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A Comprehensive Analysis of the Economic Implications, Challenges, and Opportunities of Electric Vehicle Adoption in Indonesia

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Abstract: Electric vehicles (EVs) are a recognized solution for lowering greenhouse gas emissions and decreasing oil dependency, especially in Indonesia. Existing studies have explored the economic impact, challenges, and opportunities of EV adoption separately, lacking a holistic analysis. This study addresses this gap by providing a comprehensive assessment of the economic implications, challenges, and opportunities of EV adoption in Indonesia through a systematic literature review of 65 peer-reviewed articles, industry reports, and reputable publications from 2016 to 2024. The document analysis involved keyword-based literature selection, content analysis of economic metrics, and synthesis into key thematic areas. The findings reveal that EV sales in Indonesia have been rising annually, influenced by cost, driving range, environmental impact, technological features, charging infrastructure, battery, and government policies and incentives. EV adoption has positively impacted Indonesia's GDP, attracted Foreign Direct Investment (FDI), created jobs, and reduced fuel consumption and imports. However, several challenges persist, including high EV costs, inadequate charging infrastructure, societal readiness, battery replacement costs and waste management, and limited model variety. Despite these challenges, opportunities exist in the form of market growth, FDI from nickel resources, energy security, job creation, and industrial expansion. Recommendations for creating a conducive EV ecosystem are provided for relevant stakeholders.

Keywords: electric vehicles; economic challenges; economic opportunities

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1. Introduction

Since the Paris Agreement (2015), which regulates the reduction of greenhouse gas emissions and addresses the impacts of climate change, countries have flocked to tackle this issue in various ways, such as the development of renewable energy, energy efficiency, and the reduction of transportation emissions [1,2]. Efforts have been made to reduce emissions specifically within the transportation sector, which globally accounts for 15% of greenhouse gas emissions. In addition, CO_2 accounts for 76% of the total GHG emissions [3]. With the rapid pace of urbanization, the transportation sector is expected to drive further increases in energy demand and carbon emissions in the future. Global transport-related CO_2 emissions are expected to increase by 50% by 2030 and over 80% by 2050 [3]. However, clean energy in transportation is needed for the future, especially by adopting electric vehicles as one of the solutions [4].

Electric vehicles (EVs) are widely acknowledged as a highly effective solution for reducing greenhouse gas emissions and decreasing the reliance on oil in the transportation sector [5]. Electric vehicles (EVs) rely on electricity as their primary energy source, replacing traditional fuels, such as gasoline or diesel, with battery recharging [6]. However, the environmental impact of EV development largely depends on the power generation mix and its associated carbon intensity [7]. Several studies suggest that combining EV adoption with low-carbon power generation can significantly reduce emissions. As a result, EVs contribute to cleaner air, lower carbon footprints, and enhanced energy security, positioning them as a key component in the global effort to combat climate change and transition to a more sustainable energy future [7].

Almost 14 million new electric cars were registered globally in 2023, bringing their total number on the roads to 40 million [8]. A high level of investment and government involvement in providing incentives to manufacturers has played a significant role in increasing the production of EVs [9]. Over the last decade, the worldwide market share of EVs has increased dramatically. The rise in demand for EVs is due to increasing environmental awareness, the existence of policy support from the government [10], improved consumer confidence in electric battery lifespans, rising fuel prices in some regions, the introduction of low-emission zones restricting high-polluting vehicles, and targeted taxes and parking fees for ICE vehicles.

The Indonesian government is committed to promoting EVs to replace traditional fuel-powered vehicles [11]. The Ministry of Energy and Mineral Resources' Grand National Energy Strategy aims to achieve approximately 2 million electric cars, 13 million electric motorbikes, 30,000 public electric vehicle charging stations (SPKLU), and 67,000 electric vehicle battery exchange stations (SPBKLU) by 2030 [12]. To achieve this goal, the government has implemented a legal framework supported by regulations, including the Presidential Regulation Number 55 of 2019, which focuses on accelerating the Battery-Based Electric Motor Vehicle Program for road transportation. The regulation emphasizes critical aspects of EV policy, including the utilization of domestically manufactured components, the provision of government incentives, the development of essential infrastructure, and the establishment of registration and identification systems [11]. This regulation serves as the foundation for EV development in Indonesia, prompting several ministries to initiate EV projects [13].

Indonesia has a major competitive edge due to its abundance of natural resources, especially nickel, which are essential for the manufacture of batteries [14]. Furthermore, it is anticipated that Indonesia's strategic endeavors to strengthen international alliances and local manufacturing capacities will increase domestic output and export potential. These initiatives position Indonesia as a leader in the shift to electric mobility as well as a hub for manufacturing, in line with global trends toward sustainable energy and lower carbon emissions. This all-encompassing strategy makes sure that the long-term growth and sustainability of the nation are optimized for the technological, environmental, and economic advantages of EV adoption.

Existing studies tend to focus on the economic impact, challenges, and opportunities of electric vehicle (EV) adoption in Indonesia as separate aspects, lacking an integrated analysis that connects these critical elements. To address the identified research gap, this study aims to provide a comprehensive and integrated analysis by examining the economic implications of EV adoption in Indonesia and further analyzing the challenges and opportunities arising from these economic impacts.

The main objective of this study is to evaluate the economic implications of electric vehicle production in Indonesia, motivated by the growing market share of EVs within the country. Additionally, this paper examines the challenges and opportunities facing

the EV industry in Indonesia and provides recommendations for future development. By exploring the multifaceted impact of EV production, this study aims to offer insights that will support informed decision-making and strategic planning for the continued growth of the EV sector in Indonesia.

2. Review on Electric Vehicle Adoption in Indonesia

2.1. Electric Vehicle's Market

Global sales of electric vehicles (EVs) grew significantly in 2023, rising by 3.5 million units over the previous year (Figure 1). However, this expansion was mostly focused on particular areas, with China accounting for 60% of global sales, Europe for 25%, and the US for 10%. On the other hand, EV adoption is still very low in other nations, including well-known car markets like India and Japan. As a result, this led to an increasingly concentrated global stock of electric cars [8].

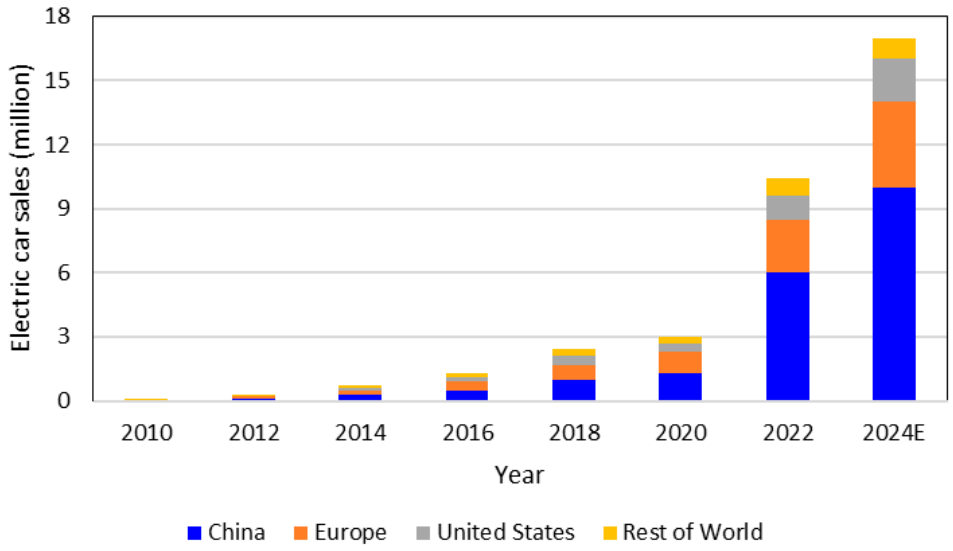

Figure 1. Electric car sales, 2010–2024 [8].

