

Review

Powering Indonesia's Future: Reviewing the Road to Electric Vehicles Through Infrastructure, Policy, and Economic Growth

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Abstract: Electric vehicles (EVs) emerged as a help for Indonesia as a pathway to address environmental challenges related to air pollution and greenhouse gas emissions from the transportation sector. Despite governmental efforts, including Presidential Regulation No. 55/2019, EV adoption rates in Indonesia remain low, although sales are increasing annually due to limited charging infrastructure, high upfront costs, and consumer perception. This study distinguishes itself from previous research by moving beyond a singular focus on policy, adoption factors, barriers, or economic opportunities. Instead, it integrates these dimensions into a cohesive analysis while placing particular emphasis on government policies. By adopting this multidimensional approach, the study presents a nuanced understanding of EV adoption in Indonesia, exploring not only the drivers, challenges, and economic potential but also the tangible benefits of EV manufacturing and usage for both producers and consumers within the current regulatory framework. It highlights the transformative impacts of EV adoption on key areas such as job creation, GDP expansion, and energy security, offering strategic insights for policymakers, industry leaders, and stakeholders. Future research could explore rural infrastructure development, local battery production impacts, and long-term economic implications of EV in Indonesia's ecosystem.



Citation: Damanik, N.; Octavia, R.C.; Hakam, D.F. Powering Indonesia's Future: Reviewing the Road to Electric Vehicles Through Infrastructure, Policy, and Economic Growth. *Energies* **2024**, *17*, 6408. <https://doi.org/10.3390/en17246408>

Academic Editors: Christos-Spyridon Karavas, Athanasios Karlis, Konstantinos G. Arvanitis and Dimitrios Piromalis

Received: 18 November 2024

Revised: 9 December 2024

Accepted: 10 December 2024

Published: 19 December 2024

Keywords: electric vehicles; infrastructure; policies; incentives; consumer preferences; economic opportunities

1. Introduction

Indonesia is the 20th most polluted country globally, with 91 percent of its 268 million people living in areas where particulate pollution levels exceed WHO guidelines [1]. One of the primary contributors to this pollution is the transportation sector, which heavily relies on fossil-fuel-powered vehicles and contributes significantly to emissions such as NO_x, CO₂, PM₁₀, and PM_{2.5}, accounting for 72.4%, 92.36%, 57.99%, and 67.03%, respectively [2]. This reliance on fossil fuels poses a major challenge to public health and environmental sustainability.

In response to the urgent need to reduce emissions, which is also related to the ratification of the Paris Agreement, and to achieve Indonesia's Nationally Determined Contribution (NDC) target, a change in fossil energy consumption to green energy is needed. [3]. The transition to electric vehicles is a key strategy to reduce transportation-related emissions. Norway, as example, is a country that successfully made an EV adoption increase to around 80% in 12 years [4]. The country's ambitious transport policies have led to a decrease in transport emissions by 8.9% from 2005 to 2019, after peaking in 2012 at 15 million tonnes of CO₂ [5]. In contrast, traditional vehicles continue to dominate in many parts of the world, contributing significantly to urban pollution and greenhouse gas emissions. Electric vehicles (EVs), however, offer significant environmental benefits, such as improved reliability of energy, enhancing renewable energy use, and including a substantial reduction in CO₂ emissions, ranging from 8.72 to 85.71 kg of CO₂ per vehicle [6–8].



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Despite the advantages of EVs, the adoption rate of EVs in Indonesia remains at 0.1%, trailing behind regional peers like Malaysia (0.3%) and Thailand (0.7%) [9]. This was tied with a survey conducted by [10], which reveals that only 21% of motorcycle users and 5% of car users in Indonesia have switched to electric or hybrid vehicles, while the majority still rely on gasoline-fueled alternatives. One of the barriers to EV adoption is inadequate charging infrastructure. The limited number of charging stations, which are only available in some areas, makes the transition to EVs difficult because of the inconvenience for users [11–13]. In addition, consumer preferences and perceptions play a critical role [14,15]. Consumers are often deterred by the higher upfront costs, long charging times, and concerns about vehicle performance [12,14,16]. This highlights the challenge of bridging the gap between available infrastructure and consumer readiness to embrace electric mobility.

Globally, EVs perform well in urban areas where charging stations are more accessible and emissions are more concentrated [17]. However, in rural areas or regions with colder climates, the performance of EVs can be less reliable [18]. In contrast, traditional gasoline vehicles are often preferred in these conditions due to their longer range, quicker refueling times, and proven performance in diverse weather conditions. As EV infrastructure develops, these challenges may be mitigated, but they remain significant factors in many parts of the world.

An effort was made by the Indonesian government to address these challenges. The government has responded by issuing Presidential Regulation No. 55/2019 on the Acceleration of Battery Electric Vehicle Program. This regulation includes fiscal and non-fiscal incentive policies, charging infrastructure development, technology research and development, and strengthening of the electric vehicle component industry to encourage the use of electric vehicles. An increase in EV adoption could also create economic opportunities for the country. The increasing use of electric vehicles has a positive effect on Gross Domestic Product (GDP) growth, and can reduce the level of fuel oil imports, increase employment, and become a new opportunity for businesses in Indonesia [19,20].

