A Bibliometric Analysis on Government Policies Shaping the Future of Sustainable Electric Transportation

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Abstract

Combating climate change and fossil fuel dependence demands a swift transition to electric vehicles (EVs). This research delves into how government policies shape this crucial shift, employing a 5-year bibliometric analysis across databases like Web of Science, Scopus, and Google Scholar. By analyzing publications, conference papers, and reviews, the study uncovers significant trends and knowledge gaps. Findings reveal a burgeoning research base on government intervention in EV technology, mirroring the global focus on environmental and energy security concerns. Content analysis identifies recurring themes: evaluating policy tools like tax breaks, subsidies, and mandates to influence EV adoption and usage. Additionally, studies assess the impact of government policies on the environment, technology advancements, and socio-economic factors within electric transportation systems. The multidisciplinary nature of this field is also highlighted, encompassing perspectives from policy studies, environmental science, engineering, and economics. Moreover, the analysis emphasizes the critical role of international cooperation and knowledge sharing in building robust, coordinated policy frameworks to propel global electric mobility forward. In conclusion, this bibliometric study offers valuable insights into the policy landscape shaping the shift towards sustainable electric vehicles. By synthesizing existing knowledge and identifying research needs, the study contributes to future research directions and policy-making efforts, ultimately accelerating the adoption and integration of electric vehicles into global transportation networks.

Keywords: Sustainability, Electric Vehicle, Government Policies, Technology, Bibliometric Analysis

Introduction

Electric cars are being extensively promoted by the Tamil Nadu government as a greener mode of transportation. Financial assistance for EV purchases, building a robust charging infrastructure, promoting local EV manufacturing, and informing the public about the benefits of electric cars are the programs' top priorities.

Financial Incentives: The Tamilnadu government is aggressively encouraging the use of electric cars by providing financial incentives on both the supply and demand sides through its Faster use and Manufacturing of Electric Vehicles (FAME) programme. This implies that individual consumers may purchase electric automobiles at a lower cost thanks to incentives. The government is also offering financial assistance to local producers of electric vehicles, which promotes local industry and strengthens Tamil Nadu's EV ecosystem as a whole. To encourage the construction of charging infrastructure and increase accessibility for owners of electric vehicles, the government also provides incentives. Apart from offering monetary incentives, the government is also emphasizing the growth of domestic electric car production. By offering assistance and incentives to regional manufacturers, the government is trying to increase the manufacturing of electric vehicles in the state , which will ultimately lead to the creation of jobs and economic expansion.

In addition, the government is actively developing public awareness programs to inform the public about the financial and environmental advantages of electric cars with the goal of boosting their adoption throughout the state. Government of Tamilnadu have to improve the funding on infrastructure of charging the electric vehicle because the availability of charging infrastructure is the main factor for the widespread adoption of electric vehicle. The government of Tamilnadu has launched a comprehensive strategy to create charging infrastructure in order to remedy this. In order to guarantee that owners of electric vehicles have easy access to charging stations, the plan calls for the development of public charging stations in metropolitan areas, beside national roads, and at strategic places.

The goal of this extensive infrastructure installation for charging electric vehicles is to reduce range anxiety among owners and open the door for more people to use electric vehicles in the state. In addition, the government is working with commercial organizations to build a strong network of charging stations, giving owners of electric vehicles a seamless charging experience.

In addition to making owning an electric car more convenient, the government's goal of developing Tamilnadu's charging infrastructure is in line with the state's efforts to establish an environmentally responsible and sustainable transportation system. The administration is establishing a strong basis for the long-term sustainability and proliferation of electric cars in the state by giving priority to the development of charging infrastructure.

