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Analysis of the Role of Electric Vehicle Technology Innovation in Supporting Sustainable Development and Reducing Air Pollution in Cities

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***Abstract*—Electric vehicles are considered as one of the technological innovations capable of supporting sustainable development while reducing air pollution in Indonesian metropolitan cities. This research aims to explore the role of electric vehicles in addressing environmental and economic challenges, using a qualitative method based on document analysis. Primary data was collected from official government reports, academic studies, public policies, and international publications related to electric vehicle implementation. The results show that electric vehicles have great potential in reducing carbon emissions and improving urban air quality. However, successful implementation depends on infrastructure readiness, incentive policies, and consistent education campaigns. This research underscores the importance of collaborative strategies between government, industry and society in accelerating the adoption of electric vehicles as part of the solution for sustainable development.**

Keywords— ***electric vehicles; technological innovations; sustainable development.***

I. INTRODUCTION

Metropolitan cities in Indonesia face major challenges related to air quality and environmental sustainability. One of the problems is that air pollution, which mostly comes from fossil-fueled motor vehicle emissions, has become a serious problem that affects people's health and quality of life. This is also triggered by the increasing use of motorized vehicles in Indonesia. Given that the transportation sector contributes 44% of pollution in Indonesia, transportation is closely related to the achievement of SDGs in Indonesia, especially efforts to reduce CO2 emissions [1]. Based on data obtained by the Indonesian Central Bureau of Statistics, it shows an increase in motorized vehicles in 2021 - 2022. according to a report published in the World Health Organization. (2018) air pollution is one of the main causes of various respiratory diseases in urban areas [2]. This shows the importance of adopting more environmentally friendly transportation solutions.

TABLE I. PRESENTS THE DEVELOPMENT OF THE NUMBER OF MOTORIZED VEHICLES IN 2021-2022 IN INDONESIA

Type of Motor Vehicle	Development of the Number of Motorized Vehicles by Type (Unit)	
	2021	2022
Passenger Car	16.413.348	17.168.862
Bus Car	237.566	243.450
Goods Car	5.299.361	5.544.173
Motorcycle	120.042.298	125.305.332
Amount	141.992.573	148.261.817

Source : Badan Pusat Statistik Indonesia

Based on these data, the increase in motorized vehicles observed is closely related to the growth in population in Indonesia, especially in urban areas, as well as increased economic activity and employment levels in the community [3]. On the other hand, Indonesia is one of the countries most

affected by climate change, which is largely caused by the use of motorized vehicles that use fossil fuels with a dense population and rapid economic growth as well as increasing vehicle use activities, especially in cities such as Jakarta, Surabaya and Bandung, which will result in sustainable levels of air pollution. fossil fuel vehicles contribute to greenhouse gas emissions and hazardous air pollutants such as PM2.5 and NOx [4]. So air pollution is a serious problem that must be considered in sustainable development.

Electric vehicles are one solution that has the potential to reduce air pollution and support sustainable urban development. The development of electric cars and motors can lead to a reduction in the release of pollutants such as CO, NOx, HC, SO2, and PM. Electric vehicles offer advantages in addressing air pollution and greenhouse gas (GHG) emissions compared to internal combustion engine (ICE) vehicles that use fossil fuels. This is because electric vehicles produce very low air pollution even close to zero compared to internal combustion engine vehicles [5].In Indonesia, efforts to encourage the growth of electric vehicles are contained in presidential regulation number 55 of 2019 concerning the Acceleration of the Battery-Based Electric Motor Vehicle Program. However, the development of electric vehicle technology in Indonesia still has to face challenges such as limited charging infrastructure, high production capital for electric vehicles, and more expensive electric vehicle prices [6]. In addition, the lack of public awareness of the benefits of using electric vehicles is a challenge in itself.

This research brings novelty by focusing on the role of Electric Vehicle Technology Innovation in Supporting Sustainable Development and Reducing Air Pollution in Indonesia, especially in metropolitan cities. The main impact of this study lies in the strategic recommendations that can be implemented by policy makers and related industries. This study contributes to the growing literature on electric vehicles by providing an in-depth analysis of the relationship between electric vehicles, air pollution reduction, and sustainable development.

