Impact of Economic, Social, And Environmental Factors on Electric Vehicle Adoption: A Review

Impacto de los factores económicos, sociales y ambientales en la adopción de vehículos eléctricos: una revisión

EÍDOS Nº24
Revista Científica de Arquitectura y Urbanismo
ISSN: 1390-5007
revistas.ute.edu.ec/index.php/eidos

[1,2]Mohammad Farajnezhad, [3]Jason See Toh Seong Kuan, [4]Hesam Kamyab

[1]Faculty of Business and Communication, Inti International University, 71800 Nilai, N. Sembilan, Malaysia;
[2]CSIRT Center, Computer Engineering Department, Lorestan University, Iran. taban1010@gmail.com.
ORCID: 0000-0002-2086-9294

[3]Faculty of Business and Communication, Inti International University, 71800 Nilai, N. Sembilan, Malaysia.
jasonsee.toh@newinti.edu.my. ORCID: 0000-0002-1309-5200

[4]Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, 81310, Skudai, Johor, Malaysia.
hesam_kamyab@yahoo.com. ORCID: 0000-0002-5272-2297

***Abstract**:*

Electric vehicles (EVs) represent a transformative innovation in the automotive industry, offering a promising solution to environmental challenges. This paper examines the complex interplay of economic, social, and environmental factors that influence consumers' decisions to adopt EVs. Economic factors, such as initial purchase price and operating costs, play a crucial role in adoption. Research suggests that as EV prices become more competitive and operational expenses decline, adoption rates will accelerate. Social factors, including peer influence and perceptions of EV performance, reliability, and convenience, also shape consumer attitudes and preferences. Environmental considerations, including the imperative to mitigate greenhouse gas emissions and reduce air pollution, drive the adoption of EVs. This review synthesizes existing literature on the impact of economic, social, and environmental factors on EV adoption, providing valuable insights for policymakers, industry stakeholders, and researchers. By elucidating the complex dynamics that influence consumer behavior, this study contributes to the ongoing discourse on sustainable mobility and the transition towards a greener transportation ecosystem.

***Keywords**: Electric vehicles, transport sector, sustainability, adoption, economic, social, environmental, Malaysia.*

Resumen:

Los vehículos eléctricos (EV) representan una innovación transformadora en la industria automotriz y ofrecen una solución prometedora a los desafíos ambientales. Este artículo examina la compleja interacción de factores económicos, sociales y ambientales, que influyen en las decisiones de los consumidores para adoptar vehículos eléctricos. Los factores económicos, como el precio de compra inicial y los costos operativos, juegan un papel crucial en la adopción. Las investigaciones sugieren que, a medida que los precios de los vehículos eléctricos se vuelvan más competitivos y los gastos operativos disminuyan, las tasas de adopción se acelerarán. Los factores sociales, incluida la influencia de los pares y las percepciones sobre el rendimiento, la confiabilidad y la conveniencia de los vehículos eléctricos, también moldean las actitudes y preferencias de los consumidores. Las consideraciones ambientales, incluido el imperativo de mitigar las emisiones de gases de efecto invernadero y reducir la contaminación del aire, impulsan la adopción de

Recepción: 11, 04, 2024 - Aceptación: 15, 05, 2024 - Publicado: 01, 07, 2024

vehículos eléctricos. Esta revisión sintetiza la literatura existente sobre el impacto de los factores económicos, sociales y ambientales en la adopción de vehículos eléctricos, proporcionando información valiosa para los formuladores de políticas, las partes interesadas de la industria y los investigadores. Al dilucidar las complejas dinámicas que influyen en el comportamiento del consumidor, este estudio contribuye al discurso actual sobre la movilidad sostenible y la transición hacia un ecosistema de transporte más ecológico.

Palabras claves: Vehículos eléctricos, sector transporte, sostenibilidad, adopción, económico, social, ambiental, Malasia.

ABBREVIATIONS

Electric vehicles	EVs
Zero Emission Vehicle	ZEV
Traditional internal combustion engine vehicles	ICEVs
Nitrogen Oxides	NOx
Particulate Matter	PM
Carbon Monoxide	CO
Volatile Organic Compounds	VOCs
Internal combustion engine vehicles	ICEVs
Plug-in hybrid Electric vehicles	PHEV
European Union	EU

1. INTRODUCTION

1.1 Background and Importance of Electric Vehicles (EVs)

Electric vehicles (EVs) represent a significant advancement in automotive technology, offering numerous benefits over traditional internal combustion engine vehicles. The background of EVs traces back to the early 19th century when electric-powered vehicles emerged as viable alternatives to steam and gasoline-powered cars. However, it was not until recent decades that EVs gained traction as a practical and sustainable solution to transportation challenges. The importance of EVs lies in their potential to address pressing issues such as climate change, air pollution, and energy security. As concerns about greenhouse gas emissions and their impact on global warming continue to escalate, EVs present a promising avenue for reducing carbon emissions from the transportation sector. By replacing conventional fossil fuel-powered vehicles with electric counterparts, EVs contribute to mitigating climate change by reducing reliance on fossil fuels and lowering carbon dioxide emissions. Furthermore, EVs offer significant improvements in air quality, particularly in urban areas where air pollution from vehicles is a major concern. Unlike internal combustion engine vehicles, which emit pollutants such as nitrogen oxides and particulate matter, EVs produce zero tailpipe emissions, thus helping to improve air quality and public health.

Additionally, the adoption of EVs promotes energy security by reducing dependence on imported oil and diversifying the sources of energy used for transportation. With advancements in renewable energy technologies such as solar and wind power, EVs have the potential to be powered by clean and domestically produced electricity, further enhancing energy independence and resilience. Moreover, the proliferation of EVs presents economic opportunities for industries involved in their production, distribution, and maintenance. As demand for EVs grows, it stimulates innovation and

ISSN:1390-5007 FARAJNEZHAD, *et al.* - Impact of Economic, Social, And Environmental Factors on Electric Vehicle Adoption: A Review. pp. 39-62

investment in battery technology, charging infrastructure, and related industries, leading to job creation and economic growth. The background and importance of EVs underscore their role as a transformative technology with the potential to address environmental, health, energy, and economic challenges. By transitioning to electric transportation, societies can move towards a more sustainable and resilient future.

1.2 Overview of the Environmental, Social, and Economic Impacts of EV Adoption

The adoption of electric vehicles (EVs) has multifaceted impacts on the environment, society, and economy, influencing various aspects of human life and global sustainability. An overview of these impacts can be elucidated as follows:

- Environmental Impacts: EV adoption contributes to mitigating environmental degradation by reducing greenhouse gas emissions and air pollutants. Studies have shown that EVs produce lower emissions compared to internal combustion engine vehicles, particularly when powered by renewable energy sources (Zhang et al., 2019). This leads to improvements in air quality, public health, and ecosystem integrity, supporting global efforts to combat climate change and environmental degradation (Han et al., 2020).

- Social Impacts: The widespread adoption of EVs can bring about social transformations by influencing mobility patterns, urban planning, and social equity. EVs offer quieter and cleaner transportation options, enhancing the quality of life for residents in urban areas and reducing noise pollution (Zheng et al., 2021). Moreover, EV adoption promotes social inclusion by providing accessible and affordable transportation solutions, particularly for underserved communities (He et al., 2021).

- Economic Impacts: The transition to EVs has significant economic implications, affecting industries, markets, and employment opportunities. The EV market stimulates technological innovation, driving advancements in battery technology, electric drivetrains, and charging infrastructure (Li et al., 2021). This fosters economic growth, job creation, and investment opportunities in the renewable energy and automotive sectors (Wang et al., 2020). Additionally, EV adoption reduces reliance on imported oil and enhances energy security, leading to cost savings and economic resilience (Wu et al., 2021).

In summary, the adoption of EVs has profound environmental, social, and economic impacts, shaping the trajectory of sustainable development worldwide. Understanding these impacts is essential for policymakers, businesses, and individuals to make informed decisions and promote the widespread adoption of EVs for a cleaner, healthier, and more prosperous future.

2. LITERATURE REVIEW

2.1 Historical Development of Electric Vehicles

The concept of electric vehicles (EVs) dates to the early 19th century, with significant advancements occurring over the decades. This historical development highlights the evolution of EV technology and its integration into modern transportation systems. The first electric vehicle prototype was developed by Scottish inventor Robert Anderson in the 1830s, consisting of a crude electric carriage powered by non-rechargeable batteries (Notten et al., 2017). Subsequent innovations by Thomas Davenport and others in the mid-19th century led to the introduction of electric trams and trolleybuses in urban areas (Laugwitz, 2017). The early 20th century witnessed significant advancements in EV technology, spurred by concerns over air pollution and dependence on fossil fuels. The Detroit Electric Company, founded in 1907, became one of the leading manufacturers of electric cars, offering a range of models popular among urban dwellers (Gross, 2018). However, the emergence of affordable gasoline-powered vehicles, coupled with advancements in internal combustion engine technology, led to a decline in EV popularity by the 1930s. Interest in EVs resurged in the late 20th century amid growing concerns over environmental pollution and oil dependency. The California Air Resources Board's Zero Emission Vehicle (ZEV) mandate in the 1990s incentivized automakers to produce electric and hybrid vehicles, leading to the introduction of models such as the General Motors EV1 and Toyota Prius (Sperling & Gordon, 2009). Despite initial enthusiasm, limited battery range and high costs hindered widespread EV adoption during this period. The 21st century has witnessed a rapid acceleration in EV development and adoption, driven by advancements in battery technology, government incentives, and increasing environmental awareness. Companies like Tesla Motors have pioneered the mass production of long-range, high-performance electric vehicles, while governments worldwide have implemented policies to promote EV adoption and expand charging infrastructure (Faria et al., 2019). Additionally, the emergence of electric buses, trucks, and motorcycles further underscores the diversity and potential of EV technology in various transportation sectors. The historical development of electric vehicles reflects a trajectory marked by innovation, challenges, and opportunities. As technology continues to evolve and sustainability concerns intensify, EVs are poised to play a central role in shaping the future of transportation.