The government's commitment to promoting a cleaner and greener environment while recognizing the revolutionary potential of electric transportation is demonstrated by this proactive approach. Apart from providing monetary incentives, the government of Tamilnadu is also emphasizing the growth of domestic electric car production. Number of jobs have been created and the economic status of Tamilnadu has been improved because the state is offering assistance and incentives to regional manufacturers as a result there will be increase in the manufacturing of electric vehicles in the state. In general, the Tamilnadu government's policies regarding electric vehicles involve public education campaigns, the creation of a thorough infrastructure plan for charging, partnerships with private companies to establish charging stations, and encouragement of domestic electric vehicle production.

China became the dominant nation in the global electric car market in 2022, with sales there surging six times faster than in the rest of the world. This marked a seismic change in the industry. Numerous reasons have contributed to this amazing increase, such as the introduction of more

reasonably priced electric car alternatives by new manufacturers, the introduction of large government subsidies, and the growing demand for tiny electric vehicles designed for urban driving in China. China remained the market leader, but other areas made significant gains as well. For example, the United States witnessed a strong 48% increase in sales of electric cars, while Europe saw consistent growth, especially in plug-in hybrids. This trend highlights how nations throughout the world are beginning to adopt sustainable transportation options, which bodes well for electric automobiles.

In Tamil Nadu, the government's policies on electric cars place a strong emphasis on building a reliable charging infrastructure, working with private companies, and encouraging domestic manufacture. In the recent years, popularity of Electric vehicles (EVs) have been increased due to the ongoing threat posed by climate change, and they are essential for environmental sustainability. They not only make moving from one place to another easier, but they also do so while taking environmental responsibility seriously. The market study on the electric cars explores the reason for the quick growth in this sector and it includes information on public charging points, infrastructure supporting EVs and increase in focus on battery electric cars & plugin hybrid electric vehicles.

The global electric car market saw explosive growth in 2022, with sales skyrocketing a staggering 55.1% compared to the previous year. This follows a trend of consistent growth, with over 10.25 million electric cars sold worldwide and generating a sizeable revenue of $538.8 billion. The future looks bright, between 2017 and 2027 with the projections estimating a healthy compound annual growth rate (CAGR) of 23.2% .

China emerged as the undisputed leader in the electric car market, outselling the rest of the world combined by a factor of six. This dominance can be attributed to several factors, including generous government subsidies that made electric cars more accessible, the rising popularity of smaller EVs suited for urban environments, and the entry of new, budget-friendly manufacturers that provided consumers with more affordable options. This confluence of factors fueled a remarkable market boom in China, solidifying its position at the forefront of the electric car revolution.

While China led the charge, other regions also saw significant growth in electric vehicle sales. The United States experienced a notable 48% increase from 2021 to 2022, fueled by a wider variety of EV models, strong marketing efforts, and attractive purchase incentives. Europe displayed a steady 15% growth from 2020 to 2021, with plug-in hybrids remaining the most popular option. Looking ahead, Europe is expected to maintain this momentum, driven by stricter CO2 emission regulations and plans for phasing in zero-emission vehicles. These trends suggest a global shift towards electric mobility, with different regions adopting diverse approaches to meet their specific needs and preferences.

An electric motor that draws power from a rechargeable battery that can be charged externally powers a vehicle known as an electric vehicle (EV). Electric vehicles can be broadly classified into two categories i.e. plugin hybrid electric vehicles and all electric vehicles. Plug-in hybrid electric vehicles can use both an internal combustion engine and an electric motor and draw power from a rechargeable battery whereas all-electric vehicles can only use an electric motor that is powered by a battery. Battery Electric Vehicles, or BEVs are the vehicles where an electric motor replaces the internal combustion engine in all-electric cars. These cars need to be connected to an electric vehicle supply equipment (EVSE) or wall socket in order to charge their large traction battery pack, which powers the electric motor. These electric-only cars don't have tailpipe emissions and don't have any traditional liquid fuel components like a fuel pump, fuel line, or fuel tank.

Essential Components of an All-Electric Vehicle

All-Electric Auxiliary Battery: In cars with electric drives, the accessory batteries power the car's functions.