Electric vehicles have great potential for Indonesia's economy, sustainable development, and environmental balance. Several studies related to electric vehicles in Indonesia have been conducted, and many highlights are related to the barriers of electric vehicles, such as high cost, limited charging infrastructure, and consumer perception [21–24]. However, these studies tend to be conducted separately based on the focus of their respective barriers and result in overlooked dynamic interactions between infrastructure gaps, financial incentives, and consumer readiness, which collectively affect the adoption rate of EVs. Furthermore, the effectiveness of government policies regarding EV adoption has not been thoroughly examined.

Unlike previous studies that focus solely on policy, adoption factors, barriers, or economic opportunities, this study offers a comprehensive analysis by integrating all these aspects and adding a focus on government policies. By doing so, it provides a holistic view of EV adoption in Indonesia, examining not only the adoption factors, barriers, and economic opportunities but also the benefits of EV manufacturing and usage for both manufacturers and consumers under existing government policies. The novelty of this study will lie in examining how increased use of electric vehicles can positively impact the economy, specifically in terms of job creation, GDP growth, and improved energy security. The subsequent sections of this paper will be organized as follows: Section 2 presents a literature review, Section 3 explores the current status of EV adoption in the Indonesia market, Section 4 delves into adoption of EVs in Indonesia and factors and aspects relating to their acceptance in the market, and Section 5 provides a conclusion.

2. Literature Review

In Indonesia, electric vehicles come in several types, including battery electric vehicles (BEVs), which are the most common; plug-in hybrid electric vehicles (PHEVs); and hybrid electric vehicles (HEVs). BEVs, relying entirely on electric power, dominate the market as

they cater to the growing demand for zero-emission transportation, and PHEVs, on the other hand, combine electric motors with internal combustion engines, offering greater range and flexibility [25]. Meanwhile, HEVs utilize a combination of internal combustion engines and batteries recharged through regenerative braking, eliminating the need for external charging. Each type presents distinct advantages and challenges, depending on user needs and the availability of charging infrastructure.

Table 1 shows the previous literature review in EV adoption worldwide. In relation to EV adoption types in Indonesia, generally, the adoption of electric vehicles (EVs) in Indonesia is still relatively slow, due to several barriers, such as limited charging infrastructure, high initial costs, and consumer perceptions of electric vehicle performance. According to research by [26,27] states that the charging infrastructure in Indonesia is still very limited, even though it is one of the important aspects for EV users. This limitation is one of the obstacles, and according to research by [28,29], electric vehicle infrastructure expansion is very important to encourage wider adoption of electric vehicle use.

Another significant barrier is the high upfront cost of EVs. According to research by [22,24] states that the high price of EVs is partly due to their batteries. The batteries used in EVs, particularly lithium-ion batteries, are among the most expensive components, though they provide high energy density and long life cycles compared to other battery technologies [30]. However, these batteries can degrade over time, especially under extreme usage conditions such as rapid charging or heavy driving cycles, which affect their performance and lifespan. This cost makes electric vehicles more expensive than internal combustion engine (ICE) vehicles and deters potential buyers despite possible long-term savings. Consumers' perception also has a critical role in the adoption of EVs. Studies by [31–33] shows how attitudes toward EVs' convenience and performance affect consumer choices. To address these kinds of issues, the Indonesian government intervened by issuing policies, such as Presidential Regulation No. 55/2019, aimed at lowering barriers to EV adoption by offering financial incentives and promoting infrastructure development.

Despite the obstacles, the transition to electricity offers economic and environmental benefits. According to research conducted by [34,35] states that the economic benefits for Indonesia related to the use of electric vehicles are able to reduce fuel oil imports and have a positive influence on trade balance. In addition, [36,37] estimate that the development of the electric vehicle ecosystem is able to create a considerable number of new jobs in the manufacturing and infrastructure sectors. From an environmental perspective, studies by [38,39] highlight that EVs significantly reduce CO₂ and NO_x emissions, aligning with Indonesia's climate commitments under the Paris Agreement. Their research demonstrates that EVs could substantially improve air quality and contribute to better public health by lowering the levels of harmful pollutants.

Table 1. Literature review.

No.	Author	Region	Data Set	Vehicle Type	Objective Focus	Examined Factor
1	Veza et al. (2022) [39]	Indonesia	Review	• HEV • BEV • PHEV	EV Opportunities and Challenges	• EV Trends • Types of EVs that available • Readiness of EVs infrastructure • Government Incentives
		Malaysia				
2	Nugroho & Widiyanto (2024) [21]	Indonesia	500 Random Sample from Twitter	EV	EV Adoption Sentiment Analysis	• EV Factor Adoption • Consumer Perceptions Based on Tweet on Twitter • Sentiment Analysis
3	Metais et al. (2024) [40]	Germany	• 30,000 Agents • 16 Different parameters	EV	Deployment & Optimizing of Charging Infrastructure	• Range Anxiety of Battery Threshold • Home Charging Rate • Searching Range of Charging Station • Maximum Budget of Charging Station Deployment

Table 1. Cont.