The EV market in Southeast Asia remains in its early stages, representing less than 2% of global sales [15], with market size of 858.76 million in 2023 [16]. Electric car sales in emerging markets and developing economies (EMDEs) outside China continued to grow in 2023, though overall volumes remained low [8]. In 2022, Indonesia had the second-largest market share of EVs in Southeast Asia, accounting for around 25% of the region's EV sales [17]. Sales of EVs in Indonesia experienced an increase from time to time. Electric car sales in Indonesia remained below 100 annually until 2019, but increased nearly tenfold to just under 1000 in 2020–2021. This growth accelerated significantly, with sales surpassing 10,000 in 2022 and reaching 17,000 in 2023 [8] (Figure 2).

Based on data from the Association of Indonesian Automotive Industries [18], wholesale car sales reached 1 million units (1,005,802) in 2023. Consequently, electric vehicle (EV) sales in Indonesia accounted for only about 1.70% of total car sales. This indicates that the penetration of electric vehicles remains significantly low compared to fossil fuel-powered vehicles. According to the roadmap for the development of battery-based electric vehicles, the government aims to achieve a target of 2 million electric cars by 2030 [12]. However, the current sales figures are still far from the government's expectations.

Several automotive companies have introduced their electric vehicles (EVs) to the Indonesian market, including Hyundai, BMW, Wuling, BYD, Chery, DFSK, Kia, Mercedes-Benz, Tesla, and several other brands. Each company offers EVs with a range of price options tailored to different market segments. The price range of electric cars in Indonesia

is quite broad, starting from approximately USD 11,960 (equivalent to IDR 189 million) for an EV model from DFSK Motors [19] to USD 250,000 (equivalent to IDR 3.95 billion) for the Mercedes-Benz EQS+ 450 Edition One [20], based on an exchange rate of 1 USD = IDR 15,800. This diverse price range reflects the efforts of these companies to cater to the needs of consumers from various income groups, from the middle class to the upper class.

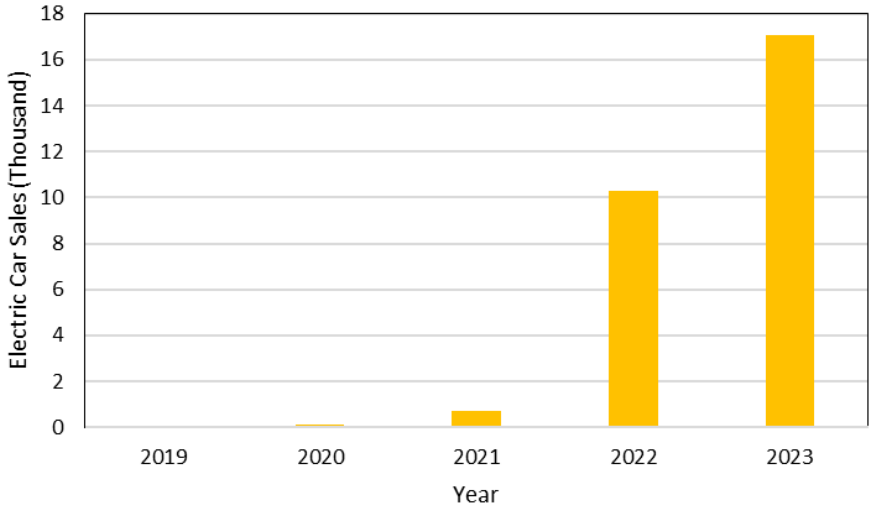

Figure 2. Electric car sales in Indonesia, 2019–2023 [8].

2.2. Indonesia's EV Regulatory Framework and Incentives

Indonesia's commitment to accelerating electric vehicle (EV) adoption is underpinned by a robust set of regulatory measures, beginning with the Government Regulation (PP) No. 55 of 2019, which established key provisions for EV development, including incentives, infrastructure development, and local content requirements (TKDN). This regulation laid the foundation for a growing domestic EV ecosystem. However, to adapt to the industry's needs, PP No. 55 was replaced by PP No. 79 of 2023, which refined the TKDN requirements, aiming to increase local manufacturing contributions and strengthen Indonesia's EV sector. The Ministerial Regulation of Industry No. 27 of 2020 further supported this effort by providing a comprehensive development roadmap and guidelines for calculating the TKDN in EV production. These policies collectively aim to enhance Indonesia's domestic EV ecosystem.

Infrastructure development is a key priority in supporting EV adoption. The Ministerial Regulation of Energy and Mineral Resources No. 13 of 2020 mandates the establishment of public and private charging stations, outlining the roles of state-owned enterprises (SOEs), private investors, and regional governments in expanding the charging network. On the manufacturing side, the Ministerial Regulation of Industry No. 28 of 2020 initially set technical standards for Battery Electric Vehicles (BEVs) in Complete Knocked Down (CKD) and Incompletely Knocked Down (IKD) forms. This was later refined by the Ministerial Regulation of Industry No. 7 of 2022, which introduced additional measures to strengthen local EV manufacturing. The Ministerial Regulation of Transportation No. 44 of 2020 ensures that EVs meet stringent safety and technical standards before entering the market. Additionally, the Ministerial Regulation of Transportation No. 15 of 2022 governs the conversion of internal combustion engine (ICE) vehicles (excluding motorcycles) into BEVs, outlining technical specifications, procedures, and safety standards for the conversion process.

Financial incentives are key to accelerating EV adoption. PP No. 73 of 2019 introduced tax reductions on EVs under the luxury goods sales tax (PPnBM), which was further refined by PP No. 74 of 2021 to establish a 0% tax rate for BEVs and introduce differentiated tax

rates based on vehicle emissions. The Minister of Finance Regulation No. 38 of 2023 further enhanced financial accessibility by implementing VAT exemptions, with the government covering 10–11% of the VAT for BEVs meeting the 40% TKDN requirement. This initiative was extended through the Minister of Finance Regulation No. 8 of 2024, which prolongs the VAT exemption program for electric vehicles until December 2024, ensuring continued affordability and market expansion. Specific BEV models, such as the Wuling Air EV and Hyundai Ioniq 5, qualify for these incentives under the Decree of the Minister of Industry No. 1641/2023.