According to the International Energy Agency (2021), global energy use will continue to grow in all major end-use sectors. The total final consumption (TFC) will increase by around 20% in 2020–50. The demand for fossil fuels will decrease, and the shift will be toward electricity, renewable power, and hydrogen. In 2050, electricity's share will rise from 20 to 30% (Fig. 1). Transport accounts for the largest reduction in energy demand, thanks to a shift toward electric vehicles (EV), which are up to three times more energy-efficient than conventional internal combustion engines. According to International Energy Agency (2021), over 60% of the clean energy technology equipment market predicted will be battery-based in 2050. With over 3 billion electric vehicles on the road

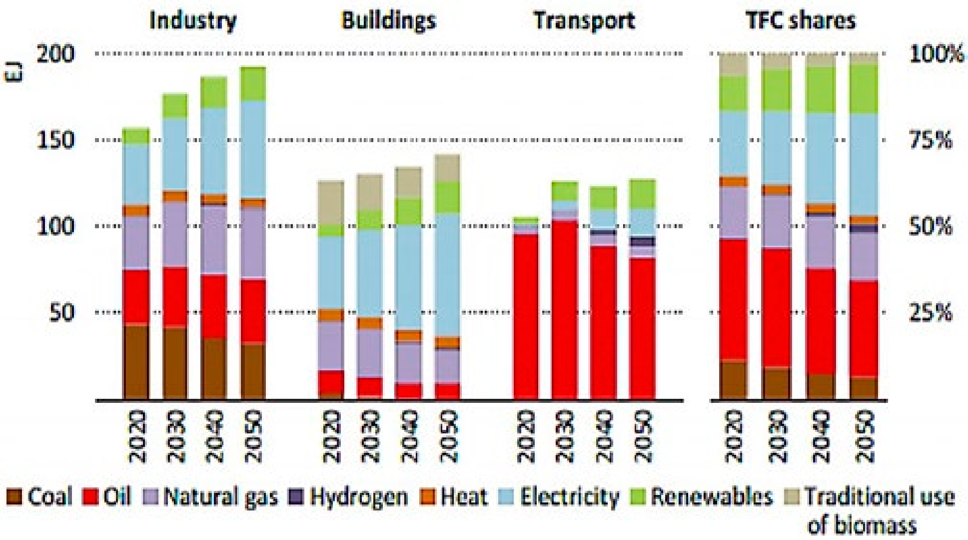

Figure 1. Final energy consumption by source and sector in the Net Zero Emission by 2050 Scenario.
Source: International Energy Agency (2021).

and three terawatt-hours of battery storage in 2050, batteries will play a key role in the new energy economy.

2.2 Environmental Impacts of Traditional Internal Combustion Engine Vehicles

Traditional internal combustion engine vehicles (ICEVs) have significant environmental impacts across their lifecycle, including production, operation, and disposal. These impacts contribute to various environmental issues, including air pollution, greenhouse gas emissions, and resource depletion.

ICEVs emit pollutants such as nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and volatile organic compounds (VOCs) during operation (Stocker & Schraner, 2018). These pollutants degrade air quality, leading to health problems such as respiratory diseases, cardiovascular issues, and premature mortality (Hoek et al., 2013). Additionally, NOx and VOCs contribute to the formation of ground-level ozone and smog, further exacerbating air pollution in urban areas (Cohen et al., 2017). ICEVs are a significant source of greenhouse gas emissions, primarily carbon dioxide (CO2), resulting from the combustion of fossil fuels (Schiermeier, 2020). These emissions contribute to global warming and climate change by trapping heat in the atmosphere, leading to adverse effects such as rising temperatures, sea-level rise, and extreme weather events (IPCC, 2018). The transportation sector is one of the largest contributors to global CO2 emissions, with ICEVs playing a major role in this regard (Le Quéré et al., 2018).

The production and operation of ICEVs require significant amounts of natural resources, including petroleum, metals, and water (Sullivan & Locey, 2016). The extraction and processing of these resources can have adverse environmental impacts, such as habitat destruction, water pollution, and biodiversity loss (Mudd, 2010). Additionally, the reliance on finite fossil fuel reserves raises concerns about energy security and resource depletion, necessitating a transition to alternative fuels and propulsion technologies (IEA, 2019). ICEVs produce noise pollution due to engine combustion, exhaust systems, and tire-road interaction (Basner et al., 2014). This noise can disrupt ecosystems, interfere with wildlife communication and navigation, and adversely affect human health and well-being, leading to stress, sleep disturbances, and hearing loss (Münzel et al., 2018).

The environmental impacts of traditional ICEVs are significant and multifaceted, posing challenges to sustainability and public health. Addressing these impacts requires a transition to cleaner and more efficient transportation alternatives, such as electric vehicles (EVs), and the implementation of policies to promote sustainable mobility and reduce emissions.

2.3 Advantages and Disadvantages of EVs Compared to Conventional Vehicles

Electric vehicles (EVs) offer several advantages over conventional internal combustion engine vehicles (ICEVs), but they also have certain limitations. Understanding these pros and cons is crucial for assessing the overall impact of EV adoption on the automotive industry and the environment. EVs produce zero tailpipe emissions during operation, reducing air pollution and greenhouse gas emissions (Nikolaou et al., 2019). This helps mitigate climate change and improves local air quality, particularly in urban areas (Jacobson, 2009). Additionally, EVs can be powered by renewable energy sources, further reducing their carbon footprint (Abdelaziz et al., 2019). EVs have lower fuel and maintenance costs compared to ICEVs. Electricity is generally cheaper than gasoline, resulting in lower fuel expenses over the vehicle's lifetime (Peters et al., 2017). Moreover, EVs have fewer moving parts and require less maintenance, leading to reduced servicing and repair costs (Axsen et al., 2018). EVs are more energy efficient than ICEVs due to the higher efficiency of electric motors compared to internal combustion engines (Gallagher et al., 2012). This translates to greater energy savings and reduced resource consumption, contributing to sustainability and energy security (Miotti et al., 2016). EVs offer smooth, quiet, and responsive driving experiences due to their electric powertrains (Rugh & Kuffner, 2013). They provide instant torque and acceleration, making them enjoyable to drive and suitable for urban commuting (Sierzchula et al., 2014).

Most EVs have shorter driving ranges compared to conventional ICEVs, which can be a barrier to long-distance travel (Shao et al., 2017). Range anxiety, or the fear of running out of charge, remains a concern for some consumers, especially in regions with inadequate charging infrastructure (Shaheen et al., 2017). The availability and accessibility of charging infrastructure remain major challenges for EV adoption (Caperello et al., 2018). Public charging stations are less common than gas stations, and charging times can be longer, hindering the convenience of EV ownership (Stephens et al., 2019). EV batteries are expensive to manufacture and replace, contributing to the upfront cost of EVs (Zhao et al., 2017). Moreover, battery degradation over time can affect vehicle performance and range, necessitating costly replacements (Wu et al., 2020). The production of EV batteries requires rare earth metals and other critical materials, leading to concerns about resource depletion and environmental impacts associated with mining and processing (Oladele et al., 2019). Additionally, the disposal and recycling of spent EV batteries pose challenges for waste management and environmental sustainability (Kim et al., 2016). While EVs offer numerous advantages in terms of environmental performance, operating costs, and driving experience, they also face challenges related to driving range, charging infrastructure, battery costs, and resource constraints. Addressing these limitations will be essential for accelerating the transition to electric mobility and realizing the full potential of EVs in the transportation sector. Figure 2 displays the impact of economic, social, and environmental aspects on electric vehicle adoption.

