THE BENEFITS AND FUTURE CHALLENGES OF ELECTRIC VEHICLES

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Abstract

The purpose of this article is to examine the advantages of electric vehicles as well as potential future difficulties. EVs promises significant environmental advantages by minimising air pollution and greenhouse gas emissions mainly when powered by renewable energy sources. Moreover, they provide economic benefits such as reduced dependence on fossil fuels and lower operational costs. However, its adoption put forward various barriers such as battery deterioration, increased strain on power grids and inadequate charging infrastructure. An assessment has completed regarding the technological advancements, policy interventions, and market trends driving EV adoption by utilising a qualitative analysis using secondary data from government reports, industry studies, and academic literature. However, high initial costs and infrastructure gaps remain significant challenges. Innovations in battery technology, government incentives and expansion of charging networks supported to overcome these barriers. Finally, it was concluded that the integration of renewable energy and fostering public-private partnerships is important for hastening EV adoption.

Keywords: electric vehicles, sustainability, carbon emissions, charging infrastructure, renewable energy, battery technology, government incentives.

Introduction

With more than eight billion metric tonnes of carbon dioxide equivalent released each year, transportation is the second-largest source of greenhouse gas emissions worldwide. Emissions have almost doubled since 1990 and are predicted to keep increasing (EPA, 2025). According to a Department of Energy (.gov) estimate, 20% of worldwide CO2 emissions come from the transportation sector, which is why electric cars (EVs) are becoming more popular. In this case, EVs are viewed as a solution to the environmental problems of air pollution, climate change, and the depletion of fossil fuels. Through incentives, infrastructure development, and technical developments, governments, automakers, and energy providers around the world are attempting to achieve universal adoption in order to promote sustainable transportation (U.S. Environmental Protection Agency (.gov), 2025). Similarly, with a compound annual growth rate (CAGR) of 6.94% from 2025 to 2029, the electric vehicle industry is projected to generate $828.6 billion in global sales by 2025. By 2029, this expansion is anticipated to generate a market volume of $1.1 trillion and 18.84 million devices sold. With an anticipated $378 billion in revenue in 2025, China is predicted to produce the most. Additionally, the market is expanding quickly worldwide, with Norway and other nations setting the standard (Statista, 2025b).

Furthermore, in 2025, the U.S. Environmental Protection Agency (.gov) emphasised that electric vehicles (EVs) have zero tailpipe emissions, which contributes to global carbon footprint reduction and better urban air quality. Additionally, they are less expensive to operate and maintain than vehicles with internal combustion engines (ICEs), which makes them a good choice for both businesses and consumers. The strain on current power grids, high initial costs, poor charging infrastructure, and battery technological limits are some of the obstacles that EV adoption faces despite its benefits. For the shift to electric mobility to be seamless and sustainable, these issues must be resolved (Janasak, 2024). This study is unique as it thoroughly examines the advantages and difficulties of adopting EVs while also looking into ways to make them more sustainable. This study adds to the current conversations on sustainable energy and transport strategies by highlighting important challenges and possible solutions.

Research aim: The purpose of this study is to examine the advantages of electric vehicles as well as potential future difficulties.

The following **objectives** have been set to achieve the aim:

1. To analyse the environmental and economic benefits of EVs.
2. To investigate key challenges hindering EV adoption.
3. To evaluate technological advancements and policy measures that can accelerate EV adoption.
4. To recommend strategies for enhancing EV adoption and sustainability.