No.	Author	Region	Data Set	Vehicle Type	Objective Focus	Examined Factor
4	Ruoso & Ribeiro (2022) [41]	Brazil	31 EV Supply Chain Actors	EV	Attractiveness, Barriers, and Solution of EV Diffusion	- Environmental Dimension - Economic Dimension - Policy Dimension - Social - DimensionTechnical Dimension
5	Lyu et al. (2024) [8]	China	1,826,095 Observations	BEV	Air Quality of BEV Usage	- Emission Reductions - Air quality
6	Kim et al. (2018) [16]	South Korea	285 respondents were in their 30s	EV	EV Adoption Factors	- Perceived Value - Economic Benefit and Charging Risk Factors - Environmental - Innovativeness - Government Support
7	Tan et al. (2023) [22]	China, Europe, USA, Japan, South Korea, India, Thailand, Indonesia, Malaysia	10 Countries	EV	EV vs. ICEs Vehicle	- Vehicle Performance - Charging Infrastructure - Government Policy - Social Factors
8	Xu et al. (2021) [42]	China, France, Germany, India, Japan, The Netherlands, Norway, UK	8 Countries monthly data	EV	EV Impact towards CO ₂ Emissions	- Stock of EV on CO₂ Emissions - CO₂ Emissions on Stock of EV
9	Singh et al. (2021) [36]	India	Review	EV	EV Trends, Development and Policies	- EV Trends - EV Research and Development - EV Policies in India - Comparison of EVs Policy with Other Countries
10	Günther et al. (2015) [43]	Europe and China	700 Mio Vehicle	EV	Role of EV for Supply Chain Sustainability	- Total Emissions - Costs of EV
11	Buhmann et al. (2024) [44]	Spain	1816 Responses	BEV	BEV Adoption Intentions	- Attitude - Perceived Behavioral Control - Norm (Subjective & Moral) - Environmental Concern - Intention to Adopt BEV
12	Huang et al. (2023) [45]	ASEAN countries	Document Published Prior to 2023	EV	EV Policy Assessment	- Sociocultural & Demographic - Technological - Economical - Legislative - Urban Design - Political
13	Chen et al. (2021) [46]	United States	2018 Social Accounting Matrix for US National Economy 1657 Surveys	BEV	Environmental and Economic Impact	- Subsidies from Government - Price Incentives - Battery Manufacturing - Productivity - Energy Cost
14	Chatzikomis et al. (2014) [47]	Greece	3 Scenarios	EV	Environmental and Economic Impact	- Environmental Impact (Well-to-Wheel CO₂ & EV-HEV penetration) - Cost of Energy Consumed
15	Kolpakov & Galingier (2020) [48]	Russia	Review	EV	Environmental and Economic Impact	- CO₂ Emissions - Gross Domestic Product - Import Dependence

Table 1. Cont.

No.	Author	Region	Data Set	Vehicle Type	Objective Focus	Examined Factor
16	Åhman (2006) [49]	Japan	- Government Programmes since the Early 1970s - Technical Development and Choices	- BPEV - HEV - FCEV	Policy Impact on Evs	- Market Support - Support for Infrastructure RD & D Support
17	Bridi et al. (2024) [50]	United Arab Emirates	5459 Participants	EV	Economic and Geographic impact on Evs	- Cost Related - Place of Residence - Monthly Income - Geographical Locations
18	Rangaraju et al. (2015) [51]	Belgium	5 Test Vehicles 1 Km Driven of Vehicle	BEV	Emissions Performance on BEV	- Charging Profile - Driving Profiles - Energy Consumptions
19	Haidar & Aguilar Rojas (2022) [52]	France	94 French Departmens (2014 to 2019 Data)	- BEV - PHEV	Impact of Infrastructure and Socio-economic on EV adoption	- Market Shares - Technical Factors - Economic Factors - Socio-demographic Factors
20	Brătucu et al. (2019) [53]	Romania	1221 Students	EV	EV Purchase Intentions	- Concept of Green Consumptions - Intentions to Buy EV - Costs and Financial Benefit

3. Current Status of Electric Vehicle Adoption in Indonesia

Globally, the use of EVs continues to experience tremendous growth and reflects a significant shift toward sustainable transportation solutions. According to Figure 1, China still dominates the EV market, but sales are rising in other countries too and adoption is no longer only exclusively a phenomenon of wealthy countries. Global EV sales in 2023 were 3.5 million higher than in 2022, a 35% year-on-year increase and six times higher than in 2018 [54]. In September 2024, global sales of EVs and PHEV increased by an annual 30.5% [55].