Charging Port: It is a connector that makes connection between the car and an outside power source easier to facilitate the recharging of traction battery pack.

DC/DC Converter: The converter lowers the high voltage DC current from the traction battery pack to a lower voltage DC level, which powers the car's accessories and recharges the auxiliary battery.

Electric Traction Motor: Some electric cars employ a unique motor generator that serves as both the power supply and the regenerative braking system, while the majority of electric cars rely on a separate traction battery pack to power the driving motor.

The on-board charger: The on-board charger is in charge of converting incoming AC power that enters through the charge connector into DC power so that the traction battery may be charged. In addition to that the on-board charger communicates with the charging apparatus, keeping an eye on the voltage, current, temperature, and charge level of the battery as it charges.

Power Electronics Controller: This part monitors and regulates the flow of power from the battery to the electric traction motor in order to provide the required speed and torque.

Thermal System (Cooling): By keeping the electric motor, power electronics, and other essential parts' temperatures within a predetermined range, this system guarantees peak performance.

Traction Battery Pack: Electricity is stored in the traction battery pack to be compatible with the electric traction motor.

Electric Transmission: Mechanical power of electric traction motor is delivered to the wheels of the car with the help of the electric transmission.

Varieties of Electric Vehicles

Electric cars come in four main varieties:

- **Battery-Operated Electric Car**

A battery serves as the main power source for a battery-electric vehicle (BEV), which runs only on electricity. When compared to its hybrid and plug-in hybrid competitors, BEVs are renowned for their exceptional efficiency.

- **Hybrid Electric Vehicle**

A hybrid electric vehicle, or HEV for short. incorporates a battery-powered motor drivetrain together with an internal combustion engine, which is usually fuelled by gasoline. In addition to propelling the car, the gasoline engine recharges the battery when it runs low. Despite having several power sources, hybrid electric cars (HEVs) are not as efficient as completely electric or plug-in hybrid cars.

- **Plug-in Hybrid Electric Vehicles**

The freedom of both worlds is available to drivers who choose plug-in hybrid electric cars, or PHEVs for short. They feature a petrol engine that starts for longer distances, but they can also operate on electricity for shorter excursions owing to a rechargeable battery that plugs into a regular outlet. This lessens the need for the engine by enabling the battery of the car to be charged with energy. Though not as efficient as BEVs, PHEVs are still more efficient than HEVs.

- **Fuel Cell Electric Vehicle**

Hydrogen fuel cell electric cars are an example of a fuel cell electric vehicle (FCEV), which produces electric energy through chemical processes.

Global Scenario

Recognizing the strategic importance of EV supply chains, policymakers are increasingly integrating them into relevant policies to enhance resilience through diversification. In March 2023, European Union announced its plan regarding Net Zero Industry Act, according to this production capacity of atleast 550 GWh is projected by 2030, with the help of which the EU battery manufacturers are planning to satisfy 90% of the yearly battery demand. Similar initiatives are being carried out in India, where Production Linked Incentive (PLI) programs aim to increase home production of batteries and electric cars. To strengthen the domestic supply chain for electric vehicles (EVs), EV batteries, and battery minerals, the Inflation Reduction Act of the United States has been emphasized. As a result of Inflation Reduction Act there is considerable investment of at least USD 52 billion between August 2022 and March 2023 in North American EV supply chains, with significant allocations for the manufacturing of batteries, components, and EVs.

Global sales of electric cars (EVs)-which include both plug-in hybrids (PHEVs) and battery-electric vehicles (BEVs)-are expected to reach 14.1 million in 2023, a 34% increase from the previous year. The market for light vehicles as a whole, which includes both passenger cars and light commercial vehicles, is anticipated to grow by a more moderate 9%. This suggests that EVs will represent 16% of the worldwide light-vehicle market in 2023, a larger market share.