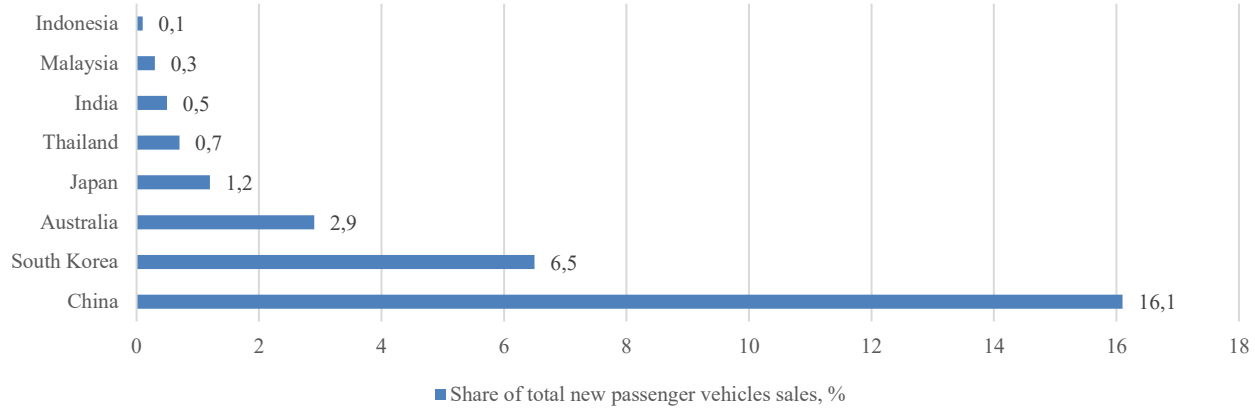
Research object and methods

The advantages and difficulties of electric vehicles (EVs) are examined in this study, with particular attention to the effects they have on the environment, the economy, and infrastructure. In addition to tackling adoption hurdles including battery constraints and gaps in the charging infrastructure, it examines how EVs save carbon emissions and operating expenses. Using secondary data from government regulations, industry reports, and scholarly journals, a qualitative method is employed. Furthermore, developments in battery technology and charging infrastructure are assessed to determine how they might hasten the adoption of EVs and guarantee sustainability over the long run.

Research results and discussion

Environmental and Economic Benefits of Electric Vehicles (EVs)

According to Alanazi (2023), the economic and environmental benefits of electric vehicles (EVs) have made their adoption more popular in recent years. EVs are becoming a competitive alternative to traditional internal combustion engine (ICE) vehicles as the globe moves towards more environmentally friendly modes of transportation. Their advantages are multifaceted and include cutting operating costs, promoting energy independence, enhancing air quality, and minimising greenhouse gas emissions. However, as illustrated in Figure 1, the adoption of electric vehicles varies significantly across countries, with certain nations leading in market penetration (Statista, 2024).



Source: Statista (2024)

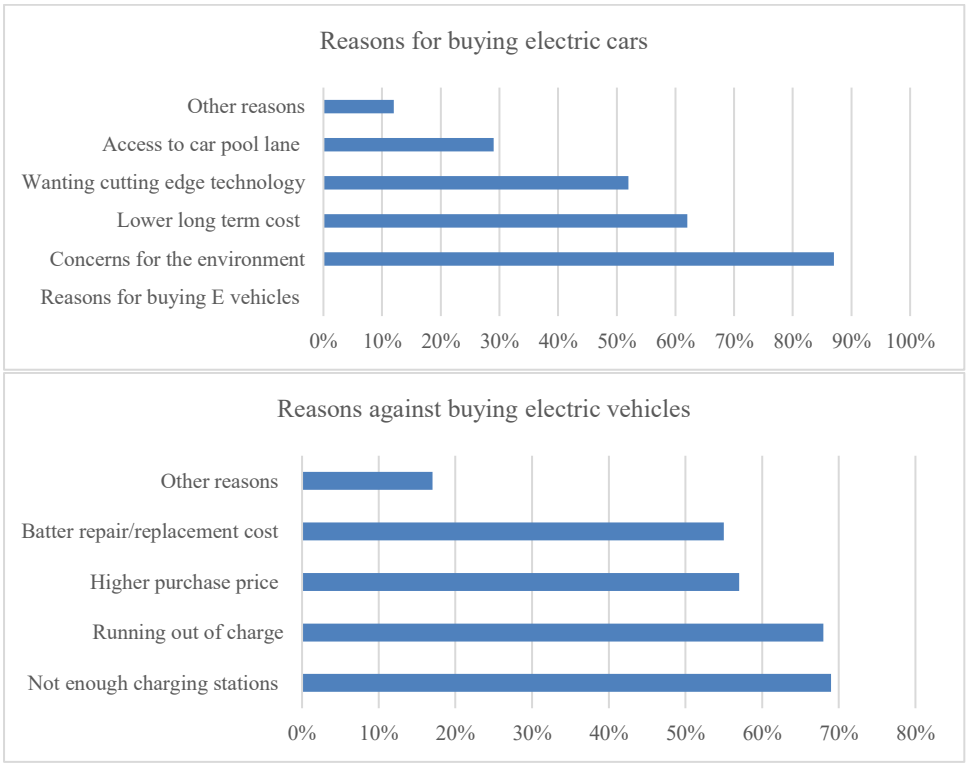
Fig. 1. APAC: electric vehicle adoption by country 2021

EVs' capacity to lower carbon emissions is among its most important benefits. Dhar et al. (2017) remarked that Electric cars (EVs) emit no exhaust emissions, in contrast to conventional gasoline or diesel-powered vehicles. This helps to significantly reduce greenhouse gases (GHGs), including carbon dioxide (CO_2). According to Ghosh (2020), EVs have a substantially reduced lifetime carbon footprint than internal combustion engines (ICEs), particularly when they are powered by renewable energy sources. The European Environment Agency (2024) estimates that over the course of their lifetime, EVs can cut CO_2 emissions by about 50% when compared to vehicles that run on fossil fuels.