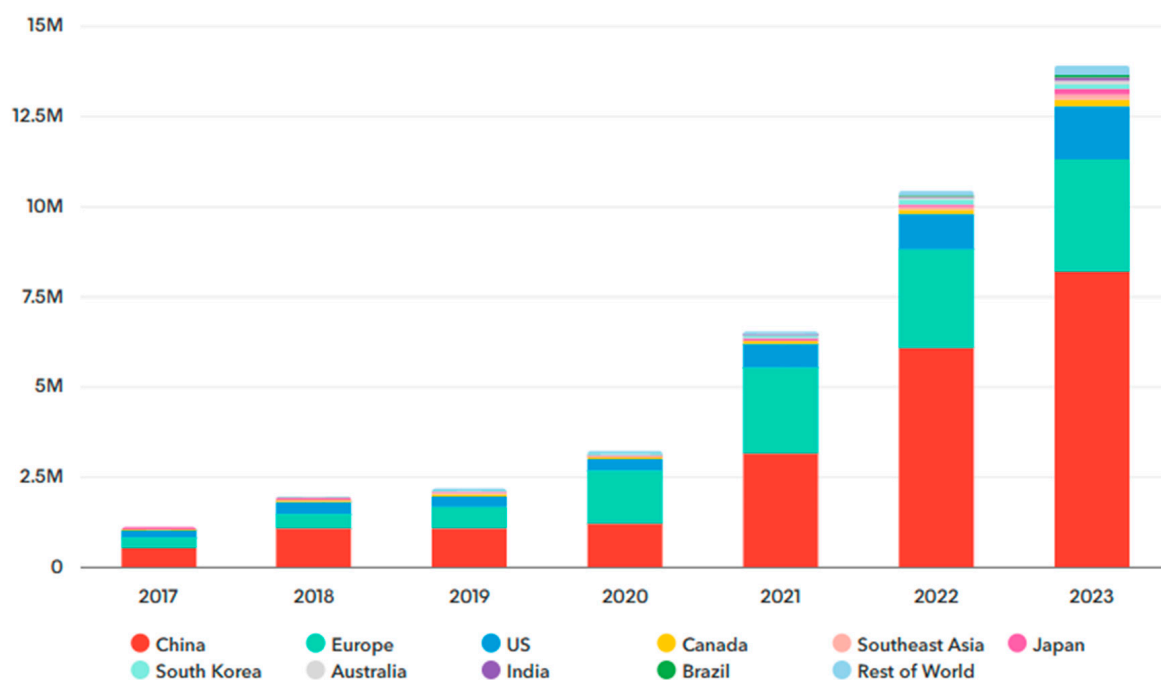


Figure 1. Global Passenger EV Sales by Market (Source: [56]).

The Indonesian government has set an ambitious target that by 2030, the adoption of EVs approximately should be at 15 million, which consists of 1.97 million electric cars and 12.90 million electric motorcycles, to support efforts in industrial transformation, energy resilience, and decarbonization. However, Indonesia's current adoption rate remains low compared to regional peers like Malaysia and Thailand [9]. Despite this, EV sales have shown promising growth. In 2020, EV sales in Indonesia amounted to just 125 units across all brands. This figure rose to 687 units in 2021 [57]. In 2022, GAIKINDO recorded a remarkable growth rate of 383.46%, with EV sales reaching 15,437 units—up from 3193 units in the previous year. Notably, the report highlights a staggering 1407.59% surge in battery electric vehicle (BEV) sales, with 10,327 units sold in 2022 compared to 685 units in 2021. Other than that, hybrid electric vehicles (HEV) are also gaining attention as an important part of Indonesia's transition to sustainable transportation. From January to September 2023, HEVs dominated the market, with a market share rising from 59.79% to 76.92% [57]. HEVs were preferred over BEVs because they combine both fuel-based engines and an electric motor with a larger battery, offering more flexibility, while also helping to reduce emissions.

Actually, developing an ecosystem of EVs in Indonesia involves several players like the state-owned enterprises Pertamina and PLN for infrastructure, and the Indonesia Battery Corporation for collaborations with foreign giants like LG Chemical and CATL for battery production. In addition, public knowledge of EVs is also needed in order to increase EV adoption. In Indonesia, around 63% of the public is knowledgeable about electric bikes, while 46% is knowledgeable about electric cars [58]. While the public's view of EVs is improving, charging infrastructure remains a challenge, as it is mainly available in urban areas like Java and Bali. To solve this, PLN has already built some charging infrastructure plans in some areas and will build 6316 general charging stations and 14,000 battery swap stations by 2025 to facilitate the growth and adoption of electric vehicles [58].

Looking forward, Indonesia's commitment to EV adoption could also be bolstered by integrating renewable energy sources into the EV charging infrastructure. By leveraging its abundant renewable energy resources, such as solar and geothermal, Indonesia has the potential to create a more sustainable and resilient EV ecosystem. Such integration not only aligns with the country's renewable energy goals but also mitigates the environmental impact associated with conventional energy sources. Therefore, to achieve this goal and to accelerate the adoption of electric vehicles in Indonesia, a focus on developing a good and distributed charging infrastructure is essential.

Ensuring an adequate EV charging infrastructure with suitable energy management schemes is crucial to facilitating a smooth transition to EVs in Indonesia. As of 2020, Indonesia's total power generation capacity was 63,336.12 megawatts [59]. It was confirmed by the State Electricity Company (PLN) that Indonesia has sufficient capacity for about 2.5 GW electricity surplus to supply electricity for EV usage. According to research by [60], 77% of respondents indicated that they would be more likely to adopt EVs if charging stations were conveniently located along their journey. This suggests that the availability and accessibility of charging infrastructure are key factors influencing consumer adoption of EVs. By now, the condition of Indonesia's charging infrastructure is still underdeveloped, with a limited number of charging stations scattered across the country, resulting in a geographical disparity in accessibility, particularly between urban and rural areas [61]. In addition to availability, charging stations should be strategically positioned to reduce range anxiety and provide convenience in daily use [40].

There are two types of EV chargers available in Indonesia, namely (1) Level 2 or Type 2 chargers, high-rate alternating current (AC) chargers that can fully charge a BEV in under 10 h and have power output capacities ranging from 7 kW–22 kW; and (2) direct current fast charging (DCFC), rapid chargers that can fully charge a BEV in 20–60 min with capacities from 25 kW–150 kW [62]. According to [58] in 2023, Indonesia has approximately 439 general charging stations and 961 battery swap stations available for electric vehicles. The distribution of these chargers shows a relatively balanced split, with 48% being Level 2

chargers and 52% being DCFC chargers [62]. However, charging station availability is mostly concentrated in some big cities.

In order to address these infrastructure gaps, the Indonesian government has set ambitious plans to expand the EV charging network. They predict that around 7,460,000 EVs will be sold in 2030 and because of that, Indonesia should provide at least 25,364 DCFC and 298,400 Level 2 charging ports [26]. However, several challenges must be overcome, including high investment costs for setting up new charging stations—especially DC fast chargers, the absence of standards for charging station operations; lack of land availability in strategic locations; and untested business models for charging/battery swap stations [63].