In parallel, the Minister of Energy and Mineral Resources Regulation No. 3 of 2023 introduces a motorcycle conversion program, offering subsidies to convert combustion-engine motorcycles to battery-powered electric ones, with a target of converting 50,000 units in 2023. In addition to the reductions in annual vehicle taxes, EVs are exempt from the odd–even traffic restriction policy, which limits vehicle movement based on license plate numbers in Jakarta and other major cities. This exemption is officially stipulated in the Jakarta Governor Regulation No. 88 of 2019 on the Odd-Even Policy, encouraging consumers to transition to electric mobility as a means to reduce urban congestion and emissions.

2.3. EV Charging Infrastructure in Indonesia

The development of electric vehicle (EV) charging infrastructure in Indonesia has been a crucial factor in accelerating EV adoption. Since the enactment of the Government Regulation (PP) No. 55 of 2019, which set the foundation for EV development, the Indonesian government has progressively introduced policies to enhance charging infrastructure accessibility. The Ministerial Regulation of Energy and Mineral Resources No. 13 of 2020 mandated the establishment of public and private charging stations, including Stasiun Pengisian Kendaraan Listrik Umum (SPKLU) for public charging, Stasiun Pengisian Listrik Umum (SPLU) for general electricity access, and Stasiun Penukaran Baterai Kendaraan Listrik Umum (SPBKLU) for battery swapping services. These initiatives aim to ensure EV users have reliable charging access across the country.

PLN, Indonesia's state-owned electricity company, has been at the forefront of this initiative, integrating EV services into the PLN Mobile application, allowing users to locate and utilize charging stations efficiently [21]. PLN SPKLU in Indonesia provides a power output ranging from 22 kW to 100 kW [22]. These charging stations offer multiple charging options to accommodate different EV needs, utilizing various connector types with distinct power capacities. PLN categorizes its charging stations based on power output into three types: medium charging, which operates at 22 kW AC using a single-gun system; fast charging, which provides 25 kW DC with a single-gun system or 25 kW DC combined with 22 kW AC using a dual-gun system; and ultra-fast charging, which includes configurations such as 2 × 25 kW DC + 22 kW AC, 2 × 50 kW DC + 22 kW AC, and 2 × 100 kW DC + 22 kW AC with a triple-gun setup [22]. The charging connectors available at SPKLU include Type 2 AC Charging, DC Charging CHAdeMO, and DC Charging Combo Type CCS2 [22]. These diverse charging options ensure that Indonesia's growing EV ecosystem is supported by a reliable and adaptable public charging infrastructure.

In addition to SPKLU, Indonesia also has SPLU, which primarily serves electric motorcycles and smaller electric vehicles. SPLU consists of four models: standing/tower, hang/wall mount, hook/pole mount, and stall/pedestal, allowing flexible installation in various locations. Most SPLU units have a power capacity ranging from 5.5 kVA to 22 kVA [23], making them suitable for low-power charging needs. While SPLU is mainly used for smaller EVs, SPKLU stations cater to electric cars and other high-power vehicles.

The Indonesian government projects the development of 63,000 SPKLU by 2030 to support the growing adoption of electric vehicles (EVs) [24]. According to the Director

General of Electricity at the Ministry of Energy and Mineral Resources (ESDM), Jisman Hutajulu, this target represents a tenfold increase from the current number of SPKLU. By 2030, the Ministry of Energy and Mineral Resources estimates that approximately 943,000 EVs will be in operation [24]. The development strategy considers both densely and sparsely populated areas, ensuring the equitable distribution of charging infrastructure. To guide this expansion, the Ministerial Decree No. 24 of 2025 outlines the strategic plan for SPKLU deployment from 2025 to 2030, with installations planned in commercial areas, office buildings, industrial zones, highways, gas stations, tourist attractions, hospitals, train stations, terminals, hotels, ports, and other key locations [24].

2.4. EV Maintenance Services in Indonesia

As the adoption of electric vehicles (EVs) increases across Indonesia, maintenance services are gradually expanding to support EV owners. Battery maintenance, a critical aspect of EV care, is becoming a key focus for both manufacturers and service providers. Companies like PT Pertamina and PLN are investing in battery swap programs and charging infrastructure [25,26], which often include battery health checks and maintenance services.

Many EV manufacturers, such as Hyundai, Wuling, and BYD, provide maintenance services through their authorized dealerships and service centers [27–29]. These centers are equipped with specialized tools and staffed by trained technicians who are knowledgeable about EV-specific systems, including battery management, electric motors, and software updates. This ensures that EV owners receive professional and reliable maintenance services tailored to their vehicles' unique requirements, including periodic servicing.

In addition to authorized dealerships, third-party service providers, like Domo Hybrid EV, are stepping up to meet the growing demand for EV maintenance [30]. Launched by Dokter Mobil (Domo) Indonesia, Domo Hybrid EV specializes in servicing hybrid and electric vehicles, particularly for owners whose warranties have expired. The service offers comprehensive maintenance, including general check-ups, battery diagnostics, specialized oil changes, and detailing. With transparent pricing based on vehicle size, full-service packages range from IDR 2.5 million to IDR 5 million, covering hybrid battery servicing, EV-specific oils, anti-rust treatments, and more.

2.5. Integration of EVs in Indonesia's Public Transportation

Indonesia has begun integrating electric vehicles (EVs) into public transportation to reduce carbon emissions and the reliance on fossil fuels. The transition started with electric buses, taxis, and ride-hailing fleets, supported by government incentives. TransJakarta began trials in 2020 and by 2023, and had over 100 electric buses, aiming for 10,000 by 2030 [31–33]. Cities like Surabaya, Medan, and Denpasar are piloting electric bus programs [34–36], with government-backed incentives encouraging public transport operators to transition. In the ride-hailing sector, companies like Gojek and Grab have introduced electric motorcycles to their fleets [37,38], providing a more sustainable option for short-distance travel. Meanwhile, Bluebird, one of Indonesia's leading taxi operators, has already deployed 200 EV units across its E-Bluebird, E-Silverbird, and E-Goldenbird services [39].

2.6. Study on Customer Preferences for Electric Vehicles

According to several surveys [13,40–42] conducted in Indonesia, there are several factors that buyers consider when purchasing EVs, such as cost, driving range, environmental impact, technological features, charging infrastructure availability, and government policies and incentives. Consumers' interest in adopting electric vehicles is largely influenced by increasing environmental awareness, the perception of EVs as a future-oriented technology [43], and their lower operational costs compared to gasoline or diesel vehicles. The

quieter engine and advanced technology offered by EVs are also benefits that consumers consider. Additionally, government support in the form of incentives encourages buyers to purchase electric cars [44]. However, the limited availability of charging stations and high service and maintenance costs remain concerns for consumers. Despite significant advancements, current battery technologies remain limited by the constraints related to range, charging times, and lifespan [41] (Figure 3).