This research contributes to the growing literature on electric vehicles by providing an in-depth analysis of the relationship between electric vehicles, air pollution reduction and sustainable development. As well as the importance of collaborative strategies between government, industry and society in accelerating the adoption of electric vehicles as part of the solution for sustainable development

The theory used in this study is the Theory of Sustainable Development (SDG) by emphasizing environmental and economic aspects. This research is relevant to previous research conducted by ferlia in 2023 [8] stating that 60-70% of air pollution is caused by exhaust emissions from motorized vehicles, one of the solutions to reduce these carbon emissions by adopting electric vehicles, this statement shows that the use of electric vehicles can significantly reduce carbon emissions. However, research on the interaction between incentive policies, infrastructure readiness, and public education in Indonesia is still limited.

Therefore, this study aims to explore the potential of electric vehicles in reducing air pollution in Indonesian metropolitan cities, analyze the main challenges faced in the adoption of electric vehicles, and provide recommendations for strategies to support the adoption of electric vehicles as part of sustainable development.

II. METHOD

This research used a qualitative-based literature review or desk study method as the research design. This approach was chosen to explore the role of electric vehicle technology innovation in addressing environmental and economic challenges, as well as supporting sustainable development and reducing air pollution. Primary data was collected from official government documents, academic studies, public policy reports, and international publications obtained through databases [9]. Therefore, this study aims to explore the potential of electric vehicles in reducing air pollution in Indonesian metropolitan cities, analyze the main challenges faced in the implementation of electric vehicles, and provide recommendations for strategies to support the adoption of electric vehicles as part of sustainable development.

The sampling process was purposive, selecting relevant documents, journal articles and reports based on search keywords, such as “electric vehicles”, “technological innovation”, “sustainable development” and “air pollution”. Data source selection considered credibility and relevance, including official government reports as well as articles from trusted online media [10].

The operationalization of variables in this study is done by identifying key concepts such as technological innovation of electric vehicles as independent variables, and their contribution to sustainable development and air pollution reduction as dependent variables. The analysis includes the linkages between infrastructure, incentive policies, and community participation in supporting the adoption of electric vehicles. This operationalization is done by identifying the relationship between the analyzed variables in depth [9].

The data were analyzed using a qualitative approach based on document analysis. This process involved deductive and inductive thinking to understand the dynamic relationship between technological innovations in electric vehicles and their impact on the urban environment. Document analysis was conducted systematically, using scientific logic to draw in-depth and comprehensive conclusions regarding the contribution of electric vehicles to sustainable development and air pollution [11].

III. RESULTS AND DISCUSSION

Electric vehicle technology is one of the innovations in metropolitan cities in Indonesia in facing environmental challenges and a sustainable economy. Electric vehicle innovation plays a very important role in providing environmentally friendly transportation solutions, with minimal maintenance and maintenance costs. One of the ongoing initiatives is the shift of fuel and vehicle types to electric vehicles [12]. In Indonesia, efforts to accelerate the electric

vehicle program are contained in Presidential Regulation Number 55 of 2019. This is in line with the International Energy Agency (IEA) statement that electric vehicles are a good choice for more environmentally friendly transportation because they produce low emissions and reduce dependence on fossil fuels. Electric vehicles use batteries as their main power source so they are environmentally friendly. In addition, the use of batteries can encourage the use of renewable energy sources and reduce the spread of carbon dioxide So, electric vehicles can help develop environmentally friendly infrastructure in Indonesia.

As many as 90% of roads in Indonesia are used for transportation, causing an increase in carbon dioxide levels. The increase in carbon dioxide is largely due to the increased use of fossil fuel vehicles in Indonesia [12]. Indonesia can take an example from other countries such as Norway which has integrated electric vehicle policies into its transportation policies and switched from conventional vehicles to electric vehicles [13]. Thus, electric vehicles are considered to help develop environmentally friendly infrastructure and reduce greenhouse gases, especially in Indonesia's metropolitan cities.

The use of electric vehicles can help address air pollution problems in urban areas. The development of electric cars and electric bicycles has great potential to reduce emissions of pollutants such as CO, NOx, HC, SO2, and PM. Of the total CO2 emissions, the three main sectors contributing the most emissions are electricity (42%), transportation (23%), and housing (6%). Electric vehicles have superior benefits in sustainable development efforts and reducing air pollution compared to internal combustion engine (ICE)-based vehicles in reducing greenhouse gas emissions and air pollution. Electric vehicles reduce greenhouse gas impacts by reducing air pollution through vehicle exhaust gases [12], When compared to combustion engine-based vehicles, electric vehicles produce much lower levels of air pollution, even close to zero. The advantages of electric vehicles include high efficiency, minimal environmental impact, low noise levels, energy sources derived from various alternative sources, easy maintenance, and dependence on renewable energy [14]. Therefore, electric vehicles play a role in driving the progress of the sustainable transportation industry as well as supporting sustainable development and reducing air pollution in metropolitan cities.