Developing an EVCS needs a quite higher investment. Although for some years, the development of EVCS has been increasing, there is a question that needs to be addressed, namely whether this investment is beneficial or not [64]. To encourage private-sector participation in building EV charging stations, the government is exploring various business models, including public–private partnerships and battery swap facilities. Yet these models are still in their nascent stages, and their feasibility remains untested. Despite these challenges, the Indonesian government is committed to accelerating EV adoption through incentives, tax reductions, and supportive policies for companies investing in charging infrastructure. With ongoing efforts and collaboration between public and private entities, the EV ecosystem is expected to become more robust and inclusive, helping the country achieve its sustainability goals and promoting greener transportation options.

4. Adoption of Electric Vehicles in Indonesia and Aspects Affecting Their Acceptance in the Market

4.1. Factors Affecting Adoption of EV in Indonesia

The use of EVs has caught the attention of the entire world and is driving the development of the EV market. However, various public opinions and responses have emerged regarding the significant advantages and disadvantages, when compared to ICE vehicles. In Indonesia, the presence of electric vehicles is still relatively new, making it important to understand consumer preferences and expectations for these vehicles.

Consumer behavior plays a significant role in the adoption of EVs especially in a diverse country like Indonesia, as in this country socio-economic and cultural disparities significantly influence people's purchasing decisions [23,65,66]. Customers living in urban areas prioritize convenience, adequate and sophisticated infrastructure, and government incentives [67]. Meanwhile, customers in rural areas will be more concerned about cost efficiency and reliability, given the limited availability of charging infrastructure in these areas and the lower level of public understanding and awareness of the benefits of EVs [68]. Socio-economic background influences perceptions of affordability, with higher-income consumers more likely to adopt EVs due to environmental concerns and social status, while lower-income consumers are deterred by high upfront costs and uncertainty about long-term savings [69].

Based on a survey conducted by [10] in 2023, customer intention to use electric vehicles is influenced by several factors, such as the environment factor, the financial factor, attributes and performance, etc. As shown in Figure 2, the survey data by [10] reveal that environmental friendliness is the most important reason for potential buyers to purchase electric cars (80%) and electric motorcycles (75%). Environmental reasons are aligned with previous research by Beck et al. in 2016, which concluded that environmental issues, which overcome the impact of energy saving, are among the important factors for attracting consumers when considering EVs as an alternative to conventionally fuelled motor vehicles. Other findings from [44,70] also stated that the effect of EVs on the environment has a relationship with the intention of consumers to use electric vehicles. In Beijing, 9.6% of the people would be willing to purchase an EV for its environmental benefits [71]. EV users expressed environmental concerns, particularly regarding the impact of using EVs on reducing greenhouse gas emissions in the transportation sector. For example, CO₂

emissions could decrease by 0.029% for every 1% increase in EV adoption, along with a 65% reduction in air pollutants like NO_x [38,42,72].

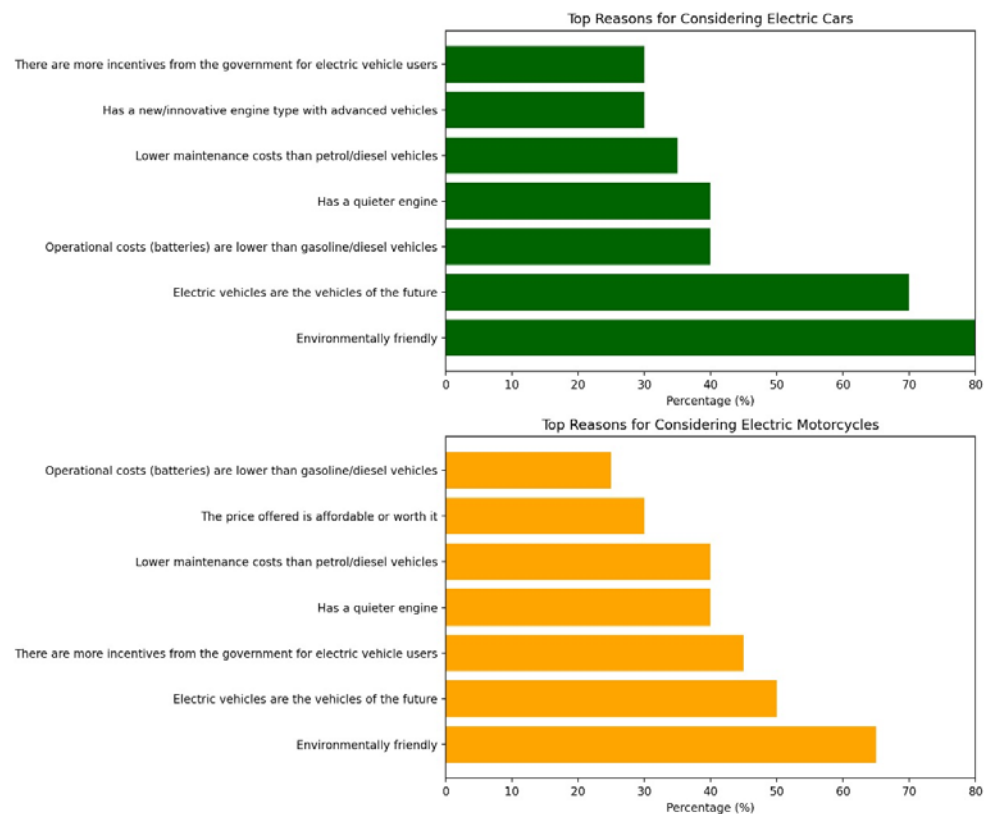


Figure 2. Reasons for Consumers Considering EVs both Cars & Motorcycles (Source: [1], Processed by Author).