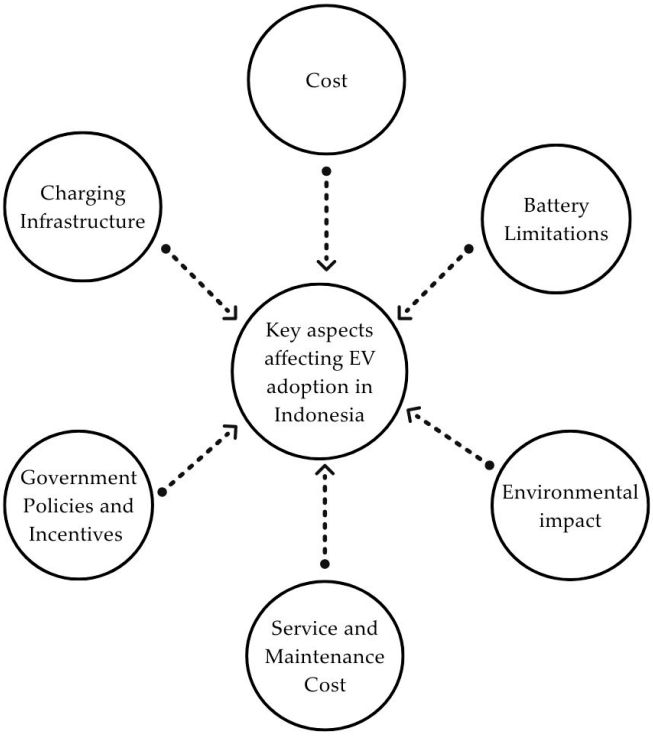

Figure 3. Key aspects affecting EV adoption in Indonesia.

3. Results and Discussion

3.1. Vehicle User's Perspective

3.1.1. Economic Implication for Vehicle Users in Adopting Electric Vehicles

The use of EVs contributes to reducing fuel consumption [45]. According to Atmo (2023), the adoption of EVs can significantly contribute to energy cost savings [46]. A study conducted in India revealed that electric cars have an average energy consumption of 123 Wh/km. With cars typically covering an average annual mileage of 18,000 km, the potential savings in fuel costs become clear. Considering a fuel cost of IDR 9000/liter for Pertamax and an electricity tariff of IDR 1444.7/kWh, the use of EVs could result in a 76% reduction in fuel expenses for cars [46] (Table 1). On a larger scale, this transition could also have significant implications for national fuel usage.

Table 1. Efficiency comparison for EV and conventional vehicles [46].

Category	Electric Cars	Conventional Cars
Energy Consumption	0.123 kWh/km 0.44 MJ/km	0.083 liter/km 2.46 MJ/km
Cost of Energy	IDR 178/km	IDR 747/km
Emission	108 g CO_2/km	178 g CO_2/km

3.1.2. Challenges in Adoption of Electric Vehicles

Despite the promising benefits, vehicle users face several barriers to EV adoption. A primary challenge is the high initial cost of electric vehicles (EVs), which remains a significant deterrent to adoption [47]. Users are concerned about the price differences between EVs and ICEVs. Research shows that the price of EVs compared to ICEVs in comparable vehicle classes remains significantly high [48,49]. EV prices are still at a premium level, costing more than 1.5 times the price of ICEVs in comparable classes [48]. The high cost of EVs in Indonesia is further exacerbated by import duties and insufficient domestic production, making EVs less accessible to many consumers [13,49,50].

In addition to the high purchase price, the battery range, although not a significant concern for more expensive EV models, still presents challenges for a broader adoption of EVs. Vehicles priced above IDR 700 million (USD 46,667) can travel over 500 km, while EVs costing around IDR 300 million (USD 20,000) can cover distances exceeding 300 km [48]. Despite these capabilities, a significant hurdle to widespread electric vehicle adoption is their limited battery life [51]. Batteries serve as the primary power source for EVs but typically last only 8 to 10 years before requiring replacement, especially when their capacity drops below 80% [52]. This necessitates additional costs for battery replacement and poses challenges for EV owners [51].

Another major challenge is the public perception of EVs as luxury items. This perception, combined with resistance to government subsidies, further hampers EV acceptance, particularly among cost-conscious consumers [49]. Charging time is another significant barrier. The long time required for charging, coupled with queues at charging stations, makes EVs less convenient compared to traditional ICE vehicles, which can refuel quickly [48]. Additionally, the long-term economic risks for users include resale anxiety. There is no certainty about the resale value of used EVs, including the price of used EV batteries which theoretically can be reused for other products and recycled [48]. This uncertainty adds to the reluctance of potential buyers to invest in EV technology.

Indonesian society, in general, is not yet fully prepared to adopt EV technology, facing challenges like a lack of knowledge and information regarding EVs and their regulations and misconceptions regarding EV technology, which hinder adoption [13]. Drivers face multiple barriers to adopting EVs. These include performance anxiety arising from concerns about the EV's speed, handling under different road and weather conditions, and overall reliability [48]. Safety anxiety involves worries about battery fires and system software malfunctions [48]. Furthermore, maintenance anxiety relates to difficulties in finding maintenance workshops and obtaining EV components and spare parts [48].

3.1.3. Opportunities for Vehicle Users in Adopting Electric Vehicles

Long-term economic opportunities for users include a lower total cost of ownership (TCO), and EV prices are becoming more affordable. The TCO is decreasing due to lower operational and maintenance costs compared to ICEVs [46,48,53]; even though EVs are initially more expensive than ICEVs. Economic benefits for users include low charging and maintenance costs. The cost of charging EV batteries at home and at charging stations is much lower than fuel costs [48].

3.2. Industries' Perspective

3.2.1. Economic Implication for Industries in Adopting Electric Vehicles

The adoption of electric vehicles (EVs) has catalyzed significant transformations across multiple sectors of the economy, most notably in the mining, energy, and manufacturing industries. This shift is supported by the Indonesian government, which formed the Indonesia Battery Corporation (IBC) in March 2021. The corporation is a collaboration

between four state-owned enterprises, PT Indonesia Asahan Aluminum (Inalum), PT Antam Tbk (ANTM), PT Pertamina, and PT PLN, each operating in industries such as aluminum smelting, mining, oil and gas, and electricity. The goal is to position Indonesia as a global producer of electric vehicle batteries [14].

The Indonesian EV market is attracting substantial Foreign Direct Investment (FDI) from international automotive manufacturers and technology firms [54] with current investments reaching approximately USD 21.4 billion to support the sector's development (see details in Appendix A). Rapidly emerging as a leader in electric vehicle investment, Indonesia is capitalizing on its extensive reservoirs of the critical raw materials essential for EV batteries, particularly nickel [55]. Data from the Ministry of Energy and Mineral Resources (MEMR) in 2023 reveal that Indonesia possesses the world's largest reserves of nickel commodities, representing approximately 23% of global reserves.

During the ASEAN Business and Investment Forum 2023, Indonesia's Minister of Investment/BKPM, Bahlil Lahadalia, reported that the total investment in Indonesia's electric vehicle (EV) ecosystem from 2020 to 2023 reached USD 42 billion [56]. However, in 2024, several companies canceled their investment agreements, including BASF and Eramet, Volkswagen through its battery subsidiary PowerCo, and Tesla [57,58]. The cancellations were primarily attributed to Indonesia's continued reliance on fossil fuel-based energy sources and the companies' concerns over significant changes in the nickel market conditions, particularly regarding the selection of nickel types used as raw materials for EV batteries [58,59].