Despite the fact that this penetration rate is marginally less than initial projections, mainly because of a reduced prognosis for China, where the predicted EV share has been cut from 35% to 33%, the overall picture is favorable, with an extra 300,000 EV sales expected globally in 2023. This increase is mostly attributable to a better forecast for China's overall light car sales.

In North America, there have been obstacles to the adoption of EVs, which has hindered the uptake. Reductions in subsidies in European countries, such as Sweden, Germany, and the UK, have also had a detrimental effect on demand, particularly for plug-in hybrid electric vehicles. As a result, it is predicted that the worldwide EV share would be lower than prior ten-year estimates, coming in at 23.5% in 2025, 45.3% in 2030, and a noteworthy 68.4% in 2035.

Fig. 1 - Global BEV & PHEV Demand SOURCE - EV VOLUMES

Here are some Salient Points to Remember from the Graph

In general, it is anticipated that demand for EVs would rise sharply in the upcoming years. The worldwide EV industry is expected to have expanded by more than 500 times between 2015 and 2023, with 14.1 million vehicles sold by that time.

Compared to PHEVs, BEVs are anticipated to account for a bigger portion of the market. It is anticipated that in 2023, BEVs will make up 64% of all EV sales, with PHEVs making up the remaining 36%. It is anticipated that EVs will account for a larger portion of the light car market overall. Global sales of new light vehicles are predicted to consist of nearly two thirds (67%) of EVs by 2035.

Fig. 2 - Europe BEV & PHEV Demand SOURCE - EV VOLUMES

In general, it is anticipated that sales of electric cars would soar in Europe. Sales of BEVs and PHEVs combined are predicted to have increased dramatically between 2015 and 2023, reaching around 9 million cars. Comparing this to 2015, there has been an increase of nearly 440 times.

It is predicted that BEVs will be the most common form of electric car. Around 69% of all electric vehicle sales in Europe are expected to be BEVs in 2023, with PHEVs making up the remaining 31%. It is anticipated that electric car market share would increase significantly. When BEVs and PHEVs are combined, they are expected to account for more than 95% of all light vehicle sales in Europe by 2035.

Review of Literature

Various studies highlight the significance of financial incentives in promoting electric vehicle (EV) adoption. Research conducted by Hao et al. (2020) and Beck & Wiedmann (2018) underscores the influential role of incentives such as tax reductions, purchase subsidies, and toll discounts in shaping consumer behavior and accelerating the uptake of EVs. These findings emphasize the effectiveness of financial measures in incentivizing EV adoption and underscore the importance of policy support in driving the transition towards sustainable transportation solutions.

Adhia (2022) analysed that in the fiscal year 2019–20, India witnessed the sale of 3.8 lakh electric cars (EVs), predominantly in the passenger car segment, followed by two-wheelers and commercial vehicles. Government initiatives like FAME-India and NEMMP 2020 aim to promote EV adoption, overseen by key bodies such as the National Automotive Board, National Board for Electric Mobility, and National Council for Electric Mobility. This study provides a comprehensive analysis of India's EV landscape, encompassing data, regulations, and pertinent initiatives.

Establishing a robust charging infrastructure is a crucial aspect of policy development. Research conducted by Sierzch et al. (2020) and Zhang et al. (2021) highlights the prevalence of "range anxiety" as a major barrier to EV adoption. To mitigate this concern, governments can invest in building a comprehensive network of charging stations along roads, in urban areas, and within residential communities. By addressing the availability of charging facilities, policymakers can effectively alleviate range anxiety and facilitate the widespread adoption of electric vehicles.

Fariba (2023) utilized the Stackelberg technique and game theory approach with Norwegian data and identified optimal solutions. Managers gain valuable insights for decision-making across various scenarios. Considering government objectives, the TOPSIS approach recommends substantial EV buyer subsidies and increased taxes on fossil fuels and vehicles to reduce pollution, boost EV adoption, extend EV range, and enhance profits for manufacturers and battery producers. These measures align with environmental goals while stimulating the EV market and related industries.