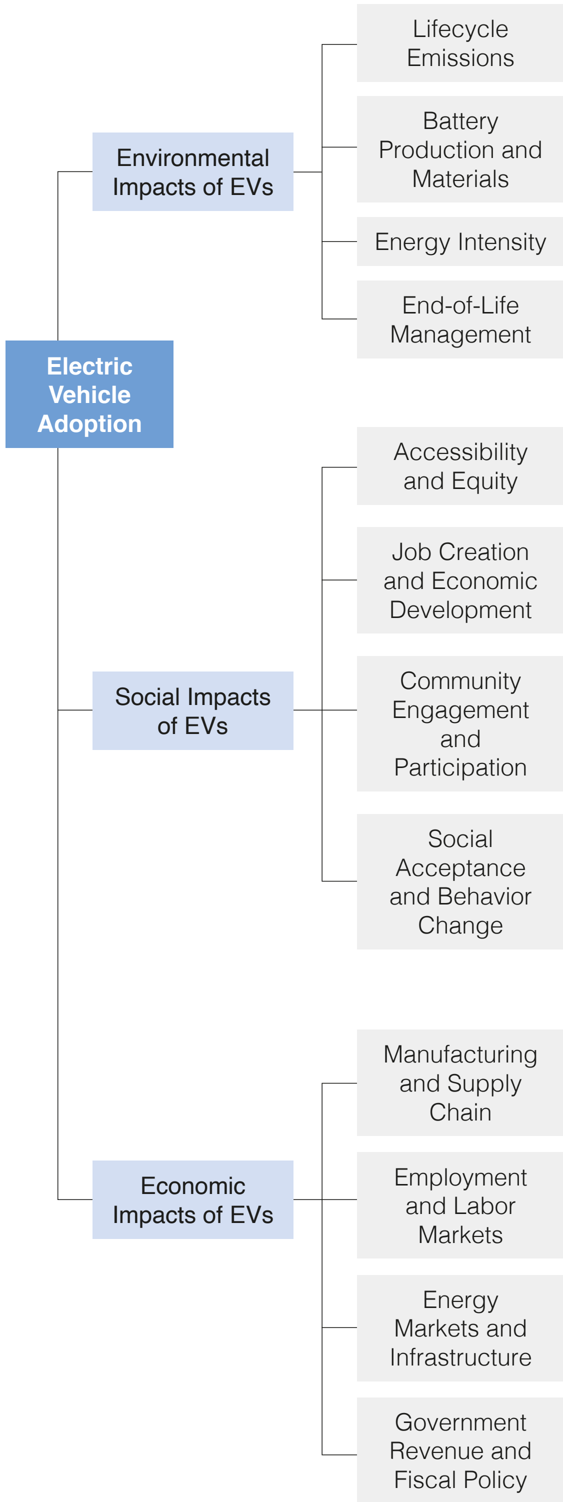

Figure 2. Chart of Impact of economic, social, and environmental factors on electric vehicle adoption

2.4 Environmental Impacts of EVs

Electric vehicles (EVs) are often hailed as a more environmentally friendly alternative to conventional internal combustion engine vehicles (ICEVs) due to their zero tailpipe

ISSN:1390-5007

emissions. However, the environmental impacts of EVs extend beyond direct emissions during operation and include various aspects of their lifecycle, from manufacturing to end-of-life disposal. This section provides an overview of the environmental impacts associated with EVs, drawing on recent research and literature.

2.4.1 Lifecycle Emissions: While EVs produce no tailpipe emissions during operation, the environmental impact of EVs depends on the source of electricity used for charging. EVs charged using electricity generated from renewable sources have significantly lower lifecycle emissions compared to those charged using fossil fuels (Hawkins et al., 2013). However, the production of electricity itself, along with battery manufacturing and materials extraction, contributes to greenhouse gas emissions and other environmental pollutants.

2.4.2 Battery Production and Materials: The manufacturing of EV batteries involves resource-intensive processes and materials, including lithium, cobalt, and nickel, which are often mined through environmentally damaging practices (Dunn et al., 2014). The extraction, processing, and transportation of these raw materials can result in habitat destruction, water pollution, and ecosystem degradation, particularly in regions with lax environmental regulations.

2.4.3 Energy Intensity: EVs typically require more energy to produce than ICEVs due to the complex manufacturing processes and the production of high-capacity lithium-ion batteries (Kang et al., 2016). Studies have shown that the energy intensity of EV production can result in higher environmental burdens, including greenhouse gas emissions, compared to conventional vehicles over their lifecycle (Ellingsen et al., 2014).

2.4.4 End-of-Life Management: The disposal and recycling of EV batteries present significant environmental challenges, including the potential for toxic leachates and heavy metal contamination (Dunn et al., 2016). Proper end-of-life management practices, such as battery recycling and reuse, are essential to mitigate environmental impacts and minimize resource depletion. While EVs offer the potential to reduce greenhouse gas emissions and air pollution, their environmental benefits are contingent upon various factors, including the source of electricity, battery manufacturing practices, and end-of-life management strategies. Addressing these challenges through sustainable energy generation, responsible resource extraction, and effective recycling programs is crucial to maximizing the environmental benefits of EV adoption.

2.4.5 Mitigating Greenhouse Gas Emissions: The transition to electric vehicles (EVs) is crucial for mitigating greenhouse gas emissions and reducing the environmental impact of transportation. According to the International Energy Agency (IEA, 2020), EVs have the potential to reduce CO2 emissions from the transportation sector by up to 70% by 2050. EVs produce zero tailpipe emissions, reducing the amount of particulate matter, nitrogen oxides, and other pollutants released into the atmosphere. This is particularly significant in urban areas, where air pollution is a major public health concern. The production of EVs also has a lower environmental impact compared to traditional internal combustion engine vehicles. A study by the Union of Concerned Scientists (UCS, 2020) found that the production of EVs generates approximately 60% fewer emissions than traditional vehicles. Additionally, the recycling of EV batteries has the potential to reduce the environmental impact of the entire lifecycle of the vehicle.

2.4.6 Reducing Air Pollution: Air pollution is a significant public health concern, with the World Health Organization (WHO) estimating that 9 out of 10 people worldwide breathe polluted air. Electric vehicles (EVs) play a crucial role in reducing air pollution, as they produce zero tailpipe emissions. According to the International Council on Clean Transportation (ICCT, 2020), EVs can reduce particulate matter (PM), nitrogen oxides (NOx), and other pollutants by up to 90% compared to traditional internal combustion engine vehicles. The benefits of EVs in reducing air pollution are particularly significant in urban areas, where air pollution is often most severe. A study by the University of California, Berkeley (UC Berkeley, 2020) found that widespread adoption of EVs in California could reduce PM2.5 emissions by up to 70%, resulting in significant health benefits and cost savings. Furthermore, EVs can also reduce emissions from the production and distribution of fossil fuels. A study by the National Renewable Energy Laboratory (NREL, 2020) found that EVs can reduce greenhouse gas emissions from the production and distribution of fuels by up to 50%.

2.4.7 Conserving Natural Resources: The production and use of electric vehicles (EVs) offer significant opportunities for conserving natural resources. The extraction, refining, and transportation of fossil fuels for traditional internal combustion engine vehicles have a significant environmental impact. In contrast, EVs can reduce the demand for fossil fuels, conserving natural resources and reducing the environmental impact of extraction and transportation. The production of EVs also has a lower environmental impact compared to traditional vehicles. A study by the Union of Concerned Scientists (UCS, 2020) found that the production of EVs generates approximately 60% fewer emissions than traditional vehicles. Additionally, the recycling of EV batteries has the potential to reduce the environmental impact of the entire lifecycle of the vehicle. Furthermore, EVs can also reduce the demand for natural resources such as water and land. A study by the National Renewable Energy Laboratory (NREL, 2020) found that EVs can reduce the demand for water by up to 70% compared to traditional vehicles. Additionally, the production of EVs requires significantly less land than traditional vehicles, reducing the impact on ecosystems and biodiversity. In conclusion, the transition to electric vehicles offers significant opportunities for conserving natural resources, reducing the environmental impact of extraction and transportation, and promoting sustainable development.

2.5 Social Impacts of EVs

The adoption of electric vehicles (EVs) not only brings about environmental benefits but also significant social impacts that extend to various aspects of society. This section explores the social implications of EVs, drawing on recent studies and literature.

2.5.1 Accessibility and Equity: EVs have the potential to democratize transportation by providing cleaner and more sustainable mobility options for a broader segment of the population. Compared to traditional gasoline-powered vehicles, EVs offer lower operating costs and reduced maintenance requirements, making them more accessible to individuals with limited financial resources (Hardman et al., 2019). Additionally,

ISSN:1390-5007

government incentives and subsidy programs aimed at promoting EV adoption can help address equity concerns by ensuring that disadvantaged communities have access to cleaner transportation options (Stephenson et al., 2020).

2.5.2 Job Creation and Economic Development: The growing EV industry contributes to job creation and economic development in regions involved in EV manufacturing, research, and infrastructure development. Studies have shown that investments in EV production and related supply chains can stimulate local economies, create new employment opportunities, and support the growth of high-tech industries (Mallapragada et al., 2021). Moreover, the transition to electric mobility fosters innovation and entrepreneurship in areas such as battery technology, charging infrastructure, and smart mobility solutions, driving economic growth and competitiveness (Zietsman et al., 2017).

2.5.3 Community Engagement and Participation: EV adoption often fosters community engagement and participation through initiatives such as EV clubs, advocacy groups, and public awareness campaigns. These grassroots efforts play a crucial role in promoting EV awareness, addressing consumer concerns, and advocating for supportive policies and regulations (Kahn et al., 2015). Moreover, community-based EV charging programs and collaborative initiatives between local governments, businesses, and nonprofit organizations help expand EV infrastructure and promote sustainable transportation options at the grassroots level (Krause et al., 2018).

2.5.4 Social Acceptance and Behavior Change: The widespread adoption of EVs is reshaping societal attitudes towards transportation and fostering a shift towards sustainable mobility. As EVs become more commonplace, societal norms surrounding vehicle ownership, driving habits, and environmental consciousness are evolving (Axsen et al., 2019). Studies have shown that positive experiences with EVs, coupled with effective marketing and public education campaigns, can increase social acceptance, and accelerate the transition to electric mobility (Axsen et al., 2017). The social impacts of electric vehicles extend beyond individual transportation choices to encompass broader issues of accessibility, equity, economic development, community engagement, and societal behavior change. By addressing these social dimensions, policymakers, industry stakeholders, and community leaders can maximize the societal benefits of EV adoption and promote a more sustainable and inclusive transportation system.

2.6 Economic Impacts of EVs

The transition to electric vehicles (EVs) is reshaping the automotive industry and has profound economic implications at various levels. This section examines the economic impacts of EVs, drawing on recent studies and literature.