Despite these setbacks, several companies have formalized investment agreements, and some are already operating in Indonesia. The investment encompasses the entire electric vehicle (EV) industry, spanning from upstream to downstream sectors. The details are presented in Appendix A. Notably, Hyundai Motor Group and LG Energy Solution have commenced operations. In July 2024, the battery cell plant located in Karawang New Industry City (KNIC) was inaugurated. This facility, operated by HLI Green Power, is a joint venture between Hyundai and LG Energy Solution. The establishment of this factory is considered a significant milestone for Indonesia, solidifying its position as a global player in the electric vehicle era.

The significant influx of capital into Indonesia's electric vehicle ecosystem has sparked a surge in economic activity, particularly in sectors directly and indirectly linked to EV manufacturing, infrastructure development, and research and development (R&D). This surge in economic vitality has led to an increased demand for skilled labor, manifesting in job creation across diverse sectors, such as engineering, manufacturing, logistics, and supply chain management. Notably, PT HLI Green Power serves as a prime example, having employed 1000 Indonesian workers by mid-2023 for its initial phase, with plans to create an additional 2800 jobs for its subsequent phase [60]. Similarly, the HPAL Project in Pomalaa Block by PT Vale Indonesia is anticipated to generate approximately 12,000 job opportunities [61]. Lastly, Huayou Cobalt Co. Ltd. (Halmahera, Indonesia), through its nine projects, has employed 52,000 workers [62], further underscoring the profound socio-economic impact of investments in the EV sector. It is anticipated that the development of nickel battery and EVs will contribute to the GDP with multiplier effects in terms of employment.

The increasing adoption of EVs is also driving a surge in electricity demand, necessitating expanded electricity generation capacity [63]. PT PLN has been tasked with developing the Electric Vehicle ecosystem infrastructure. As of the first half of 2024, PLN successfully provided 1081 units of Public Electric Vehicle Charging Stations (SPKLU), which increased to 1582 SPKLU, 2182 Public Electric Vehicle Battery Swap Stations (SPBKLU), and 9956 Public Electric Charging Stations (SPLU) across Indonesia. Through these stations,

total electricity consumption reached 2438.8 megawatt hour (MWh) in the first half of 2024, an increase of 229% from the first half of 2023 [21].

Home charging services saw a significant increase, with 14,524 units installed in the first half of 2024, marking a 335% rise compared to the first half of 2023. Moreover, electricity usage by home charging customers surged to 4264.8 MWh in the first half of 2024, reflecting a 344% increase compared to the first half of 2023 [21]. Transitioning towards sustainability, PT PLN (Persero) now utilizes Renewable Energy Certificates (REC) for electricity at PLN-owned Public Electric Vehicle Charging Stations (SPKLU) from 2022 to 2023, ensuring that these stations operate solely on 100% electricity from renewable energy sources, enabling emission-free transportation for EV users [64,65].

EV penetration will increase demand for electricity (see Figure 4). Electric passenger vehicles will increase the total electricity demand by 0.2–3.9 TWh by 2025 and 11.6–68.2 TWh by 2050 [66]. To date, there have been no issues regarding electricity availability. In 2022, PLN even faced the challenge of the oversupply of electricity in several regions due to the growth in electricity sales, which in the previous few years was lower than initially planned, mainly due to the conditions of the COVID-19 pandemic between 2020 and 2022 [67]. The Electricity production details are shown in Table 2. Additionally, according to the electricity supply business plans of the national electric company (PLN), Indonesia has significant potential to generate over 207 GW of solar energy [68].

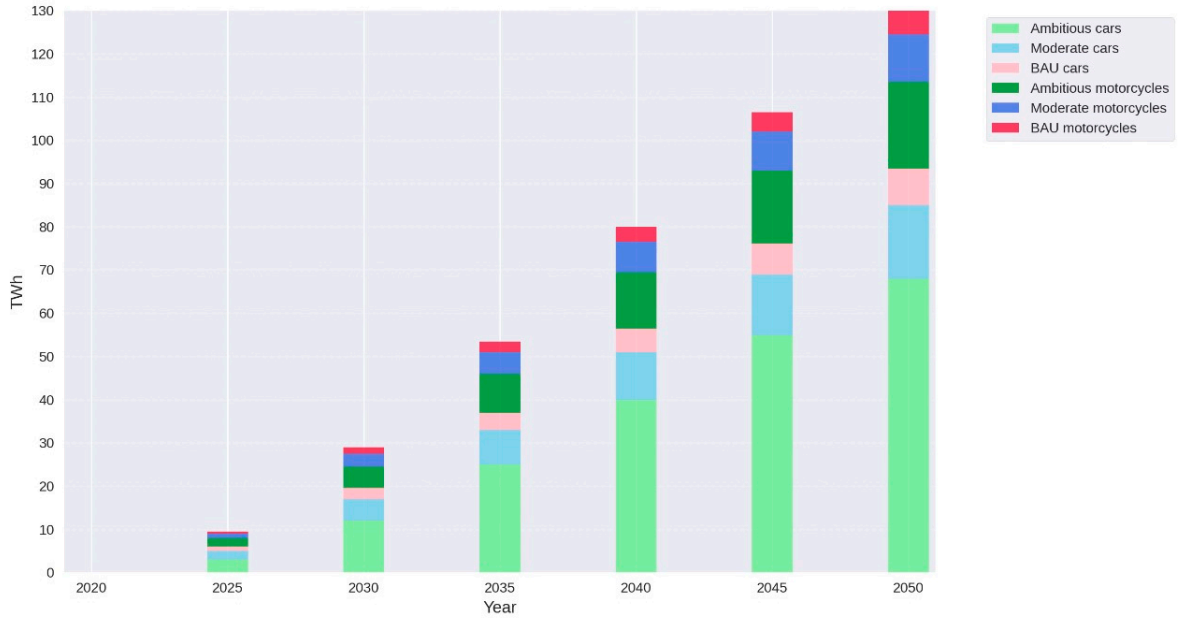

Figure 4. Contribution of electric cars and motorcycles to additional electricity demand in different scenarios [66].

Table 2. Electricity production [69].

Description	2018	2019	2020	2021	2022
Total Power Plants (unit)	6545	6723	6677	6760	6928
Number of Customers (mio)	71,917,397	75,705,614	79,000,033	82,543,980	85,636,198
Power Capacity (MW)	57,822	62,833	63,336	64,553	69,040
Electricity Production (GWh)	267,085	278,941	274,851	289,471	308,002

3.2.2. Challenges in the Adoption of Electric Vehicles

The low availability of spare parts and repair and maintenance services remains a critical issue in Indonesia [51]. This scarcity is attributed to the early adopter phase of

electric vehicle adoption, which hampers the presence of dealers, suppliers, and EV service providers. Factors contributing to this include insufficient knowledge and skills required for sales, lower profitability for dealers, reduced after-sales revenue from services, and the complexities associated with installing charging infrastructure [51].