Financial or economic factors significantly influence consumers' intentions to adopt EVs. EVs generally have lower operational and maintenance costs than conventional vehicles, e.g., cheaper charging expenses compared to fossil fuel cost and battery warranties of up to 8 years [20,73]. As reported by the Federal Office of Energy Efficiency and Renewable Energy, maintenance costs for EVs are projected to be approximately \$06 per mile, which is notably lower than the \$0.10 per mile required for internal combustion engine (ICE) vehicles [74]. However, concerns about battery replacement costs, particularly in developing markets with limited data, remain [39]. An example of this financial or economic analysis was performed by [22]. They found that over five years, the Hyundai Kona Electric costs RM 3691.00 to maintain, less than the Kona Active's RM 5514.70, even though some EV maintenance tasks are costly. In addition, there is a suggestion that the ideal EV ownership period is between 7 and 9 years for drivers with an annual mileage of 10,000 to 25,000 km, with economic efficiency reached around nine years for those driving between 10,000 and 25,000 km [75]. However, research by [76] suggests that cost parity between EVs and ICE vehicles, such as the Honda HR-V and Hyundai Kona EV, cannot be reached within six years of ownership, even with current tax incentives or if luxury goods and transfer taxes are eliminated.

Another factor that influences a customer's intention to use an EV is that when they drive an EV, there are no distracting sounds, and the safety features give the rider peace of mind [20,77]. A government policy related to incentives for EVs users is also one of the factors that influence customer intention. In Indonesia, a customer who wants to purchase an EV will get a subsidy of IDR 7 million for purchasing two-wheeled EVs with local content $\geq 40\%$ and for EV conversions [2]. Meanwhile, for purchasing four-wheeled EVs with local content levels of 40%, the government bears VAT 10%, so the user only pays 1%, which is cheaper than the VAT of conventional cars in which the customer has to pay

11% [3]. In addition, based on DKI Jakarta Governor Regulation No. 3 of 2020, driving with EVs is exempt from the odd-even policy.

Actually, both ICEs and EVs serve the same fundamental purpose of transportation; however, they differ in several respects including technology, environmental impact, operating costs, and driving experience. In Indonesia, most of the EVs are imported and this adds one factor of why EVs are more expensive and less appealing to potential buyers. For example, the price of an entry-level EV model (in this case, the Wuling Air EV) is USD 18,125, while the price of a similar-model ICE vehicle, e.g., a Daihatsu Ayla, is USD 9825 [78]. In Malaysia, some electric vehicles (e.g., the Nissan Leaf and the BMW i3s, with a life cycle cost (LCC) of USD 1.75 and USD 2.5 per km, respectively) are not financially competitive compared to internal combustion vehicles (ICVs) based on current data available in Malaysia [73]. The situation is quite different in other countries and regions, like Japan, China, Europe, and the United States, whereas the EV price is cost-competitive with the cheapest ICE vehicles [22].

Related to driving range, based on data from the [4], the median driving range of EVs was 234 miles, while for gasoline vehicles it was 403 miles. The maximum range of an EV model in 2021 was around 405 miles. The range for EVs is based on Environmental Protection Agency (EPA) estimates for a single charge, and for gasoline vehicles it is based on tank size and EPA-combined fuel economy rating. The main factor limiting EV range is the energy density, which represents how much electrical energy the battery can store per unit mass [79].

4.2. Economic Opportunities and Impact

EV adoption has a beneficial impact not only on the environment and the health of customers but also on the country. EV adoption can help reduce fuel oil imports, add a layer of energy security in the area where gas and oil prices are volatile and hit customers hard, increase employment, and become a new opportunity for businesses in Indonesia [20,80].

One of the economic benefits from EV adoption is to reduce the level of fuel oil imports, as there will be a shift in consumption from the use of fuel oil to more locally produced electricity. Indonesia's transportation and households significantly rely on energy imports, especially imported fuels, costing the country about two-thirds of its annual import spending [81]. This has long been an energy issue, and this consumption causes pollution. According to the Indonesia Battery Corporation (IBC), the state-owned battery holding company, if the use of EVs is widespread by 2035, it can cut fuel imports by 23 million barrels, and this will certainly have a positive effect on Indonesia's financial resources [5]. Significantly, the use of electric vehicles is able to reduce energy consumption, which positively impacts macroeconomic indicators by reducing overall energy costs and environmental degradation [19].

There is a positive correlation between EV adoption and Gross Domestic Product per capita [82,83]. A study by [41] found that wealthier countries are more likely to embrace EVs quickly due to higher purchasing power and a greater willingness to invest in innovative technologies, positioning GDP per capita as a key factor driving global EV adoption. If Indonesia shifts from ICE vehicles to EVs, the country's economy could gain an additional IDR 400–500 trillion or around USD 28–35 billion by the year 2030, assuming a scenario in which there will be a local manufacturing and supply chain for EVs and its technologies [84].