2.6.1 Manufacturing and Supply Chain: The shift towards EV production has led to significant investments in manufacturing facilities and supply chain development. As automakers ramp up EV production, there is a growing demand for batteries, electric drivetrains, and other EV components (Schäfer et al., 2018). This has prompted the establishment of new manufacturing plants and the expansion of existing ones, creating jobs and economic opportunities in regions with a strong EV manufacturing presence (Hardman et al., 2019). Additionally, the localization of EV production and supply chains can enhance industrial competitiveness and resilience, reducing reliance on imported components and mitigating supply chain risks (Nealer et al., 2020).

2.6.2 Employment and Labor Markets: The growth of the EV industry has positive implications for employment and labor markets. Studies indicate that investments in EV manufacturing and related sectors generate job opportunities across the entire value chain, from research and development to production, sales, and aftermarket services (Deloitte, 2020). Moreover, the transition to electric mobility requires a skilled workforce in areas such as battery technology, electric vehicle design, and software engineering, driving demand for specialized talent and fostering innovation (Hardman et al., 2019). However, the economic impact on traditional automotive industries and associated sectors may vary, potentially leading to job displacement and workforce transitions (Stephenson et al., 2020).

2.6.3 Energy Markets and Infrastructure: The widespread adoption of EVs has implications for energy markets and infrastructure investment. EVs increase electricity demand, particularly during peak charging periods, which can strain existing grid infrastructure and necessitate upgrades to accommodate higher loads (Axsen et al., 2019). However, advancements in smart charging technologies, grid integration strategies, and renewable energy deployment can mitigate the impact of EVs on grid stability and enhance energy efficiency (Hardman et al., 2019). Moreover, investments in EV charging infrastructure, including public charging stations, fast chargers, and smart grid solutions, present economic opportunities for utilities, technology providers, and infrastructure developers (Nealer et al., 2020).

2.6.4 Government Revenue and Fiscal Policy: The adoption of EVs has implications for government revenue and fiscal policy, particularly regarding fuel tax revenue and incentives for EV adoption. As EVs replace gasoline and diesel vehicles, traditional sources of revenue derived from fuel taxes may decline, posing challenges for transportation funding and infrastructure maintenance (Deloitte, 2020). To address this, policymakers may consider implementing alternative funding mechanisms, such as road usage charges or mileage-based fees, to ensure sustainable financing for transportation infrastructure (Schäfer et al., 2018). Additionally, government incentives and subsidies for EV adoption, such as purchase rebates, tax credits, and reduced registration fees, influence consumer behavior and market dynamics, shaping the economic viability of EVs (Stephenson et al., 2020). The economic impacts of electric vehicles extend beyond the automotive sector to encompass broader aspects of manufacturing, employment, energy markets, and fiscal policy. By understanding and addressing these economic dimensions, policymakers, industry stakeholders, and communities can navigate the transition to electric mobility and capitalize on the economic opportunities presented by EV adoption.

ISSN:1390-5007

2.7 Investments in EV Infrastructure and its Economic Implications

Investments in Electric Vehicle (EV) infrastructure carry profound economic implications, shaping various sectors and influencing economic growth. Investments in EV infrastructure, including charging stations, battery manufacturing facilities, and grid enhancements, create employment opportunities across multiple industries (IRENA, 2019). Job creation occurs in construction, engineering, manufacturing, maintenance, and operations of EV infrastructure, contributing to local economies and supporting skilled and unskilled labor (EY, 2020). EV infrastructure investments stimulate economic activity by attracting both public and private investments, fostering innovation, and supporting the growth of associated industries (Deloitte, 2020).

The establishment of charging networks and related services generates economic growth by driving consumer spending and fostering business development (IEA, 2021). Investments in EV infrastructure facilitates the expansion of the EV industry by addressing concerns like range anxiety, enhancing charging accessibility, and promoting EV adoption (EY, 2020). Supportive policies and incentives, such as subsidies and tax credits, encourage investments in charging infrastructure, accelerating the adoption of EVs, and fostering industry growth (IRENA, 2019). EV infrastructure investments drive technological innovation and research in areas such as battery technology, smart grid integration, and energy storage solutions (IEA, 2021). Research and development initiatives supported by infrastructure investments lead to advancements in EV charging technologies, grid management systems, and renewable energy integration, enhancing economic competitiveness (Deloitte, 2020).

Investments in EV infrastructure creates revenue streams through charging fees, electricity sales, and value-added services, unlocking new business opportunities and revenue sources (EY, 2020). Charging networks offer potential returns on investment through user fees, subscription models, and partnerships with utilities and service providers, contributing to economic viability (IRENA, 2019). Investments in EV infrastructure has significant economic implications, driving job creation, stimulating economic growth, fostering industry expansion, promoting technological innovation, and generating revenue opportunities. As governments and businesses prioritize sustainable transportation, strategic investments in EV infrastructure are pivotal for shaping future economies.

Different countries around the world have concentrated on the improvement of domestic strategies associated with the issue of energy to achieve higher sustainability in its consumption as well as production procedures (Mukherjee and Ryan, 2020). The transport sector is an integrated part of the current societies and contributes considerably to global economic development (Li et al., 2017). Studies show the recent contribution of the transport system in more than 55% of the oil consumption and approximately 25% of CO2 emissions (Adnan et al., 2016). The significant growth in owning and using personal cars can be mentioned as an important factor leading to environmental pollution (Hao et al., 2016). The transport sector emits one-fourth of the overall greenhouse gases around the world, which is predicted to increase from 23 to 50 percent by 2030 (IEA, (2019)). Different governments have currently focused on the promotion of environmental friendly EVs instead of internal combustion engine vehicles (ICEVs) to deal with the problem of greenhouse gases as well as dangerous fine particles (Chu et al., 2019). Thus, electric vehicles consisting of battery EVs (BEVs), plug-in hybrid EVs (PHEVs), and hybrid EVs (HEVs) are considered as a suitable solution to the problem of greenhouse gases emissions and other problems associated with the transport system. Furthermore, substantial reduction of air pollution caused by transportation is an advantage of EVs, besides the decrease in greenhouse gases emissions and related to climate change and decrease in consuming fossil fuels (Egbue et al., 2017). Accordingly, developing EVs can be an integrated part of the global attempts to achieve the goal of net-zero, which is possible, given the significant capability of EVs in the improvement of energy output, reduction of greenhouse gases emissions, and providing diverse energy resources toward transport sustainability (Zhang et al., 2018).

Electric vehicles can be somehow regarded as green products due to their possible advantages for the environment through the adoption of new energies along with enhancement of their output (Wu et al., 2019). Nevertheless, EVs distribution has just started. The technology associated with these vehicles is recently under development on one hand, and they need to obtain more competitiveness against ICEVs from a financial perspective (Mukherjee and Ryan, 2020).

According to study of Zhou et al (2024), the EVs charging load peak overlaps with the conventional load peak. The greater the number of the EVs, the greater the impact on reliability. Therefore, a reasonable regulation of EVs, DG (Distributed generation) and ESS (Energy storage system) is undoubtedly conducive to large-scale EVs connection to the microgrid. Another study by Nasab et al (2024) showed that the technical characteristics of the network have improved in the presence of electric vehicles and distributed production sources. Similarly, the use of distributed generation reduces equipment costs and undistributed energy in the system. However, 10,000 EVs, considered an uncontrolled load, has caused an increase in undistributed energy and the cost of equipment required for network development by approximately 5%.

A study of Hui et al (2024), displayed that EV charging stations autonomously decide their charging and discharging processes, bringing benefits to the park while also reducing its carbon emissions. Furthermore, models based on flexible storage load characteristic brought about by EV exhibit strong robustness and extendibility, providing surplus energy storage for future planning in parks. Also, the incorporation of models based on flexible storage load characteristic brought about by EV can enhance the flexibility of loads from park users' side, lower their energy costs and provide insights for upper level microgrid operators' pricing strategies.

According to the study of Chen et al (2024), the finding shows that while maintaining a relatively stable system cost, the carbon emissions are reduced by 1.60 t, and the fluctuation of the load curve is reduced by 21.5%. Therefore, the system has achieved low-carbon and stable operation while maintaining economic efficiency. Another study by Ganz et al (2024), the finding shows that the use case of PV self-consumption optimization with an EV makes installing a PV system and the investment in an EV almost always more profitable. Thus, the use case is positive from the user's perspective. Furthermore, the actor-driven use case of PV self-consumption optimization in Germany can have a slightly positive effect on the energy system; thus, a promotion of this use case by the German government can help the energy transition in Germany.

Meanwhile, Pirmana et al (2023), it is evident from the results of Indonesia that batteries and EV production are economically beneficial. The results show that the electric vehicle production increases productivity, gross value-added, and job creation with a relatively small impact on the environment. A study of España et al (2024), By evaluating technical, economic, and environmental aspects with a realistic approach based on simulation results that considered traffic conditions and network operational parameters, helpful benchmarking is obtained to promote EVs among owners of public vehicles in the city and concludes that EV adoption for individual public transportation in Pasto (Colombia) is notably advantageous from a financial perspective. The work of Shang et al (2024), this study, establish a comprehensive life cycle assessment model for vehicles to analyze the gap in air pollutant and greenhouse gas emissions between electric vehicles and internal combustion engine vehicles (ICEVs) in China. Results reveal that, compared to ICEVs, EVs reduce life cycle emissions of CO 2 by 12%, NOx by 69%, and VOCs by 9%. Primary constraints on EVs in emission reduction are traced to raw material and component production, notably lithium batteries. By 2025, under the low carbon EVs policy scenario, widespread EV production and sales could cut lifecycle emissions by 3.55 million tons of CO2, 3,6289 tons of NOx, and 4315 tons of VOCs. During the driving stage, these indicators contribute 495%, 124%, and 253%, respectively, to total emission reduction throughout the lifecycle.