Several studies, such as those by Khadayi et al. (2021) and Nykvist & Nilsson (2015), investigate the effectiveness of Zero Emission Vehicle (ZEV) mandates and stricter pollution regulations in promoting electric vehicle (EV) adoption. By setting ambitious targets to reduce vehicle emissions and increase the penetration of EVs in the market, these regulations incentivize manufacturers to prioritize research and development efforts in EV technology and production. This proactive approach fosters innovation and stimulates the growth of the EV market, contributing to a cleaner and more sustainable transportation ecosystem.

Public awareness plays a crucial role in promoting the benefits of electric vehicles (EVs) and debunking misconceptions surrounding them. Studies by Berrone et al. (2017) and Schwanen et al. (2018) highlight the effectiveness of government-led awareness campaigns in educating the public about the financial and environmental advantages of EVs. These initiatives address concerns related to battery life, range, and charging infrastructure, ultimately influencing consumer preferences towards EV adoption. By disseminating accurate information, public awareness programs play a pivotal role in fostering the uptake of EVs and advancing sustainable transportation solutions.

Government policies significantly shape the trajectory of electric vehicle (EV) adoption, yet several critical issues warrant attention. Ensuring equitable access to EV incentives and charging infrastructure across income levels is imperative, as highlighted by the IEA (2021). Additionally, the environmental impact of battery manufacturing and disposal requires careful examination. Research by Dunn et al. (2015) underscores the importance of sustainable battery lifecycle management for a truly sustainable EV future. Addressing these challenges is vital for fostering widespread EV adoption while minimizing environmental consequences.

Objectives of the Study

- The objective of this study is to assess the increasing significance of environmentally friendly electric vehicles and their ability to solve environmental issues.
- To provide an overview of the current policies and initiatives implemented by governments at both the national and sub-national levels to support sustainable electric transportation.
- To identify the key barriers and challenges hindering the wider adoption of electric vehicles and hybrid electric vehicles
- To understand the growth in the number of articles published in Scopus publication related to electric vehicles.
- To evaluate how different countries encourage the research in electric vehicles.

Data Source and Methodology

The choice of an appropriate data source carries great weight. In this investigation, specifically, scholarly literature was scrupulously procured from the Scopus core collection, a repository that boasts around 17,200 esteemed journals and a wealth of 9,191 cited references. The method for retrieving literature employed an advanced search methodology, and the specific strategies utilized are delineated below for clarity and transparency.

Languages = 'All languages'
Document types = 'All document types'
Time span = 2019-2023
Databases = Scopus Core Collection

Following the execution of the retrieval strategy, a grand total of 3,297 publications were procured. However, given the inherent limitations associated with retrieval technologies, it was necessary to remove irrelevant and duplicated publications from this pool. As a result of this refinement process, a total of 191 closely-related publications within the field of government policies and

electric vehicle were retrieved from Scopus Core on January 22nd, 2024. It is important to note that these scholarly articles include literature reviews which provide condensed presentations of existing data while also introducing potential research opportunities. Despite their brevity in nature, literature reviews play an integral role in promoting knowledge communication and advancing the development of electric vehicles. Over the past decade or so there have been an increasing number of scholarly articles focused on electric vehicles.

Analysis

- Scopus documents analysed on the basis of types

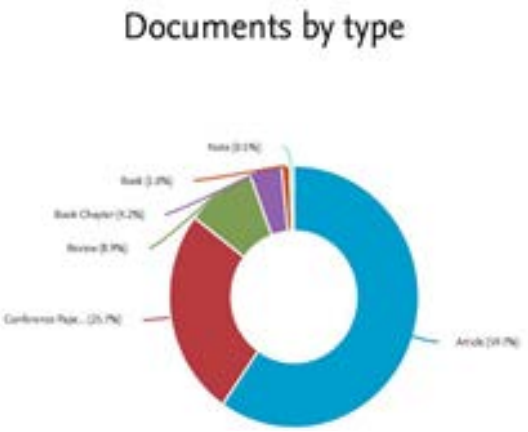

Fig. 3 - Document by Types SOURCE - SCOPUS

From the above chart we can understand that majority of documents published in Scopus that are related to Electrical Vehicles are in the form of articles i.e 59.7% and next 25.7% documents are from conference proceedings. After that the documents are mostly published in review, book chapter and book. Scopus is an well recognized publication. Many universities highly values the articles published in Scopus. That is one of the main reason for the high number of articles.

