, particularly in price-sensitive areas such as India. To combat that,

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governments provides subsidies and tax incentives. However, a long-term sustainability remains a challenge (Kumar et al., 2024). Another key issue is a lack of charging infrastructure, especially in developing markets. China leads in the implementation of charging stations, although rural areas continue to lack access to high-speed chargers. Europe is extending its fast-charging networks, but the requirement for consistent charging protocols and interoperability remains a concern. In India, the charging network is still in its early stages, with most stations concentrated in metropolitan regions, limiting EV adoption in smaller cities and villages. The battery chain of supply and raw material dependencies present additional issues. The production of cobalt, lithium, and nickel—critical components in EV batteries—is reliant on a few resource-rich countries, resulting in supply chain weaknesses and price volatility. China dominates the manufacturing of batteries, but India and Europe are investing in domestic battery manufacture and recycling schemes to minimise their reliance on imports (Jetin, 2023). Uncertainty about policies and regulations also has an impact on EV adoption. While China and Europe have established specific emission reduction targets and EV regulations, India is still fine-tuning its long-term EV plans. Automakers and investors face uncertainty due to unclear incentive structures, fluctuating tax policies, and uneven state-level laws. Finally, range anxiety and consumer perception are still concerns. Many potential purchasers are concerned about limited driving range and long charging times, but advances in battery technology and fast-charging technologies are addressing these issues. Furthermore, a lack of customer awareness of the benefits of electric vehicles, concerns about resale value, and restricted model availability all contribute to sluggish adoption.

Lessons for India from China and Europe

India can take useful lessons from Europe and China in order to accelerate the adoption of electric vehicles (EVs) and establish a strong sustainable transportation ecosystem. China's success in the EV market is fuelled by strong government policies, such as the New Energy Vehicle (NEV) mandate, which establishes explicit production objectives for automakers, and enormous expenditures in charging infrastructure. India may take a similar approach by enacting long-term EV policy, providing consistent incentives, and maintaining solid regulatory frameworks to encourage investment. China's massive charging network, which includes more than 2.5 million charging points, emphasises the necessity of large-scale infrastructure investment, which India must prioritise. Furthermore, considering India's reliance on two- and three-wheelers, China's investment in battery-swapping technology could prove transformative (Kumar & Singh, 2023). Europe has implemented sustainable EV legislation and emission control measures, including strong CO_2 reduction objectives and renewable energy-powered charging networks. India can learn from Europe's urban planning and smart grid integration to ensure that its EV transition is consistent with overall clean energy aspirations. Furthermore, Europe's emphasis on battery recycling and circular

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economy practices serves as a model for India to create sustainable battery disposal and reuse techniques, lowering environmental effect and reliance on raw material imports. India can create a comprehensive electric vehicle roadmap by combining China's large-scale infrastructure approach with Europe's sustainability-driven legislation. Expanding charging infrastructure, increasing domestic battery manufacture, enforcing tight emissions standards, and offering tailored incentives will be critical to emulating worldwide success while customising solutions to India's specific issues (Bhattacharyya & Thakre, 2020).

Recommendations for India

To accelerate the adoption of electric cars (EVs) and create a sustainable mobility ecosystem, India has to develop strong policies, extend charging infrastructure, improve battery manufacture, incentivise customers, and support automakers. A long-term and stable legislative framework is required, including defined EV adoption target for automakers, higher emission standards, and unified state policies to assure consistent benefits across the country. Investment in charging infrastructure, such as a statewide network of fast chargers and battery swapping stations, is crucial, especially for two- and three-wheelers, which account for the majority of India's EV market. Public-private partnerships (PPPs) should be promoted to accelerate infrastructure development while including renewable energy sources for long-term charging solutions. Strengthening domestic battery manufacture through the Production-Linked Incentive (PLI) plan would assist to minimise reliance on imports and lower costs. India should also invest in research and development for alternative battery technologies such as sodium-ion and solid-state batteries, as well as promote battery recycling and secondary usage. To make EVs more accessible, increased purchase subsidies, tax credits, lower GST on EV elements, and low-interest financing choices should be implemented. Furthermore, consumer awareness campaigns can assist educate potential purchasers on the benefits of electric vehicles, addressing issues like range anxiety and savings over the long term. Supporting indigenous automakers and innovators is also critical for driving creativity and competitiveness in the industry. The government should provide R&D grants, incentives for production, and foreign investment opportunities to assist Indian firms in scaling up EV production and developing sophisticated mobility solutions. Creating a localised EV supply chain will lessen reliance on Chinese imports while strengthening India's position as a global EV centre. By implementing these strategies, India can build a strong and sustainable EV ecosystems, ensuring an environmentally friendly and more self-sufficient future in mobility.

Conclusion

The broad adoption of electric automobiles (EVs) is critical to India's long-term sustainability. With increased worries about air pollution, greenhouse gases, and fossil fuel dependency, EVs provide a more sustainable and energy-efficient alternative to traditional automobiles. By

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drawing from China's large-scale infrastructure investments and Europe's policy-driven sustainability approach, India can create a complete EV plan that balances cost effectiveness, innovation, and environmental responsibility. Policy frameworks should be strengthened, charging infrastructure expanded, domestic battery manufacturing boosted, and consumer incentives increased. Strategic investments in sustainable energy-powered electric vehicle (EV) charging, battery reuse and recycling, and smart transportation options can help India's EV ecosystem remain sustainable. Furthermore, government backing, industry collaboration, and general knowledge will all play an important role in advancing EV adoption (Ravuri et al., 2023). With the appropriate policies and actions, India has the possibility to become the world's leader in electric transportation, lowering its carbon footprint while promoting economic growth and technical innovation. A well-planned transition to electric vehicles would not only help India fulfil its climate targets, but will also assure a healthier, greener, and more environmentally friendly future for future generations.

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