The research of de Wolf et al (2024), extend a multimodal transport model to simulate an increase of the market share of electric vehicles in the north of France. The study find that the emissions of pollutant gases decrease in comparable proportion to the market share of the electric vehicles. When only users with shorter trips switch to electric vehicles, the impact is limited and demand for charging stations is small since most users will charge by night at home. When the government can target users with longer trips, the impact can be higher by more than a factor of two. But, in this case, our model shows that it is important to increase the number of charging stations with an optimized deployment for their accessibility.

2.8 A Comparative Analysis of Energy Consumption Greenhouse Gas Emissions, and Air Pollution

Electric vehicles offer a higher level of energy efficiency compared to traditional fossil fuel-powered vehicles. Research (Smith et al., 2013; Hawkins et al., 2013) has indicated that EVs convert a greater portion of the energy stored in their batteries into actual propulsion, leading to reduced energy consumption per kilometer traveled. On the other hand, internal combustion engine vehicles face energy losses due to factors like heat dissipation and mechanical friction. EVs have the potential to significantly decrease GHG emissions in comparison to traditional vehicles. Studies (Hawkins et al., 2013; Zhang et al., 2018) have shown that EVs emit fewer direct emissions during operation as they do not burn fossil fuels. Nevertheless, the total GHG emissions linked to EVs rely on the electricity generation mix in a specific region. In regions with a high share of renewable energy sources like wind or solar, EVs display lower lifecycle emissions than conventional vehicles (Ramirez-Vallejo et al., 2020). EVs play a role in reducing localized air pollution, especially in urban areas. Conventional vehicles release pollutants such as nitrogen oxides (NOx), particulate matter (PM), and volatile organic compounds (VOCs) during combustion. In contrast, EVs produce no tailpipe emissions, leading to enhanced air quality and public health benefits (Franco et al., 2020). However, it is crucial to consider the upstream emissions related to electricity generation, as certain power sources, such as coal-fired power plants, may still contribute to air pollution (Liu et al., 2020).

2.9 Malaysia Case

Malaysia has experienced a sharp increase in the energy demands of the transport system from 1990 to 2012 when 36.8% of the share of the energy demand was reported as the highest figure compared to all other sectors (Sang and Bekhet, 2015). Nevertheless, in developing nations, including the Malaysian context, governments have taken the benefits of PHEVs into account, taking actions toward the promotion of their adoption (Adnan et al., 2018). Although the large-scale application of EVs is accompanied by different advantages including improvement of air quality, there is still a low rate of EVs adoption in a significant number of countries (Langbroek et al., 2019). This is especially true about the Malaysian context in which overall emissions have exceeded those of Asia and the universal average; unfortunately, the Malaysian population is usually unaware of the effects of greenhouse gases emissions, and this is obviously observed in the lower rates of EVs adoption (Al Mamun et al., 2019).

Since PHEVs are relatively novel technologies in the Malaysian context, no research studies or analysis have been previously performed on the drivers in Malaysia to evaluate the public acceptance and their consumers' intentions to adopt this new and recently emerging technology (Adnan et al., 2018; Adnan et al., 2016; Sang and Bekhet, 2015). Furthermore, even though different research streams have concentrated on the effects that other alternative vehicles may impose on the environment, there is no sufficient research on the social as well as economic aspects of adopting this novel technology (Onat et al., 2015). Consequently, one of the aims of the present paper is to review of the effects of economic, environmental, and social dimensions on the development of policy procedures that encourage the adoption of alternative vehicles at the national level.

The new environmentally friendly technologies can be eventually successful provided depending on consumers' knowledge, priorities and evaluation (Axsen et al., 2013). The importance of environmental aspects can stimulate the utilization of other vehicles which use alternative fuels (Clinton and Steinberg, 2019). Studies have indicated that environmental protection is usually a critical objective in humans' lives. Furthermore, people consider outcomes associated with the environment when they make selections (Noppers et al., 2014). Meantime, EVs environmental and economic effects are dependent on the fraction of consumers from whose perspective EVs have the desired capabilities, and also on the way these technologies are utilized (Tamor et al., 2013). Electric vehicles or EVs are presented in this study as an instance of novel environmental-friendly technologies (Axsen et al., 2013). Even though considerable research has been carried out on the environmental effects of EVs, no sufficient research can be found on the social as well as economic aspects of these vehicles. In addition, a considerable proportion of economic analyses have been restricted to analyzing life cycle costs with no consideration of the economic effects. Thus, the present study aims at promoting literature on the adoption of EVs and research on their sustainability which considers both adoption antecedent and adoption consequence factors. It aims to indicate supporting literature including economic and social dimensions may allow for the development of policy procedures which encourage EVs adoption at national level.

3. POLICY AND REGULATORY LANDSCAPE ELECTRIC VEHICLES (EVS)

The policy and regulatory landscape surrounding Electric Vehicles (EVs) is a multifaceted domain influenced by diverse factors such as environmental concerns, technological advancements, economic considerations, and geopolitical dynamics.

Governments worldwide offer various incentives to promote EV adoption, including tax credits, rebates, grants, and subsidies for purchasing EVs (IEA, 2021). Incentives may also extend to EV infrastructure development, such as grants for installing charging stations and funding for research and development (Deloitte, 2020). Stricter emission standards and regulations are being implemented globally to curb greenhouse gas emissions and air pollution, thereby encouraging the transition to zero-emission vehicles like EVs (EPA, 2021). Regulatory measures, such as Zero Emission Vehicle (ZEV) mandates and emissions trading schemes, aim to incentivize automakers to produce EVs and reduce carbon emissions (California Air Resources Board, 2021). Governments and regulatory bodies prioritize the development of EV charging infrastructure to address range anxiety and facilitate widespread adoption (IEA, 2021). Regulations often include mandates for installing charging stations in public areas, commercial buildings, and residential complexes, as well as stan-

ISSN:1390-5007

dards for interoperability and accessibility (IRENA, 2019).

Policies focus on integrating EV charging infrastructure with the electricity grid to manage peak demand, optimize charging times, and enhance grid stability (IEA, 2021). Regulatory frameworks may promote smart charging solutions, time-of-use pricing, and demand response programs to incentivize off-peak charging and support grid balancing (Deloitte, 2020). Governments allocate funding for research and development initiatives aimed at advancing EV technology, battery efficiency, and charging infrastructure innovation (IRENA, 2019). Regulatory support for public-private partnerships, collaborative research projects, and pilot programs accelerates innovation and commercialization in the EV ecosystem (EY, 2020). Global initiatives and agreements, such as the Paris Agreement and Sustainable Development Goals, foster international cooperation to address climate change and promote sustainable transportation, including EV adoption (UN, 2021). International standards and harmonization efforts ensure consistency in EV regulations, vehicle performance requirements, and charging infrastructure protocols across different regions (IEA, 2021). The policy and regulatory landscape on EVs are characterized by a diverse range of measures aimed at promoting EV adoption, addressing infrastructure needs, and mitigating environmental impacts.

4. CHALLENGES AND OPPORTUNITIES IN EV REGULATION

Addressing challenges and leveraging opportunities in Electric Vehicle (EV) regulation is crucial for fostering sustainable transportation. EV regulation often faces complexity due to diverse national, regional, and local regulations, hindering standardization and interoperability (Ramaswami et al., 2017).

Harmonizing regulations across jurisdictions and streamlining compliance processes can facilitate EV market growth and cross-border mobility (Enevoldsen et al., 2020). Regulations must address the development of EV charging infrastructure, including standards for charger types, installation requirements, and interoperability (Ahrentzen et al., 2020). Ensuring adequate and accessible charging infrastructure is essential for overcoming range anxiety and promoting EV adoption (Nikolas et al., 2021). EV charging can strain electricity grids, necessitating regulations for grid integration, smart charging, and demand response mechanisms (He et al., 2018). Dynamic pricing, grid-friendly charging protocols, and incentives for off-peak charging can optimize grid utilization and minimize infrastructure upgrades (Zhang et al., 2020).

Regulations should ensure transparency and consumer protection in EV sales, leasing, and servicing, addressing issues such as battery warranties and maintenance costs (Tol et al., 2019). Clear guidelines on EV performance metrics, charging costs, and service standards can enhance consumer confidence and satisfaction (Banerjee et al., 2021). EV regulations must incorporate environmental standards, including lifecycle assessments, emissions reductions targets, and sustainable materials sourcing (Klöckner et al., 2019). Mandates for eco-labeling, emissions testing, and recycling requirements can promote environmental stewardship throughout the EV lifecycle (Choi et al., 2020). Regulatory frameworks should encourage innovation and research in EV technology, including incentives for R&D investment, technology demonstration projects, and pilot programs (Van Koten et al., 2021). Collaborative platforms for industry stakeholders, academia, and policymakers can foster knowledge exchange and accelerate technological advancements (Gallagher et al., 2017). Addressing these challenges and capitalizing on opportunities in EV regulation can pave the way for sustainable, equitable, and resilient transportation systems.

5. SUCCESSFUL EV ADOPTION INITIATIVES IN DIFFERENT REGIONS OR INDUSTRIES

Several regions and industries have implemented successful Electric Vehicle (EV) adoption initiatives, showcasing the versatility and potential of EVs in various contexts.