- Scopus documents analysed on the basis of documents per year by source

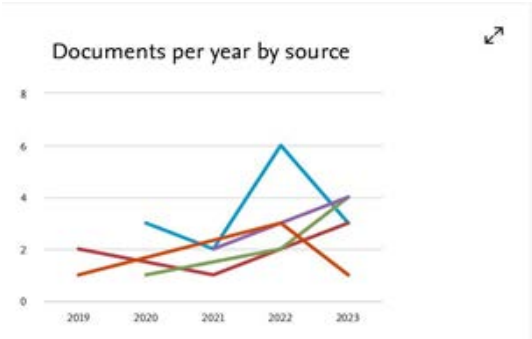

Fig. 4 - Documents per year by Source SOURCE - SCOPUS

In general, Articles are always highly preferred for the publication in scopus and in this particular case, the articles related to electric vehicles also the number of articles are higher every year but there is an drastic reduction in the number of articles in 2023, same in case of books, the

books related to electric vehicles increases constantly from 2019 to 2022 but then there is a steep reduction in 2023. This reason can be further analysed in the future studies. Whereas other sources like reviews, book chapters and conference proceeding are at raise.

- Scopus documents analysed on the basis of the documents by country/ territory

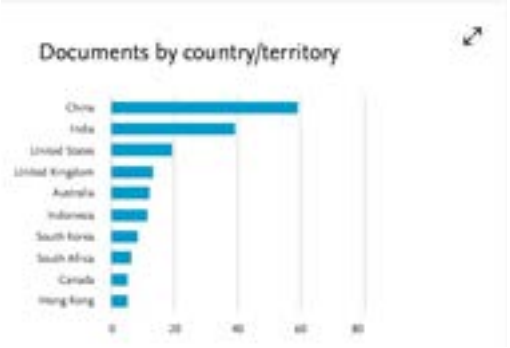

Fig. 5 - Documents by Country/ Territory SOURCE - SCOPUS

China is the most populated country in the world. Its evident from the above chart that China (nearly 60%) is highly researching about electric vehicles following by India(nearly 40%) to get a better alternative than fuel powered vehicles so that they win the battle against increasing pollution in their respective countries. Other countries like United States, United Kingdom, Australia, and Indonesia (less than 20%) are also exploring but not as much as China and India.

- Analysis of documents on the basis of countries in Scopus with the help of VOSviewer

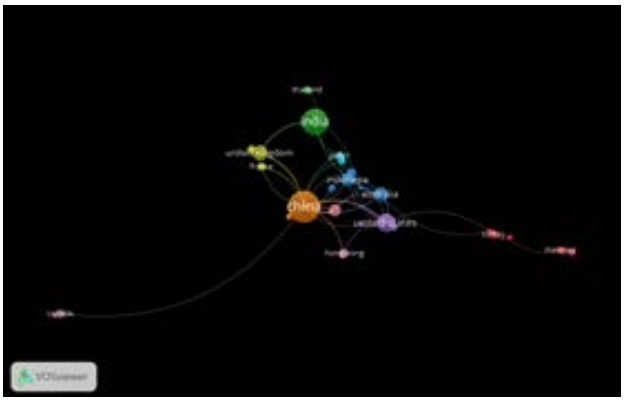

Fig. 6 - Co-authorship on the basis of different countries SOURCE - VOSViewer

VOSviewer analysis confirms the previous graph output stating that China and India are the two major countries that are contributing documents related to electric vehicles in Scopus. The VOSViewer analyse the co-authorship between different countries. There has been relation between the co-authors of different countries. Like India and Japan, India and United Kingdom, India and Indonesia, India and Thailand and China and United States, China and United Kingdom, China and Canada, Japan, Hong-kong, Indonesia, Australia and France.