In addition to these operational challenges, EV manufacturers face significant barriers on the production side. One such challenge is their heavy reliance on imported raw materials and critical components, particularly batteries and semiconductors. These components must be sourced from the global supply chain, which currently dominates the EV industry, making the process time consuming. Moreover, the lack of preparedness within the local industry further exacerbates these supply chain issues, slowing down domestic production and innovation [13]. Therefore, addressing these challenges is crucial not only for improving the availability and reliability of EVs in the Indonesian market but also for fostering local economic growth and technological advancement in the EV sector.

Further complicating matters, there is an urgent need to develop effective battery waste management practices, as EV batteries are classified as B3 hazardous materials due to their toxic components [13,70]. This issue adds another layer of complexity, as the improper disposal of these batteries could have serious environmental consequences. Therefore, establishing sustainable practices in the management of EV battery waste is essential to mitigate these environmental impacts and ensure long-term industry viability.

Another significant barrier to the widespread adoption of EVs in Indonesia is the limited variety of available EV models [51]. The current market lacks diversity in electric vehicle offerings, which hampers the ability to meet diverse consumer needs and preferences, including considerations, such as seating capacity and affordability [48,51]. The availability of a wider range of EV models is crucial for expanding consumer choice and increasing adoption rates. A more diverse selection would cater to different segments of the market. This diversity not only addresses varying consumer preferences but also enhances competitiveness and innovation within the electric vehicle sector.

Lastly, the insufficient charging infrastructure remains a major obstacle to EV adoption in Indonesia [51]. Both home and public charging remain impractical due to the limited infrastructure available. Home charging, which is essential for widespread EV adoption, remains impractical in multi-unit residential buildings and apartments [13]. Similarly, public charging stations play a critical role as the primary energy source for EVs, yet accessibility remains insufficient. Although the Regulation of the Minister of Energy and Mineral Resources Number 13 of 2020 provides a regulatory framework to support the development of charging infrastructure, progress has been slow, with only 1370 charging stations currently operational, far from the national target of 30,000 stations by 2030. This lack of charging infrastructure, especially compared to the number of gas stations, leads potential EV buyers to question whether Indonesia is adequately prepared to transition to EVs. The few existing charging stations are unevenly distributed across the country, compounding the problem [48]. This shortfall is due to the high cost of installation [51].

3.2.3. Opportunities for Industries in Adopting Electric Vehicles

Although the adoption of EVs in Southeast Asia has historically been slow, the region is now witnessing a rapid shift in policies and consumer attitudes. This transition is largely driven by the increasing societal awareness of climate change and the urgency to achieve carbon reduction targets. Countries in the region are now prioritizing cleaner energy sources and sustainable transportation solutions. According to an EY-Parthenon analysis, the ASEAN-6 EV market is projected to achieve a compound annual growth rate of 16–39% between 2021 and 2035. Annual sales opportunities are anticipated to reach an impressive USD 80 billion–USD 100 billion by 2035, a substantial rise from approximately USD 2 billion

in 2021. This dramatic rise underscores the accelerating momentum in the EV sector within Southeast Asia.

Within this regional growth, Indonesia is expected to play a central role. The study projects that EV sales across six Southeast Asian markets will reach approximately 8.5 million units by 2035. The country is projected to have an annual sales volume of 4.5 million units, generating a sales value between USD 26 billion and USD 30 billion by 2035 [71]. This projection is further supported by AC Ventures (2023), which forecasts that Indonesia will have opportunities worth over USD 20+ billion by 2030 (Table 3) [72]. Observing the increase in EV sales, Gumiwang Kartasasmita, the Indonesian Minister of Industry, expects the country's EV market to develop at a remarkable CAGR of 58.5% between 2023 and 2030 [72].

Table 3. EV market size estimation [72].

Category	Estimated Indonesia Market Size ($B, 2030)
Cell manufacturing and battery management system	3–4.5
Auto R&D and manufacturing	12.5–15
Vehicle sales and dealership	1–2
Charging infrastructure	2–3
Service maintenance and battery recycling	0.5–1.5

Central to this growth is Indonesia's position as the world's leading producer of nickel, a critical component in lithium-ion batteries, which are the primary choice for EV battery packs. The country's nickel reserves make up 23% of the global total [73]. Additionally, Indonesia has access to cobalt, which extends EV battery life, and bauxite, used in aluminum production, an important element in EV manufacturing [54]. This abundant access to raw materials could significantly lower production costs and, over time, strengthen Indonesia's position in the global EV market.

With the assumption that around 600,000 EV units will be produced by 2030, in line with the government's target, it is predicted that the EV industry will create more than 500,000 jobs, with 14% of the additional jobs in the economy coming from the electric vehicle and electric vehicle battery sectors [7]. Other sectors set to absorb these workers include mining and energy, raw material processing, charging infrastructure development, dealership networks, supply chain and logistics, as well as the service and maintenance sector.

As EV production grows, local economies flourish with new manufacturing jobs and bustling mining operations for essential minerals. Dealerships emerge, meeting consumer demand for sustainable transportation. Increased EV ownership boosts the need for skilled technicians, driving innovation and ensuring operational excellence. Investing in education prepares Indonesia for future workforce demands, fostering economic growth and global industrial leadership.

3.3. Government's Perspective

3.3.1. Economic Implications for Governments in Adopting Electric Vehicles

Economically, the use of EVs in Indonesia has positively impacted the country's GDP. This is evident from the 2023 GDP growth in the Transportation Equipment Industry sector, which includes the Battery-Based Electric Vehicle Industry (KBLBB). This sector showed a year-over-year increase of 7.63% [74], contributing 1.49% to the national GDP. According to GAIKINDO data, domestic electric car sales reached 17,147 units in 2023, with electric car exports totaling 1504 units (Coordinating Ministry for Economic Affairs 2024 [75]).

Beyond this, the EV ecosystem, including the downstream development of EV batteries, is expected to have broader implications for Indonesia's energy landscape. According to Toto Nugroho, CEO of Indonesia Battery Corporation (IBC), investments in the EV battery industry and the wider EV sector will be instrumental in reducing the country's reliance on fuel imports, which is crucial for enhancing energy security [76]. This shift comes at a time when Indonesia's crude oil production continues to experience a steady year-on-year decline (Figure 5), with output recorded at 605 MBOPD, equivalent to 221 million barrels, in 2023 [77]. As a result, crude oil exports reached 21.3 million barrels, while imports totaled 132.4 million barrels, reflecting increases of 38% and 26%, respectively, compared to the previous year [77].