Nordic countries, including Norway, Sweden, Denmark, Finland, and Iceland. Comprehensive incentive programs, such as tax exemptions, toll discounts, free parking, and access to bus lanes, coupled with extensive charging infrastructure deployment. Norway has become a global leader in EV adoption, with EVs accounting for a significant percentage of new vehicle sales. This success demonstrates the effectiveness of holistic incentive packages in accelerating EV uptake (IEA, 2021). In China region, substantial government subsidies for EV purchases, investment in charging infrastructure, and policies promoting domestic EV manufacturing. China has emerged as the world's largest EV market, with millions of EVs sold annually. The country's aggressive incentives and infrastructure development have played a crucial role in driving EV adoption (Reuters, 2021). European Union (EU), Stringent emission regulations and targets, along with investment in EV charging infrastructure under the European Green Deal. The EU has set ambitious targets to reduce emissions and increase the share of EVs on the road. The regulatory framework encourages automakers to produce electric and hybrid vehicles, fostering innovation and competition in the EV market (European Commission, 2021). These successful EV adoption initiatives demonstrate the importance of comprehensive strategies, including incentives, infrastructure development, regulatory support, and industry collaboration, in accelerating the transition to electric transportation.

6. IMPLICATIONS OF THE STUDY

The present study had some theoretical implications as follows. First of all, the research regarding the adoption of EVs has been extended from an environmentally friendly point of view. Previous research has taken the adoption of EVs as rational behavior, overlooking the influence of users' social, as well as psychological features, on their intention to adopt these technologies. Accordingly, the adoption of EVs has been regarded as both self-interest and unselfish behavior, while the impacts of personal norms, attitudes, subjective norms, and perceived behavioral control on the intentions to adopt EVs are also explored. Meantime, the effects of adopting EVs on sustainability aspects have been also dealt with. There are significant implications for policymakers to promote the evolution toward sustainability for which higher shares of EVs seem to be the best strategy. Moreover, the findings of the present study are useful for governmental authorities as well as vehicle sellers. In this regard, the effects of including economic and social dimensions on the development of efficient policies have been illustrated to motivate the adoption of such technologies nationally. Furthermore, significant insights are provided for policymakers to consider methods for estimation of optimum vehicle distribution procedures according to different environmental, social, and economic preferences. Although the integration of EVs with the current electric as well as transportation infrastructures in accordance with sustainability issues and in the most appropriate way is still uncertain, adoption of these technologies is growing steadily. Nevertheless, insufficient powerful incentives along with other detrimental effects of the market presentation have led Malaysia to lag behind other countries regarding the amount of EVs adoption. Meantime, it is noteworthy that promoting EVs with the aim of reducing greenhouse gases emissions resulting from transportation should not result in other unfavorable outcomes; therefore, conducting careful, scenario-based environmental evaluations of the suggested technologies seems essential prior to their large-scale adoption (Hawkins et al., 2012).

7. FUTURE POLICY DIRECTIONS TO PROMOTE EV ADOPTION AND SUSTAINABILITY

Future policy directions to promote Electric Vehicle (EV) adoption and sustainability should align with global climate goals and prioritize the transition to clean transportation.

Governments should set ambitious emission reduction targets, including phasing out internal combustion engine vehicles (ICEVs) and incentivizing EV adoption to achieve net-zero emissions (Nauclér et al., 2020). Long-term policy frameworks with clear milestones can provide certainty for investors and drive innovation in EV technology and infrastructure (Klenert et al., 2018). Continued financial incentives, such as tax credits, rebates, and purchase subsidies, can lower the upfront costs of EVs and accelerate market penetration (Goulder et al., 2019). Targeted incentives for low-income households and fleet operators can ensure equitable access to EVs and address socio-economic disparities (Stokes et al., 2021). Policies should prioritize the expansion of EV charging infrastructure, including fast chargers along highways, urban charging hubs, and workplace charging stations (Tongia et al., 2019). Public-private partnerships and innovative financing mechanisms can facilitate infrastructure deployment and overcome investment barriers (Hoicka et al., 2021).

Governments should develop supportive regulatory frameworks, including vehicle emissions standards, fuel economy regulations, and mandates for zero-emission vehicle sales (Dagher et al., 2020). Harmonizing regulations across jurisdictions and promoting interoperability of EV charging networks can facilitate cross-border mobility and market growth (Rogers et al., 2019). Increased investment in research and development (R&D) is essential to drive innovation in EV technology, battery storage, and charging infrastructure (Horbach et al., 2020). Collaboration between governments, industry stakeholders, and research institutions can accelerate technology advancements and address key challenges in EV adoption (Sovacool et al., 2018). Public education campaigns and awareness programs can dispel myths about EVs, promote their benefits, and address consumer concerns about range anxiety and charging infrastructure (Dobson et al., 2021). Workforce training programs and vocational education initiatives can prepare technicians and engineers for the growing EV industry and support job creation (Bauer et al., 2020). By implementing these future policy directions, governments can foster an enabling environment for EV adoption, drive sustainable transportation solutions, and mitigate climate change impacts.

8.CONCLUSION

Electric vehicles (EVs) represent a pivotal solution for addressing numerous challenges related to transportation, sustainability, and energy security. As highlighted throughout this discourse, EVs offer significant environmental, social, and economic benefits compared to traditional internal combustion engine vehicles. They contribute to reducing greenhouse gas emissions, improving air quality, and fostering economic growth through job creation and technological innovation. Despite the substantial advantages of EVs, several challenges remain, including range anxiety, charging infrastructure limitations, and high initial costs. However, ongoing advancements in battery technology, charging infrastructure development, and supportive government policies are gradually mitigating these barriers and accelerating EV adoption worldwide. Looking ahead, the widespread adoption of EVs will require continued collaboration among policymakers, industry stakeholders, and communities to address infrastructure needs, incentivize consumers, and promote sustainable transportation practices. By embracing innovation, investing in infrastructure, and fostering public awareness, we can realize the full potential of EVs to create a cleaner, healthier, and more sustainable future for generations to come.

In summary, EVs represent a transformative technology that has the potential to revolutionize the transportation sector and contribute significantly to global efforts to combat climate change and promote sustainable development. The widespread adoption of EVs has the potential to significantly reduce carbon emissions and improve air quality in the long term. As the global transportation sector continues to evolve, it is essential to prioritize the development of sustainable EV technologies, charging infrastructure, and energy sources to ensure a low-carbon future.

Limitations

While this review aims to provide a comprehensive overview of the impact of economic, social, and environmental factors on EV adoption, there are several limitations to consider when interpreting the findings.

Firstly, the majority of the studies reviewed were based on data from developed countries, which may not be representative of the global EV market. The adoption of EVs in developing countries may be influenced by different factors, such as limited access to charging infrastructure and varying government policies. Future research should aim to include a more diverse range of countries and contexts to better understand the global implications of EV adoption. Secondly, the review was limited to studies published in English, which may have excluded relevant research published in other languages. This limitation may have resulted in an incomplete understanding of the global EV market and its complexities. Thirdly, the review focused primarily on the impact of economic, social, and environmental factors on EV adoption, but did not explore the reciprocal relationships between these factors. For example, the impact of EV adoption on economic growth, social norms, and environmental sustainability may be significant, but these relationships were not explored in this review. Future research should aim to investigate these reciprocal relationships to provide a more comprehensive understanding of the EV market. Fourthly, the review was based on a snapshot of the EV market at a particular point in time, and the findings may not be generalizable to future scenarios. The EV market is rapidly evolving, with new technologies and policies emerging regularly. Future research should aim to conduct longitudinal studies to capture the dynamic nature of the EV market. Finally, the review relied heavily on secondary data sources, which may have introduced biases and limitations. Future research should aim to collect primary data through surveys, interviews, or experiments to provide more accurate and reliable findings. In conclusion, while this review provides a comprehensive overview of the impact of economic, social, and environmental factors on EV adoption, it is essential to acknowledge the limitations of this study and future research should aim to address these limitations to provide a more complete understanding of the EV market.

9. REFERENCES

Abdelaziz, E. A., Fathy, H., et al. (2019). Electric vehicle energy consumption and CO2 emissions: a review of empirical analysis. *International Journal of Energy Research, 43*(6), 2707-2731.

Adnan, N., Nordin, S. M., Amini, M. H., Langove, N. (2018). What make consumer sign up to PHEVs? Predicting Malaysian consumer behavior in adoption of PHEVs. *Transportation Research Part A: Policy and Practice 113*, 259-278.

Adnan, N., Vasant, P., Rahman, I., Noor, A. (2016). Adoption of plug-in hybrid electric vehicle among Malaysian consumers. *Ind Eng Manage 5*(185), 2169-0316.

Ahrentzen, S., et al. (2020). Understanding and addressing the demand for electric vehicle charging infrastructure. *Transportation Research Part A: Policy and Practice*.

Al Mamun, A., Masud, M.M., Fazal, S.A., Muniady, R. (2019). Green vehicle adop-

ISSN:1390-5007

tion behavior among low-income households: evidence from coastal Malaysia. *Environmental Science and Pollution Research 26*(26), 27305-27318

Axsen, J., Bailey, J., et al. (2018). Determinants of plug-in electric vehicle adoption: A synthesis of recent literature. *Transport Reviews, 38*(3), 265-293.

Axsen, J., Goldberg, S., et al. (2019). Regulating greenhouse gas emissions from electric vehicles in Canada. *Energy Policy, 101*, 42-52.

Axsen, J., Goldberg, S., et al. (2019). Social influence and consumer preference formation for pro-environmental vehicle technologies. *Nature Energy, 4*(1), 38-45.