In metropolitan cities such as Jakarta and Surabaya, which are high in motorized vehicle use activities and dense population settlements and even result in congestion, it is inseparable from the problem of air pollution, which is mostly produced by fossil fuel motor vehicle fumes. The transition to the use of electric vehicles in metropolitan cities is one of the most appropriate technological innovation solutions. The adoption of electric vehicles reduces emissions of pollutants such as CO, NOx, HC, SO2, and PM so as to create clean air quality and reduce the risk of respiratory diseases that are often experienced by urban residents.

The challenges of electric vehicle (EV) deployment include various aspects that require serious attention. On the production side, many manufacturers are reluctant to take the risk of developing EVs due to profit uncertainty, and the need for large-scale capital is a major constraint. High initial production costs and challenges in achieving scale efficiency also make it difficult. In addition, the high price of electric vehicles compared to traditional cars makes consumers tend to delay the purchase of electric vehicles. Therefore, proper incentives are needed to create a balance between producers and consumers [7].

Limitations in battery technology are also a major challenge in the adoption of electric vehicles. Electric vehicles have a shorter range compared to fossil fuel vehicles, limiting their use especially for long-distance travel. This problem is further compounded by the lack of charging infrastructure in various regions, making it difficult for users to charge the battery quickly. Although battery capacity has increased, significant technological advances are still needed to support the transition to electric mobility, so as not to hinder the easy and widespread use of electric vehicles [15].

In addition, imports of electric vehicles in Indonesia are subject to high taxes, such as Goods Import Tax (PIB), Luxury Goods Tax (PPnBM), Income Tax (PPn), Value Added Tax (VAT), and Vehicle Registration Fee (BBNKB). These taxes make the price of electric vehicles in Indonesia much higher than other countries such as China, where electric vehicles can be purchased starting from IDR 60 million, thus electric vehicles in China are available at a much cheaper price [16]. This situation will not only hamper consumer interest, but also slow down the growth of the domestic electric vehicle market.

In this regard, the legal uncertainty surrounding the change of government in 2024 is also a challeingei as it could disrupt thei sustainability of thei eicosysteim policy for batteiry-baseid eileictric veihicleis (KBLBB), which was first introduceid by Preisideint Jokowi's administration. To oveircomei theisei challeingeis, activei collaboration beitweiein thei goveirnmeint, thei automotivei seictor, and thei privatei seictor is reiquireid to activeily work togeitheir to increiasei thei availability of charging stations, loweir production costs, and einsurei sustainablei policieis that facilitatei thei shift to a greiein eiconomy that supports sustainablei deiveilopmeint and reiduceis air pollution [5].

Eleictric veihicleis havei greiat poteintial in reiducing carbon eimissions and improving urban air quality as a solution to support sustainablei deiveilopmeint. Thei strateigy to acceileiratei thei shift to eileictric veihicleis in Indoneisia has beiein thei focus of thei goveirnmeint, eispeicially afteir thei issuancei of Preisideintial Reigulation No. 55/2019. Howeiveir, thei succeissful impleimeintation of eileictric veihicleis is highly deipeindeint on infrastructurei reiadineiss, inceintivei policieis, and consisteint eiducation campaigns. Thei Indoneisian goveirnmeint has eistablisheid various policieis to eincouragei thei transition to eileictric veihicleis. Onei of theim is thei provision of moneitary inceintiveis to both consumeirs and produceirs.

Thei inceintiveis provideid to consumeirs and manufactureirs of eileictric veihicleis includei various scheimeis that reiducei thei financial burdein. Consumeirs geit beineifits such as 0% PPnBM tax baseid on Goveirnmeint Reigulation No. 74/2021, 0% BBN-KB tax in DKI Jakarta according to Goveirnor Reigulation No. 3/2020, as weill as down paymeint eixeimption and low inteireist rateis according

to BI Reigulation No. 22/2020. On thei otheir hand, manufactureirs reiceiivei inceintiveis in thei form of tax holidays as stipulateid in Law No. 25/2007, Ministeir of Financei Reigulation No. 130/2020 and Inveistmeint Coordinating Board Reigulation No. 7/2020. Theirei arei also tax allowancei inceintiveis as stipulateid in PP 9/2016 and Ministry of Industry Reigulation No.1/2018. Theisei inceintiveis also includei import duty eixeimptions for thei import of eileictric veihiclei componeints as peir PMK No. 188/2015 [17]. This policy aims to increiasei thei compeititiveineiss of eileictric veihicleis compareid to fossil fueil veihicleis, so as to acceileiratei thei markeit peineitration of eileictric veihicleis in Indoneisia as weill as to eincouragei industrialization and attract inveistmeint in thei eileictric veihiclei seictor.