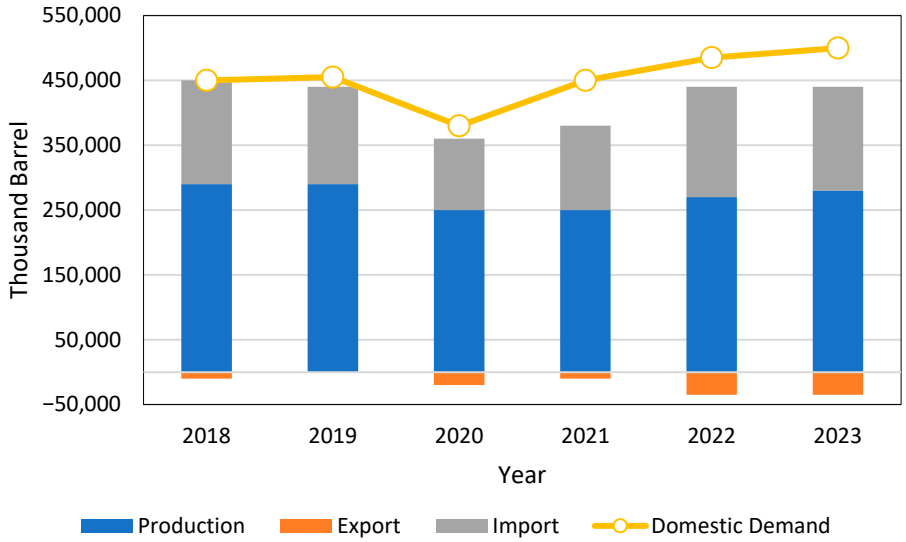

Figure 5. Oil fuel supply demand [77].

Looking forward, the transition to electric vehicles is projected to yield significant energy savings. By 2030, it is estimated that the use of 2 million electric cars and 13 million electric motorcycles could save approximately 29.79 million barrels of oil equivalent (MBOE) annually (Tables 4 and 5) [46]. This aligns with the presentation by IBC CEO Toto Nugroho during a hearing with the VII Commission of the Indonesian House of Representatives in Jakarta on 27 November 2023, where he revealed that Indonesia's battery industry has the potential to save nearly 30 million barrels of fuel imports per year [76].

Table 4. Energy saving estimation [46].

Activities	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Number of Electric Cars (cumulative)	500	93,875	187,250	280,625	374,000	738,200	1,102,400	1,466,600	1,830,800	2,195,000
Number of Electric Motorcycles (cumulative)	200,000	3,098,250	5,996,500	8,894,750	11,793,000	12,034,800	12,276,600	12,518,400	12,760,200	13,002,000
Energy Savings (MBOE)	0.25	4.37	8.49	12.62	16.74	19.35	22.19	24.57	27.18	29.79
Emission Reduction ($MtonCO_2$-e)	0.1	1.2	2.3	3.4	4.5	5.1	5.6	6.1	6.7	7.2

Table 5. Indonesia electric cars roadmap [46].

Electric Cars Roadmap	Notes	Electric Motorcycle Roadmap	Notes
Annual mileage	18,000 km	Annual mileage	8000 km
Total vehicles by 2030	2,195,000 unit	Total vehicles by 2030	13,002,000 unit
Energy Savings 2030	13.96 MBOE	Energy Savings 2030	15.83 MBOE
Emission Reduction 2030	2.79 Mton CO_2	Emission Reduction 2030	4.44 Mton CO_2

The normalized trends analysis further reinforces these projections (see Figure 6), emphasizing the significant contributions of electric vehicles to energy savings and emissions reduction. The analysis for 2024 is based on an estimation (2024E), as this year falls within the transitional phase between early adoption and peak growth. The graph below shows that the number of electric motorcycles increased the fastest, reaching its peak in 2025 and remaining stable through 2030. This trend indicates that electric motorcycles were adopted earlier compared to electric cars. Meanwhile, the adoption of electric cars experienced slower growth during the initial period (2021–2025) but showed significant acceleration after 2025, eventually reaching its peak in 2030. Under these two scenarios, energy savings from EVs are projected to reach their maximum potential by 2030.

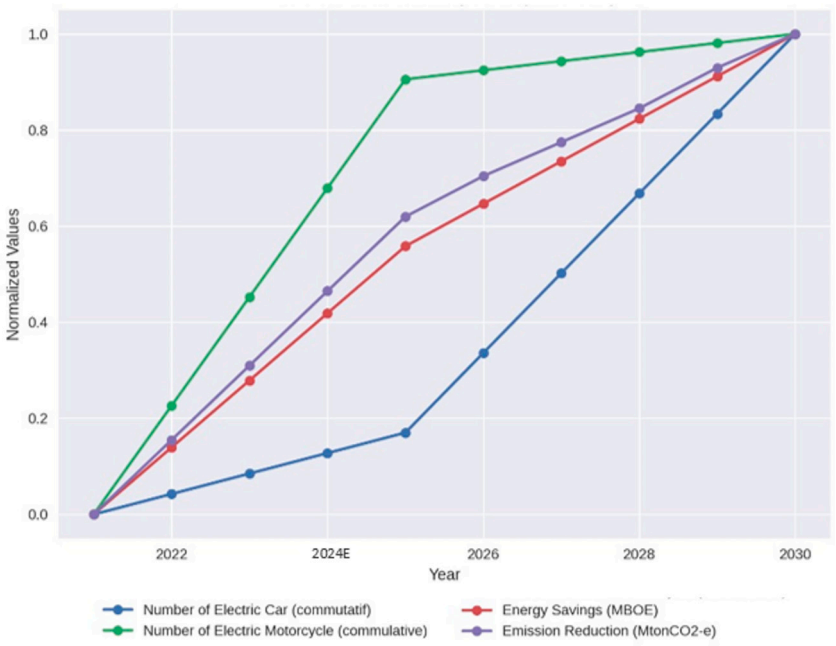

Figure 6. Normalized trends, 2021–2030 (Source: authors' analysis).

Addressing the high reliance on imported fuels and crude oil, which poses risks to Indonesia's energy security due to their status as global commodities with fluctuating prices, is imperative. Switching from petroleum fuels to less volatile energy sources such as electricity in transportation could offer a promising solution to mitigate this issue in the future.

3.3.2. Opportunities for Government in Adopting Electric Vehicles

Energy security, defined by the International Energy Agency (IEA) as the availability of affordable and uninterrupted energy sources, is critical for sustaining production and services [78]. Currently, oil production is declining while consumption continues to rise, leading to increased imports and trade balance deficits [46]. Fluctuating fossil fuel prices further underscore the volatility of the global energy market (Figure 7).

In response to these challenges, the adoption of EVs emerges as a transformative opportunity. According to the IEA (2023) [79], the shift towards clean energy technologies in sectors traditionally dominated by fossil fuels is reducing the global demand for oil, coal, and natural gas. By transitioning to EVs, Indonesia's substantial energy savings represent approximately 29.79 million barrels of oil equivalent (MBOE) [46]. Furthermore, the strategic deployment of EVs can bolster national security by reducing vulnerabilities associated with the reliance on foreign oil imports [78]. As governments worldwide prioritize clean energy policies, EV adoption aligns with long-term sustainability goals and strengthens resilience against energy supply disruptions.