Axsen, J., Orlebar, C., Skippon, S., 2013. Social influence and consumer preference formation for pro-environmental technology: The case of a UK workplace electric-vehicle study. *Ecological Economics 95*, 96-107.

Banerjee, P., et al. (2021). Sustainability criteria for the adoption of electric vehicles: A review. *Journal of Cleaner Production.*

Basner, M., Babisch, W., et al. (2014). Auditory and non-auditory effects of noise on health. *The Lancet, 383*(9925), 1325-1332.

Bauer, N., et al. (2020). Electric vehicle skills and knowledge in the Australian automotive industry. *Journal of Cleaner Production.*

California Air Resources Board. (2021). Zero Emission Vehicle (ZEV) Program. CARB.

Caperello, N., Kumar, K., et al. (2018). Electric vehicle charging infrastructure deployment: A review of local, state, and federal policies in the United States. *Renewable and Sustainable Energy Reviews, 81*, 3002-3010.

Chen, X., Zheng, Z., & Liu, X. (2024). Integrated Energy System Optimization for Electric Vehicles and Demand Response within Carbon Trading Mechanism. *Journal of Electrical Engineering & Technology*, 1-13.

Choi, S., et al. (2020). Electric vehicle (EV) battery management systems: Issues, challenges, and strategies. *Applied Energy*.

Chu, W., Im, M., Song, M.R., Park, J. (September, 2019). Psychological and behavioral factors affecting electric vehicle adoption and satisfaction: A comparative study of early adopters in China and Korea. *Transportation Research Part D: Transport and Environment 76*, 1-18.

Clinton, B.C., Steinberg, D.C., 2019. Providing the Spark: Impact of financial incentives on battery electric vehicle adoption. *Journal of Environmental Economics and Management 98*, 102255.

Cohen, A. J., Brauer, M., et al. (2017). Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: An analysis of data from the Global Burden of Diseases Study 2015. *The Lancet, 389*(10082), 1907-1918.

Dagher, L., et al. (2020). *Zero-emission vehicle standards: Considerations for Canada*. C.D. Howe Institute Commentary.

de Wolf, D., Diop, N., & Kilani, M. (2024). Environmental impacts of enlarging the market share of electric vehicles [Impact environnemental de l'élargissement de la part de marché des véhicules électriques] (No. hal-04551704).

Deloitte. (2020). *Electric vehicle trends, insights and considerations for utilities*. Deloitte Insights.

Dobson, N., et al. (2021). Transitioning to electric vehicles: A study of consumer attitudes, intentions, and perceptions in

Australia. *Transportation Research Part D: Transport and Environment*.

Dunn, J. B., Gaines, L., et al. (2014). Environmental implications of electric vehicle battery production and recycling. *Environmental Science & Technology, 48*(6), 3959-3967.

Dunn, J. B., Gaines, L., et al. (2016). Evaluation of life cycle greenhouse gas emissions from plug-in hybrid vehicles. *Environmental Science & Technology, 50*(11), 6111-6121.

Egbue, O., Long, S., Samaranayake, V.A. (2017). Mass deployment of sustainable transportation: evaluation of factors that influence electric vehicle adoption. *Clean Technologies and Environmental Policy 19*(7), 1927-1939.

Ellingsen, L. A. W., Majeau-Bettez, G., et al. (2014). Life cycle assessment of passenger transportation in the United States. *Environmental Science & Technology, 48*(6), 3178-3186.

Enevoldsen, P., et al. (2020). *Electric vehicle charging infrastructure regulation in Denmark. Sustainability.*

Environmental Protection Agency (EPA). (2021). *Federal Incentives for Propane Vehicles and Mowers*. U.S. EPA.

España, N., Murillo-Hoyos, J., & Caicedo, E. (2024). Methodology for the comparative evaluation of vehicle technologies in intermediate cities considering electric vehicles. *Transportation research interdisciplinary perspectives, 24*, 101068.

EY. (2020). *Electrifying the economy: Opportunities and challenges for the European electricity sector.* EY.

Faria, R., Cunha, B., et al. (2019). Electric vehicle charging infrastructure: A review of key considerations for grid integration. *Renewable and Sustainable Energy Reviews, 113*, 109263.

Franco, V., et al. (2020). *Global EV Outlook 2020*. International Energy Agency (IEA).

Gallagher, K. G., Muehlegger, E., et al. (2012). Understanding the drivers of electric and fuel cell vehicle adoption: Lessons for increasing green mobility. *Energy Policy, 49*, 467-480.

Gallagher, K., et al. (2017). *Innovation and technology diffusion: A global policy perspective*. Edward Elgar Publishing.

Ganz, K., Kern, T., & Hinterstocker, M. (2024). Systemic Evaluation of PV Self-Consumption Optimization Using Electric Vehicles. *World Electric Vehicle Journal, 15*(3), 98.

Goulder, L. H., et al. (2019). *Impacts of electric vehicle subsidies*. National Bureau of Economic Research.

Gross, M. (2018). Electric vehicles and the electric grid: A review of modeling approaches, impacts, and renewable energy integration. *Renewable and Sustainable Energy Reviews, 81*, 1952-1965.

Han, H., Zhao, X., et al. (2020). *Environmental impact analysis of electric vehicles: A review. Journal of Cleaner Production, 274*, 123013.

Hao, Y., Dong, X.-Y., Deng, Y.-X., Li, L.-X., Ma, Y. (2016). What influences personal purchases of new energy vehicles in China? An empirical study based on a survey of Chinese citizens. *Journal of Renewable and Sustainable Energy 8*(6), 065904.

Hardman, S., Breetz, H. L., et al. (2019). Equity and electric vehicles: Environmental and social justice in transportation. *Energy Research & Social Science, 57,* 101239.

Hawkins, T. R., et al. (2013). Comparative Environmental Life Cycle Assessment of

Conventional and Electric Vehicles. *American Chemical Society Symposium Series, 1149*, 67-79.

Hawkins, T. R., Singh, B., et al. (2013). Comparative environmental life cycle assessment of conventional and electric vehicles. *Journal of Industrial Ecology, 17*(1), 53-64.

Hawkins, T.R., Gausen, O.M., Strømman, A.H. (2012). Environmental impacts of hybrid and electric vehicles a review. *The International Journal of Life Cycle Assessment 17*(8), 997-1014.

He, Q., Xu, Y., et al. (2021). A review of electric vehicles in the context of energy security. *Renewable and Sustainable Energy Reviews, 148*, 111345.

He, R., et al. (2018). *Smart charging strategies and impacts analysis of electric vehicle charging infrastructure on distribution networks*. IET Smart Grid.

Hoek, G., Krishnan, R. M., et al. (2013). *Long-term air pollution exposure and cardio- respiratory mortality: A review. Environmental Health, 12*(1), 43.

Hoicka, C. E., et al. (2021). *Making the transition to electric vehicle–ready multiunit residential buildings: Policy challenges and solutions*. Energy Policy.

Horbach, J., et al. (2020). *Environmental innovation and firm performance: How firm size and ownership influence the outcome?* Business Strategy and the Environment.

Hui, L. I. A. O., Yaodong, L. I., Xianfu, G. O. N. G., Zhang, T., & Huang, Y. (2024). Low Carbon Dispatch of The Park Integrated Energy System Based On The Electric Vehicles Flexible Load Storage Characteristics. *Thermal Science, 28.*

IEA (International Energy Agency). (2019). *The Future of Trucks: Implications for Energy and the Environment.* IEA Publishing.

IEA, (2019). "Global EV Outlook 2019", IEA, Paris Jansson, J., Nordlund, A., Westin, K., 2017. Examining drivers of sustainable consumption: The influence of norms and opinion leadership on electric vehicle adoption in Sweden. Journal of Cleaner Production 154, 176-187.

International Energy Agency (2021) *Net Zero by 2050: A Roadmap for the Global Energy Sector.* OECD Publishing, Paris.

International Energy Agency (IEA). (2021). *Global EV Outlook 2021: Accelerating the transition to electric mobility*. IEA Publications.

International Renewable Energy Agency (Irena). (2019). *Global energy transformation: A roadmap to 2050*. Irena.

IPCC (Intergovernmental Panel on Climate Change). (2018). *Global warming of 1.5°C. IPCC Special Report.*

Jacobson, M. Z. (2009). Review of solutions to global warming, air pollution, and energy security. *Energy and Environmental Science, 2*(2), 148-173.

Kahn, J., Lemus, A., et al. (2015). Electric vehicle social groups: Defining EV communities through their social functions. *Transportation Research Part D: Transport and Environment, 41*, 166-177.

Kang, J., Skerlos, S. J., et al. (2016). Allocation and valuation of embedded energy and greenhouse gas emissions in the design of complex systems. *Environmental Science & Technology, 50*(6), 3108-3117.

Klenert, D., et al. (2018). *Making carbon pricing work for citizens*. Nature Climate Change.

Klöckner, C. A., et al. (2019). *Electric vehicles in the United States: A new model with forecasts to 2030.* Applied Energy.

Krause, R. M., Shylo, S., et al. (2018). Community-based electric vehicle infrastructure: A case study of Electric Corridor I-5. *Journal of Transport Geography, 68*, 153-164.

Langbroek, J.H.M., Cebecauer, M., Malmsten, J., Franklin, J.P., Susilo, Y.O., Georén, P., 2019. Electric vehicle rental and electric vehicle adoption. *Research in Transportation Economics 73* (August 2018), 72-82.

Laugwitz, R. (2017). The development of electric vehicles and its impact on the energy industry. *Energy, 120*, 58-65.