- Analysis of documents on the basis of different keywords used in Scopus

Fig. 7 - Co-occurance of all keywords SOURCE - VOSViewer

With the help of VOSViewer, the co-occurance of all the keywords in the Scopus documents were analyzed. Different keywords that are related to the study were selected and analyzed. It is comprehended that the keywords like electric vehicle(s), government or public policies, greenhouse gases and sustainable development are the majorly used keywords in many Scopus Documents. With the help of the analysis of keywords, one can understand the major research focus in this area.

Findings

The study examined the increasing popularity of electric vehicles (EVs) and the legislative frameworks that facilitate their adoption. The primary findings can be summarized as follows:

The Tamil Nadu government is vigorously advancing the adoption of electric vehicles (EVs) through various initiatives. These include the development of charging infrastructure, provision of financial incentives for both EV purchases and manufacturing, and extensive campaigns to enhance public awareness regarding the advantages of EVs. Concurrently, China has emerged as the global frontrunner in the swiftly expanding EV market.

EVs are broadly categorized into four primary types: Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Hybrid Electric Vehicles (HEVs), and Fuel Cell Electric Vehicles (FCVs). Market forecasts indicate a substantial upsurge in EV numbers, with an estimated total of 14.1 million anticipated by 2023. Among these, BEVs are projected to seize a larger portion of the market compared to PHEVs.

China and India are pivotal players in the realm of EV research, actively contributing to the burgeoning body of literature on this transformative technology. Their proactive involvement underscores a global shift towards sustainable transportation solutions. This collective effort not only fuels innovation but also paves the way for widespread adoption and integration of EVs into mainstream transportation systems.

The concerted efforts of governments, coupled with technological advancements and increasing consumer interest, are propelling the EV market towards unprecedented growth. As nations worldwide strive to reduce carbon emissions and combat climate change, the promotion of EVs emerges as a pivotal strategy in achieving sustainable mobility and environmental stewardship on a global scale.

Recommendations

This paper underscores the critical roles of various stakeholders in fostering the widespread adoption of electric vehicles (EVs) and advancing towards a more sustainable transportation landscape. Governments are urged to continue crafting and enforcing laws that incentivize EV usage, encompassing measures such as financial incentives, the establishment of charging infrastructure, and public awareness campaigns. By prioritizing such initiatives, policymakers can

significantly bolster the EV market and accelerate its growth trajectory.

Manufacturers are encouraged to focus their efforts on producing more affordable EVs with extended driving ranges. Addressing these key factors can enhance consumer accessibility and attractiveness, ultimately driving greater EV adoption rates. Furthermore, ongoing research and development efforts are paramount, particularly in overcoming challenges such as limited battery range and expanding charging infrastructure. Researchers play a pivotal role in driving innovation within the EV sector, continually exploring new technologies and solutions to propel the industry forward.

Customers are urged to consider transitioning to EVs, recognizing the environmental benefits and potential cost savings over time. By embracing EVs, individuals can actively contribute to reducing their carbon footprint and mitigating the impacts of climate change. Moreover, widespread consumer adoption is instrumental in driving market demand and spurring further advancements in EV technology and infrastructure.

In essence, this paper emphasizes the collaborative efforts required across all stakeholder groups to ensure a more sustainable transportation future. By engaging in research and development endeavors, promoting public awareness, and advocating for supportive legislation, stakeholders can collectively propel the EV industry towards greater innovation and accessibility. Through concerted action and commitment to sustainable mobility solutions, stakeholders can collectively pave the way for a greener, more environmentally conscious transportation ecosystem.

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