Additionally, Alimujiang& Jiang (2020) found that EVs are essential for enhancing the quality of the air in cities. Since, Particulate matter (PM) and nitrogen oxides (NO_x) are two pollutants released by conventional automobiles that aggravate respiratory conditions and harm the environment, on the converse, air quality and public health have significantly improved in cities like Oslo and Amsterdam that have embraced EV adoption (Bielaczyc et al., 2015; Torkey &Abdelgawad, 2022). Lower healthcare expenses and an overall improvement in life quality are closely correlated with lower air pollution levels. Furthermore, Sathiyan et al. (2022) highlighted that EV adoption in the transportation industry supports international initiatives to tackle climate change. EVs are seen as a key component of sustainability plans by nations like Germany and the United Kingdom that have made a commitment to net-zero emissions (Geels et al., 2022).

In addition to their positive effects on the environment, EVs have major financial advantages, especially when it comes to cost savings. Figenbaum et al. (2014) pointed out that fuel savings is one of the main financial advantages of owning an EV. In general, electricity is less expensive than petrol or diesel, especially when it comes from renewable sources. According to research from the International Council on Clean Transportation (2022), EV owners can save up to 70% on fuel expenses when compared to owners of conventional vehicles. Furthermore, compared to fossil fuel pricing, electricity rates are typically more stable, providing businesses and consumers with long-term financial predictability. Similarly, Malmgren (2016) observed that reduced maintenance expenses are yet another significant benefit of EVs. Compared to ICE vehicles, EVs require less regular maintenance because they have fewer moving parts. Complex parts of conventional gasoline engines, like fuel injection mechanisms, exhaust systems, and transmissions, are prone to wear and strain. The simpler drivetrains of EVs, on the other hand, eliminate the need for exhaust system maintenance, engine repairs, and oil changes. Over the course of their vehicle's life, EV owners can save up to 40% on maintenance expenses (Rapson &Muehlegger, 2023; Parker et al., 2021).

In addition, EVs have positive economic effects on the entire economy in addition to individual consumers. Jobs in manufacturing, battery production, and infrastructure development have increased as a result of the EV industry (Eddy et al., 2019). For instance, China and the US, two nations that produce the most EVs, have made significant expenditures in battery technology and charging infrastructure (Statista, 2025a). Economies are moving towards a more technologically sophisticated and sustainable automotive sector as a result of the growing demand for EVs, which is encouraging innovation and economic resilience. Furthermore, by lowering reliance on imported oil, EV adoption enhances national energy security. According to Statista (2024b), the global adoption of electric vehicles in 2022 led to the displacement of almost 25 billion litres of petrol equivalent. Many nations are economically vulnerable as a result of volatile oil prices, especially those that import a lot of fossil fuels



Source: Statista (2017)

Fig. 2. The Pros and Cons of Driving Electric

Figure 2 presents a comparative analysis of the advantages and disadvantages of electric vehicles (Statista, 2017). While lower operating costs and environmental benefits drive adoption, challenges such as battery limitations and infrastructure gaps remain key barriers.

Challenges Hindering EV Adoption

According to Upadhyay et al. (2021), the majority of EVs are powered by lithium-ion batteries, which have a lower energy density than traditional internal combustion engine (ICE) cars and hence, their driving ranges are shorter. Range anxiety is still a major turnoff for buyers, even if improvements in battery technology have increased range. Eventually, many prospective consumers are deterred from switching to EVs by the concern that they will run out of charge before they can reach a charging station (Tao et al., 2020). Furthermore, Waseem et al. (2023) noted that, numerous cycles of charging and discharging lower battery efficiency, which impairs vehicle performance and accordingly, battery deterioration over time is a serious concern. The long-term viability of EVs is also thrown into doubt by the ethical and environmental issues surrounding the mining of lithium and cobalt for battery manufacture (Luong et al., 2022).

Moreover, long-distance travel is difficult in many places because of inadequate or non-existent of charging networks, especially in rural areas (Singh et al., 2022). This is mainly because of the lagging to adopt EV charging stations since they need a large investment and grid connectivity, in contrast to petrol stations, which are common and easily accessible (Ghasemi-Marzbali, 2022). Likewise, enhancing EV convenience requires fast-charging stations. However, there are obstacles to the adoption of such infrastructure, such as expensive installation costs, site acquisition, and legal barriers (Ghasemi-Marzbali, 2022). Additionally, the uneven adoption landscape caused by differences in the availability of charging stations between urban and rural regions limits the viability of EVs for people living outside of metropolitan areas (Singh et al., 2022). The widespread use of EVs is a serious problem for electrical infrastructure as well. Widespread EV charging might cause an abrupt spike in demand for electricity, overloading current networks and perhaps resulting in power shortages and increased electricity prices (Aguilar-Dominguez et al., 2020). This problem is especially problematic in areas where increased energy usage is already putting a strain on networks.