In most countries, the additional cost of two-wheel electric vehicles is relatively modest, typically under 10% of GNI per capita, except in Nepal where it reaches 80%. For four-wheel EVs, affordability is a more significant barrier, with costs exceeding 20% of GNI per capita in countries such as Cambodia, Ethiopia, Jamaica, and Vietnam, and soaring above 100% in Nepal. Despite these challenges, the adoption of EVs presents substantial economic potential. Projections from [85], estimate that increased EV use could raise GNI per capita to USD 46,275 per person by 2060. In Indonesia, the development of national EVs

could contribute an additional USD 21,434 million in value by 2035, supported by growth in upstream and downstream industries and the electric battery sector [86,87].

Beyond economic growth, the transition to EVs is expected to generate significant employment opportunities [88]. Indonesia's EV sector alone could create 538,658 new jobs, with the majority stemming from industries like plant-based fiber cultivation and machinery rentals [37]. Globally, similar trends are evident: Australia projects 13,400 new jobs by 2030 [89], while Europe anticipates creating 199,470 permanent jobs with a 35% EV market share and up to 1.2 million jobs with a full EV fleet [90]. By 2050, the energy transition could yield between 7.07 million and 12.17 million new jobs globally [91]. These findings highlight the dual impact of EV adoption in addressing affordability challenges and fostering economic and employment growth worldwide.

In addition, a transition from ICEs to EVs will have an impact on the automotive industry. According to [6], the effect of shifting to EVs for the automotive industry in Europe can reduce European automakers' market share from 60% to 45%. The automotive industry in Europe currently contributes around USD 1.9 trillion to Europe's economy, and if European automakers invest in local battery production, new technologies, and strategic partnerships through EV infrastructure, they can gain an additional USD 240–300 billion. In Indonesia, the transition to EVs poses several challenges for the automotive industry, particularly given that the country boasts the largest automotive sector in Southeast Asia. The production capacity of Indonesia's automotive industry is up to 2.35 million units per year with substantial foreign investment, primarily from Japan, which accounts for 83% of the industry's ownership. The challenge faced by some sectors of the automotive industry in Indonesia is that shifting to EVs could lead to a 30% reduction in ICE component manufacturers because of EVs' reliance on imported components, underdeveloped local supply chains, and significant investment requirements for new technologies [92].

One of the most important impacts of EV adoption is reducing greenhouse gas emission. EVs can reduce CO₂ emissions by up to 216 g per km for electric cars and 31 g per km for electric motorcycles. These reductions align with Indonesia's targets under the Paris Agreement, which aim for a 43% reduction in transportation emissions by 2030. EV adoption will reduce the use of fossil fuels, save Indonesia's expenditures for imported oil, and help to improve energy security. However, EV adoption also has other significant impacts, including supporting the transition to renewable energy (with a target of 100% renewable energy by 2060), increasing electricity demand, and driving higher nickel demand, which is critical for EV batteries, as Indonesia is one of the largest nickel producers [93,94]. On the positive side, EVs can help bolster energy security by integrating with renewable energy sources like solar and geothermal sources, reducing reliance on fossil fuels. Additionally, technologies like Vehicle-to-Grid (V2G) allow EVs to act as a means of mobile energy storage, feeding excess electricity back into the grid during peak demand, which enhances grid stability and resilience [95]. This integration supports Indonesia's long-term goals of renewable energy transition, energy diversification, and sustainability, making EV adoption a crucial part of the country's strategy for a cleaner, more secure energy future.

4.3. Government Policy of Electric Vehicles in Indonesia

Government intervention through financial or non-financial incentives plays a crucial role in accelerating the adoption of electric EVs. Presidential Regulation Number 55 of 2019 concerning the Acceleration of the BEV Program for Road Transportation is a legal umbrella issued by the government of Indonesia. Then, it was revised to Presidential Regulation (Perpres) No. 79/2023. The updated regulation regulates the transition from oil-fueled cars to electric vehicles, regulations for EV charging stations that involve battery replacement, adjustments to domestic content level regulations, provisions related to the import of battery electric vehicles, regulations and incentives for recipients, and specifications for electric charging infrastructure. In addition, there are several other supporting regulations in the use of EVs that can be considered by the producer and consumer sides.

Under the Regulation of the Investment Coordinating Board of the Republic of Indonesia Number 7 of 2020, businesses in the electric vehicle sector benefit from tax incentives in the production of EVs. According to [96,97], the Indonesian government has set a target to make up by 20% of all domestic e-cars and e-motorbikes manufactured by 2025. With these policies and the government's target, the expectation is that it will encourage businesses to invest in local EV production and also that mass production will be able to lower the upfront cost of EVs.

Simultaneously, policies such as Minister of Industry Regulation No. 27 of 2020 incentivize the use of locally sourced components, reducing reliance on imports and supporting the growth of domestic suppliers. In addition, there is a policy that regulates the requirements and facilities for the domestic EV industry in carrying out the production process if it requires imported components written in the Minister of Industry Regulation Number 28 of 2020. These regulations aim to gradually increase the proportion of local components in EVs, contributing to a reduction in overall manufacturing costs.

In terms of EV infrastructure, The Ministry of Energy and Mineral Resources Policy 13 of 2020 regulates both private and public charging stations and addresses the placement of battery swap stations. This infrastructure policy is integral to supporting EV users and to promoting the transition to electric vehicles across Indonesia. The government aims to develop 1000 public EV charging stations by the end of 2025, with an additional 31,000 expected by 2030. The government aims to develop 1000 public EV charging stations by the end of 2025, with an additional 31,000 expected by 2030. To install these 31,000 charging stations, an investment of approximately IDR 54.6 trillion is needed over the next 10 years [98]. This investment will come not only from government funding but also from private and public investments. This expansion is expected to improve the convenience of EV usage and reduce range anxiety, thus contributing to higher adoption rates of EVs.