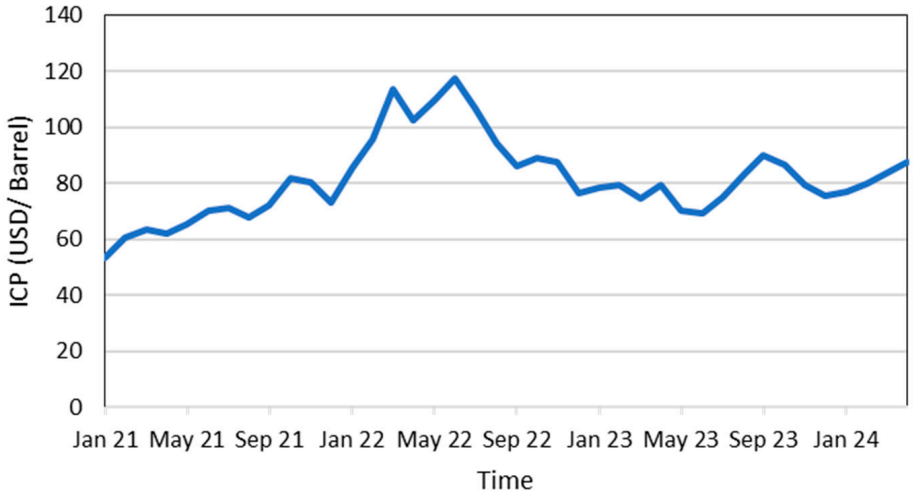

Figure 7. ICP in USD/barrel (Source: MEMR).

4. Conclusions and Recommendations

This study employed a systematic literature review to explore the adoption of electric vehicles (EVs) in Indonesia, focusing on their economic implications, challenges, and opportunities. The government has made significant progress in establishing a regulatory framework through the Government Regulation (PP) No. 55 of 2019, Presidential Regulation No. 73 of 2019, and Ministerial Regulation No. 13 of 2020, which promote EV adoption through tax incentives and infrastructure expansion. In line with these efforts, Indonesia continues to develop its EV ecosystem, targeting 63,000 SPKLU charging stations by 2030, though current progress remains far from the target. Maintenance services are gradually expanding, with automakers, PLN, and third-party providers offering specialized EV servicing. Public transport integration is also advancing, with electric buses, taxis, and ride-hailing services operating in major cities. However, market penetration remains limited, highlighting gaps between policy efforts and actual adoption.

The economic implications of EV adoption in Indonesia have shown positive contributions, including increased GDP within the transportation equipment sector, rising investment opportunities, job creation, reduced oil consumption and imports, and increased electricity demand. However, several challenges continue to hinder more significant progress, including high upfront vehicle costs, insufficient charging infrastructure, low public awareness, and concerns regarding battery performance. Despite these barriers, Indonesia holds substantial economic opportunities in the EV sector, supported by its abundant nickel reserves, growing market potential, enhanced energy security, and job creation through industrial expansion.

To foster a more conducive EV ecosystem in Indonesia, several strategic recommendations are proposed, emphasizing collaboration among key stakeholders, including government bodies, industry players, and investors. First, to overcome the high prices hindering

widespread EV adoption, assessing and refining current incentives and subsidies can help lower ownership costs. Extending VAT exempt incentives for customers can further enhance affordability and encourage adoption. Additionally, policies such as tax breaks and exemptions for manufacturers and buyers, along with tax holidays, allowances, and super tax deductions, can attract investors and accelerate EV innovation and manufacturing. Maintaining supportive tax policies until EVs achieve broader market penetration is essential. Policymakers should also reconsider or limit charging price incentives due to their minimal benefits and high utility costs.

Second, the government could streamline policies by reducing fuel subsidies and introducing a carbon tax simultaneously. This unified approach aims to effectively discourage the use of ICEVs and drive the transition toward EVs. Third, EV manufacturers should strengthen their supply chains by establishing direct connections with principal suppliers. Fourth, to enhance awareness, the government should mandate manufacturers to share EV benefits, launch comprehensive public campaigns, collaborate with private sectors for outreach through events and campaigns, and develop educational resources for officials, businesses, and the public. These efforts will promote a deeper understanding of the EV advantages.

Fifth, promoting charging infrastructure with renewable energy sources is crucial. Expanding fast-charging options alleviates range anxiety and encourages long-distance travel. Public–private partnerships are essential for building and maintaining these stations. Standardizing charging technology ensures compatibility globally, enhancing convenience. Incentives like rebates or tax breaks for home charging enhance accessibility. Sixth, to address the need for a skilled EV workforce, we recommend government-funded training programs and supportive policies for vocational education. Update educational curricula to include EV technology, partner with industry for hands-on training, and collaborate with foreign firms for knowledge transfer and skill enhancement. These efforts are crucial for meeting EV sector demands and technological advancements.

Eighth, develop and implement robust recycling infrastructure specifically tailored for EV batteries, ensuring efficient collection, dismantling, and recycling processes. Lastly, investing in EV research and development is critical for advancing battery technology, improving charging infrastructure efficiency, enhancing vehicle performance, developing autonomous capabilities, and promoting sustainability in production and materials. These efforts drive innovation, reduce costs, and accelerate the adoption of EVs for a greener future.

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Appendix A. Foreign Direct Investment Plan and Realization

Company	Country	Investment Plan (in Billion USD)	Project Plan	Collaboration	Realization	Source
LG Energy Solution-Hyundai Motor Company (Karawang, West Java, Indonesia)	South Korea	9.8	An electric vehicle battery cell project integrating mining, smelting, refining, precursor, and cathode industries (Buli, Halmahera)	PT Indonesia Asahan Aluminium (Persero), PT Aneka Tambang Tbk, PT Pertamina (Persero), PT Perusahaan Listrik Negara (PLN), PT Indonesia Battery Corporation (IBC)	First Phase: USD 1.1 billion investment by PT HLI Green Power in a production facility at Karawang New Industry City (KNIC). Capacity: 10 GWh, producing 32.6 million battery cells for approximately 150,000 units. The inauguration was held in July 2024. Second Phase: USD 2 billion investment, construction ongoing, with commercial production beginning in March 2025. Capacity: 20 GWh.	[80,81]
PT Ningbo Contemporary Brunp Lygend Co., Ltd. (CBL), a subsidiary of Contemporary Amperex Technology Co. (CATL) (Morowali, Central Sulawesi, Indonesia)	China	6	A nickel mine (joint venture with PT ANTAM) and further nickel downstream processing in refining, precursor, cathode, battery cells, and recycling stages	PT Indonesia Battery Corporation (IBC), PT Sumberdaya Arindo (a subsidiary of PT Aneka Tambang Tbk.)	Signed a Conditional Share Purchase Agreement (CSPA) on January 16, 2023, to invest the initial USD 420 million. This agreement involves the transfer of 49% of Antam'Fs shares in its subsidiary, PT Sumberdaya Arindo (SDA), for the joint project with CBL.	[82]
Ford-Zhejiang Huayou Cobalt (Halmahera, North Maluku, Indonesia)	United States-China	4.5	High-pressure acid leaching (HPAL) plant in Pomalaa in Southeast Sulawesi	PT Kolaka Nickel Indonesia (KNI), PT Vale Indonesia (INCO)	The HPAL plant was constructed in November 2022 and is expected to start production in 2026, producing 120 kilotons of mixed hydroxide precipitate (MHP) annually.	[83]
PT BYD Motor Indonesia (BYD) (Subang, West Java, Indonesia)	China	0.74	An electric vehicle factory in Subang Smartpolitan Industrial Zone, designed to produce 150,000 EVs per year.	PT Suryacipta Swadaya	The construction of the factory is expected to be completed by the end of 2025, with production likely to begin in 2026.	[84,85]

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