Technological Advancements and Policy Measures

Technological developments and pro-EV government regulations are greatly speeding up the adoption of electric cars (EVs). For instance, solid-state batteries, which have a higher energy density, better safety, and longer lifespans than conventional lithium-ion batteries, are being investigated by researchers (Yu et al., 2023). By avoiding the flammable liquid electrolyte included in traditional batteries, these batteries lower the possibility of overheating and fires. Furthermore, materials like lithium-sulphur batteries and silicon anodes are being developed to increase price and efficiency, opening up EVs to a wider market (Sunkari et al., 2024). Innovations in battery recycling and second-life applications are becoming more and more popular, in addition to advancements in energy storage. According to Montes et al. (2022), recycling programs seek to recover important resources such as nickel, cobalt, and lithium in order to lessen reliance on mining processes that harm the environment. EV batteries can be repurposed for energy storage in residences

and commercial buildings through second-life applications, expanding their usefulness beyond automobile use. These developments solve issues with battery waste management while also promoting sustainability.

In addition, government regulations are essential for encouraging the use of EVs making EVs more affordable than gasoline-powered cars. Through extensive incentives including tax exemptions, toll-free highways, and subsidies for charging infrastructure, nations like Norway have attained a market share of 64.5% in 2021 for electric vehicles (Yang et al., 2023). Likewise, automakers are being pressured to hasten their shift to electric vehicle manufacturing by the European Union's strict pollution requirements (Martins et al., 2023). In addition to investments in charging infrastructure, the federal and state governments of the United States provide tax credits, subsidies, and refunds for the purchase of electric vehicles (Liu et al., 2022). China, the largest EV market in the world, has also established itself as a worldwide leader in the sector by actively assisting EV producers with advantageous regulations and subsidies (Zhao et al., 2024). Moreover, investing in ultra-fast charging stations and wireless charging technologies are decreasing range anxiety and improving convenience by recharging in minutes and allowing cars to be charged while parked or even while travelling simultaneously (Mohammed et al., 2024).

Strategies for Enhancing EV Adoption and Sustainability

A comprehensive strategy that tackles infrastructural deficiencies, sustainability issues, affordability, and industry cooperation is needed to make the shift to an EV-dominated future. Mohammed et al. (2024) claimed that, by establishing fast-charging stations in residential areas and along roads requires cooperation between Governments and private companies. However, optimising energy distribution, smart grid technologies can prevent current power systems from being overloaded by charging demand. EV adoption will continue to be hampered by accessibility problems and range anxiety in the absence of such solutions (Tao et al., 2020). Moreover, the environmental benefits of EVs are diminished when they are charged using power produced from fossil fuels and hence, charging stations need to be powered by renewable energy sources like solar and wind in order to be truly sustainable (Barman et al., 2023). Likewise, investing in energy storage devices and microgrids can also help to enable this integration and provide a steady supply of renewable energy; however, EVs run the danger of increasing emissions rather than lowering them (Güven & Yücel, 2024). As the adoption is significantly hampered by high initial expenses, government subsidies, improved mass manufacturing efficiency, and battery technological advancements can all contribute to price reductions (Zhao et al., 2024). Tax breaks and financial assistance must be put in place by policymakers to increase EV accessibility, especially for low-income buyers. Hence, collaboration between governments, automakers, and technology firms is important drive a sustainable and widespread EV transition.

Conclusions

1. While there are many economic and environmental advantages to the widespread use of electric vehicles (EVs), there are also important issues that need to be resolved to guarantee a sustainable shift. EVs, especially those that run on renewable energy, are essential for lowering greenhouse gas emissions and enhancing air quality and through reduced fuel and maintenance costs, they also provide consumers with long-term cost benefits.

2. However, mass adoption is still hampered by issues including battery efficiency, gaps in the charging infrastructure, and the burden on electrical grids. To overcome these obstacles, technological developments are crucial, especially in the areas of battery innovation and recycling. For instance, energy efficiency and sustainability will be improved by the development of solid-state batteries and second-life applications.

3. Likewise, global EV adoption can also be greatly aided by government incentives like as tax credits, subsidies, and regulatory measures. Accessibility and convenience for EV customers are further guaranteed by the growth of charging networks through public-private partnerships. Accordingly, accelerating EV adoption requires a comprehensive strategy that combines affordability measures, infrastructure development, and stakeholder participation.

4. EVs can achieve their full potential as a sustainable mode of transportation by maximising grid management and incorporating renewable energy sources into charging stations. A cleaner, more effective mobility future will be possible if these important issues are resolved efficiently.

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