EV manufacturers, including those producing EV components, can benefit from substantial corporate tax reductions. According to Regulation of the Ministry of Finance Number 150/PMK.010/2018 and Regulation of the Investment Coordinating Board of the Republic of Indonesia Number 1/2019, companies may receive a tax deduction of up to 100%, depending on the level of investment they contribute. This incentive is a significant draw for investors looking to support the growth of Indonesia's electric vehicle industry.

Next, policy focuses on the elimination or reduction of the Sales Tax on Luxury Goods (PPnBM) for electric vehicles, as outlined in Government Regulation Number 73 of 2019. According to this regulation, pure electric vehicles, or Battery Electric Vehicles (BEVs), are now subject to a 0% tax on luxury goods, which significantly reduces their cost and encourages adoption.

Local governments have also taken steps to promote EV use. For example, in Jakarta, incentives include reductions or exemptions from the tax on the transfer of vehicle ownership (BBNKB) for electric vehicles, as well as exemptions from the odd-even traffic rule, which limits car usage based on license plate numbers. These incentives are detailed in the DKI Jakarta Provincial Governor Regulation No. 3 of 2020 and Governor Regulation Number 88. Similarly, Bali has introduced tax incentives for electric vehicles, formalized in Bali Governor Regulation Number 45 of 2019, which is specifically designed to support electric vehicle adoption within the province.

To further facilitate the transition to electric vehicles, Perusahaan Listrik Negara (PLN) has introduced a fee waiver for households upgrading their power capacity to accommodate electric cars. Additionally, households using electric motorcycles benefit from a 75% discount on this power capacity upgrade fee, making it easier and more affordable for residents to integrate EVs into their daily lives. Another initiative aimed at encouraging EV ownership is the zero down payment policy for purchasing EVs on installment plans, as stated in Bank Indonesia Regulation Number 22/13/PBI/2020. This policy allows banks to offer customers the option of buying an EV with no initial down payment, reducing the financial barrier to entry for potential buyers.

These policies, implemented by the government of Indonesia and various regulatory bodies, collectively aim to bolster the EV market in Indonesia. By offering corporate

tax incentives, the government seeks to encourage growth on the supply side of the EV industry. Simultaneously, demand-side policies, such as incentives for buyers and infrastructure development, are being introduced to make EV ownership more attractive and accessible for the public. Through these combined efforts, Indonesia is fostering a supportive environment for the growth of EVs.

5. Conclusions

In conclusion, the adoption of electric vehicles (EVs) in Indonesia presents a multifaceted opportunity to address significant environmental challenges while enhancing economic growth. The evident benefits of EVs, such as reducing greenhouse gas emissions and decreasing dependence on imported fossil fuels, highlight the critical role they can play in Indonesia's transition to a more sustainable transportation system. However, several barriers persist, including inadequate charging infrastructure, high upfront costs, and consumer perceptions regarding vehicle performance. These challenges must be systematically addressed to promote broader acceptance and utilization of EVs.

A novel contribution of this review is its comprehensive examination of Indonesia's unique challenges and opportunities in the context of EV adoption, with a specific focus on infrastructure development and policy support. The government's commitment, as evidenced by regulations such as Presidential Regulation No. 55/2019, marks a critical step toward creating a supportive environment for EV adoption. Nevertheless, further efforts are essential to bridge the gaps identified in this study. To foster a robust EV ecosystem, it is imperative to expand charging infrastructure beyond urban areas, ensuring that all potential users have convenient access to charging facilities. Additionally, targeted public awareness campaigns should be implemented to educate consumers about the long-term economic benefits of EVs, while also addressing common misconceptions and concerns.

Financial incentives play a crucial role in encouraging the adoption of EVs. Enhancing government policies to include comprehensive tax breaks and subsidies can significantly mitigate initial purchase costs and promote EV uptake. Such measures will not only incentivize consumers but also encourage manufacturers to localize production, thereby reducing vehicle costs and creating jobs within the country.

In terms of scientific novelty, this review suggests that future research should focus on areas that have not been sufficiently explored, such as the development of rural charging infrastructure, the local production of EV batteries, and its effects on EV affordability. Furthermore, research that investigates the impact of localized battery production on EV affordability and market expansion might be beneficial. Research may go further into consumer behavior and attitudes regarding EVs to discover cultural or geographical concerns. Another area of focus is the long-term economic implications of expanding EV infrastructure, such as job development and energy security. Finally, evaluating the impact of public awareness efforts on EV adoption rates may provide insights for policy improvements.

Overall, Indonesia's journey toward widespread EV adoption is still ongoing. Achieving the country's ambitious EV targets requires a coordinated effort involving government, industry, and consumers. By addressing the barriers identified in this review, Indonesia can position itself as a leader in the global transition to sustainable transportation, with lasting benefits for both the environment and the economy.

Author Contributions: Conceptualization, R.C.O.; methodology, R.C.O.; formal analysis, R.C.O.; writing—original draft preparation, N.D. and R.C.O.; writing—review and editing, N.D. and R.C.O.; visualization, N.D. and R.C.O.; supervision, D.F.H.; funding acquisition, N.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Perusahaan Listrik Negara (PLN).

Data Availability Statement: Not applicable.

Conflicts of Interest: Author Natalina Damanik was employed by the company Perusahaan Listrik Negara (PLN). The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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