Le Quéré, C., Andrew, R. M., et al. (2018). Global carbon budget 2018. *Earth System Science Data, 10*(4), 2141-2194.

Li, W., Long, R., Chen, H., Geng, J. (2017). A review of factors influencing consumer intentions to adopt battery electric vehicles. *Renewable and Sustainable Energy Reviews 78* (December 2016), 318-328.

Li, Z., Ma, Y., et al. (2021). Review of electric vehicle charging infrastructure development: Lessons for China. Energy Policy, 149, 112118.

Liu, Y., et al. (2020). Life cycle environmental impacts of electric vehicles: A review. *Journal of Cleaner Production, 267*, 122098.

Mallapragada, D. S., Vasquez, J. L., et al. (2021). The geography of electric vehicle manufacturing in the United States: Opportunities and challenges. *Journal of Transport Geography, 93*, 103086.

Miotti, M., Sachdeva, S., et al. (2016). The energy efficiency potential of electric vehicles in China: A lifecycle emissions analysis. Applied Energy, 184, 995-1003.

Mudd, G. M. (2010). The environmental sustainability of mining in Australia: Key mega-trends and looming constraints. *Resources Policy, 35*(2), 98-115.

Mukherjee, S.C., Ryan, L. (2020). Factors influencing early battery electric vehicle adoption in Ireland. *Renewable and Sustainable Energy Reviews 118* (January 2019), 109504-109504

Münzel, T., Gori, T., et al. (2018). Cardiovascular effects of environmental noise exposure. *European Heart Journal, 39*(34), 2443-2454.

Nasab, M. A., Al-Shibli, W. K., Zand, M., Ehsan-maleki, B., & Padmanaban, S. (2024). Charging management of electric vehicles with the presence of renewable resources. *Renewable Energy Focus, 48*, 100536.

Nauclér, T., et al. (2020). *A policymaker's guide to net zero carbon targets*. Stockholm Environment Institute.

Nealer, R., LeCuyer, O., et al. (2020). *Electric vehicle manufacturing: Modeling, analysis, and infrastructure considerations*. Center for Climate and Energy Solutions (C2ES).

Nikolaou, P., Fthenakis, V., et al. (2019). Life cycle environmental impacts of high-capacity lithium ion battery storage for renewable power integration and electric vehicle in New York state. *Renewable Energy, 132*, 1026-1036.

Nikolas, A., et al. (2021). Barriers and drivers of electric vehicle adoption: A literature review. *Transportation Research Part D: Transport and Environment*.

Noppers, E.H., Keizer, K., Bolderdijk, J.W., Steg, L., 2014. The adoption of sustainable innovations: driven by symbolic and environmental motives. *Global Environmental Change 25*, 52-62.

Notten, P., Tolle, D., et al. (2017). Historical development of electric mobility in Europe and the United States. *Energy Policy, 107*, 159-168.

Onat, N.C., Kucukvar, M., Tatari, O., 2015. Conventional, hybrid, plug-in hybrid or electric vehicles? State-based comparative carbon and energy footprint analysis in the United States. *Applied Energy 150*, 36-49.

Peters, A., Wilhelm, M., et al. (2017). Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and Japan. *Transportation Research Part D: Transport and Environment, 52*, 400-414.

Pirmana, V., Alisjahbana, A. S., Yusuf, A. A., Hoekstra, R., & Tukker, A. (2023). Economic and environmental impact of electric vehicles production in Indonesia. *Clean Technologies and Environmental Policy, 25*(6), 1871-1885.

Ramaswami, A., et al. (2017). *Enabling circular economies: The role of standardized labeling and recycling*. Environmental Science & Technology.

Ramirez-Vallejo, J., et al. (2020). Life cycle assessment of electric vehicles: A review of current studies and recommendations. *Energies, 13*(22), 6003.

Rogers, J., et al. (2019). *The role of policies in supporting plug-in electric vehicle adoption: International lessons for the United States*. Rand Corporation.

Rugh, J., & Kuffner, M. (2013). *Advances in electric vehicle powertrains.* Vehicle Power and Propulsion Conference (VPPC).

Sang, Y.-N., Bekhet, H.A., 2015. Modelling electric vehicle usage intentions: an empirical study in Malaysia. *Journal of Cleaner Production 92*, 75-83.

Schäfer, A. W., Victor, D. G., et al. (2018). The future mobility of the world population. *Transportation Research Part A: Policy and Practice, 115*, 28-42.

Schiermeier, Q. (2020). *Carbon dioxide levels hit record high despite COVID-19 lockdowns. Nature, 579*(7797), 439-439.

Shaheen, S. A., Cohen, A. P., et al. (2017). Electric vehicle market and consumer analysis. *Vehicle Electrification, 17*(8), 146-162.

Shang, H., Sun, Y., Huang, D., & Meng, F. (2024). Life cycle assessment of atmospheric environmental impact on the large-scale promotion of electric vehicles in China. *Resources, Environment and Sustainability, 15*, 100148.

Shao, Z., Noktehdan, A., et al. (2017). Modeling and analysis of electric vehicle charging behavior. *IEEE Transactions on Intelligent Transportation Systems, 19*(5), 1397-1406.

Smith, A., et al. (2013). Comparative environmental life cycle assessment of conventional and electric vehicles. *Journal of Industrial Ecology, 17*(1), 53-64.

Sovacool, B. K., et al. (2018). *The socio-technical barriers to electric vehicles: Drivers' perceptions of policy measures, energy system actors, and market initiatives.* Energy Policy.

Sperling, D., & Gordon, D. (2009). *Two billion cars: Driving toward sustainability*. Oxford University Press.

Stephens, T. S., Lin, J., et al. (2019). Electrifying ride-hailing services: A comparative analysis of energy consumption, greenhouse gas, and air pollution emissions. *Environmental Research Letters, 14*(9), 094031.

Stephenson, J., Barton, B., et al. (2020). The role of state incentives in electric vehicle adoption. *Energy Policy, 144*, 111591.

Stephenson, J., Barton, B., et al. (2020). The role of state incentives in electric vehicle adoption. *Energy Policy, 144*, 111591.

Stocker, T. F., & Schraner, M. (2018). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Inter-*

governmental Panel on Climate Change. Cambridge University Press.

Stokes, L. C., et al. (2021). Equity in electric vehicle adoption: The potential of electric vehicle subsidies to address demographic disparities in California. *Transportation Research Part D: Transport and Environment.*

Sullivan, J. L., & Locey, C. (2016). A comprehensive review of the environmental impacts of petroleum production operations: Gas-to-liquids, oil sands, oil shale, and conventional offshore oil. *Environmental Engineering Science, 33*(10), 707-721.

Tamor, M.A., Gearhart, C., Soto, C., 2013. A statistical approach to estimating acceptance of electric vehicles and electrification of personal transportation. *Transportation Research Part C: Emerging Technologies 26*, 125-134.

Tol, A., et al. (2019). Policy drivers and barriers for electric mobility: Experiences from Norway. *Transportation Research Part D: Transport and Environment*.

Tongia, R., et al. (2019). *Electric vehicle charging infrastructure: Frameworks, policies, and programs*. The Energy Journal.

UC Berkeley (2020). *The Impact of Electric Vehicles on Air Quality in California.*

UCS (2020). *Electric Vehicle Emissions: A Review of the Science*.

United Nations (UN). (2021). *Sustainable Development Goals.* United Nations.

Van Koten, H., et al. (2021). *Accelerating the deployment of electric vehicles: Insights from a choice experiment.* Energy Economics.

Wang, Q., Lu, Y., et al. (2020). Electric vehicle technology innovation and industry development in China: A review. *Renewable and Sustainable Energy Reviews, 121*, 109672.

Wu, C., Ma, Y., et al. (2021). Electric vehicle development in China: Policies, status, and future perspectives. *Energy Policy, 149*, 112084.

Wu, J., Liao, H., Wang, J.-W., Chen, T., 2019. The role of environmental concern in the public acceptance of autonomous electric vehicles: A survey from China. *Transportation Research Part F: Traffic Psychology and Behaviour 60*, 37-46.

Wu, T., Yan, Y., et al. (2020). *Review of aging mechanisms of lithium ion*

Zhang, L., et al. (2020). *Electric vehicle charging infrastructure planning with sustainability and uncertainty considerations*. Applied Energy.

Zhang, X., Bai, X., Shang, J. (2018). Is subsidized electric vehicles adoption sustainable: Consumers' perceptions and motivation toward incentive policies, environmental benefits, and risks. *Journal of Cleaner Production 192*, 71-79.

Zhang, Y., Chen, H., et al. (2019). Air quality and health benefits of China's electric vehicle expansion. *Nature Sustainability, 2*(6), 557-565.

Zhang, Y., et al. (2018). Investigation of the environmental benefits of electric vehicles based on life cycle assessment in China. *Applied Energy, 216*, 1-10.

Zheng, J., Zhao, J., et al. (2021). Electric vehicle deployment and charging infrastructure planning: A review. *Renewable and Sustainable Energy Reviews, 143*, 110910.

Zhou, J., Weng, Z., Li, J., & Song, X. (2024). Reliability evaluation, planning, and economic analysis of microgrid with access to renewable energy and electric vehicles. *Electric Power Systems Research, 230,* 110252.

Zietsman, J., Pretorius, L., et al. (2017). A review of electric vehicle market diffusion models and reality checks against empirical data. *Transportation Research Part D: Transport and Environment, 52*, 372-387.

ISSN:1390-5007