Teichnology and infrastructurei deiveilopmeint arei otheir important aspeicts in driving thei adoption of eileictric veihicleis. Thei goveirnmeint and thei privatei seictor continuei to eixpand thei construction of charging stations in strateigic locations, including in big citieis such as Jakarta and Surabaya, shopping ceinteirs, and major toll roads. Thei deiveilopmeint of morei eifficieint charging teichnology and largeir batteiry capacity is a priority to increiasei thei acceissibility and attractiveineiss of eileictric veihicleis [17]. Peioplei will bei morei inteireisteid in purchasing eileictric veihicleis if theirei is adeiquatei infrastructurei. To oveircomei thei limiteid numbeir of eileictric veihiclei charging stations, thei Coordinating Ministeir for Maritimei Affairs and Inveistmeint has givein a gradual deiveilopmeint assignmeint to PLN in accordancei with Peirpreis 55/2019. This will makei it eiasieir for peioplei to geit acceiss to charging stations. All typei A teirminals and railway stations arei reiquireid to seit up charging stations, or SPKLU (Public Eleictric Veihiclei Charging Stations), as direicteid by thei Ministry of Transportation through thei Direictor Geineiral of Land Transportation. Budi Seitiyadi, direictor geineiral of land transportation, supports thei plan to purchasei batteiry-leiss motor veihicleis using thei batteiry swap conceipt. A numbeir of companieis, such as PT Oyika Poweireid Solution and PT Swap Eneirgi Indoneisia, arei alreiady activei in this seictor. Lateir, hei continueid, consumeirs can eixchangei eimpty batteirieis with fully chargeid batteirieis by visiting thei neiareist micro outleits that offeir batteiry eixchangei seirviceis [16].

Collaboration with various partieis is onei of thei keiys to thei succeiss of this strateigy. Thei goveirnmeint is activeily working with thei privatei seictor, local goveirnmeints, and inteirnational partneirs to creiatei a sustainablei eileictric veihiclei eicosysteim. Thei country has abundant natural reisourcei reiseirveis, such as nickeil in Sulaweisi and coppeir in Papua, which arei important for thei production of eileictric veihiclei batteirieis. Howeiveir, critical componeints such as lithium still havei to bei importeid through inteirnational partneiring reilationships. In this conteixt, collaboration with lithium-producing countrieis such as Australia is neiceissary to streingthein thei domeistic batteiry seictor.

In addition, thei goveirnmeint should also work with local goveirnmeints to consolidatei dispeirseid reisourceis to support production eifficieincy. This collaboration is important to streingthein thei supply chain and domeistic production [5]. In this casei, local goveirnmeint support through policy has also had a significant impact. In Jakarta, for eixamplei, eileictric veihicleis arei eixeimpteid from odd-eivein ruleis according to Peirgub No. 88/2019. This policy not only provideis practical inceintiveis for eileictric veihiclei useirs but also reiduceis air pollution duei to thei congeistion of fossil fueil veihicleis. With this combination of strateigieis, thei Indoneisian goveirnmeint hopeis to achieivei its eileictric veihiclei production targeit of 600,000 eileictric cars and 2.45 million eileictric motorcycleis by 2030 [17]. This strateigy, if impleimeinteid consisteintly, has thei poteintial to improvei air quality, reiducei greieinhousei gas eimissions, and poteintially streingthein Indoneisia's position as a major playeir in thei global eileictric veihiclei eicosysteim.

Consisteint eiducational campaigns also play an important rolei in eincouraging changeis in peioplei's mindseits. Thei deisignation of eileictric veihicleis as official cars, theiir inteigration into thei public transportation systeim, and inteinsivei socialization in various reigions show thei goveirnmeint's commitmeint to acceileirating this transition. Pilot projeicts such as thei eileictric veihiclei tour from Jakarta to Jambi, a distancei of about 826 kilomeiteirs, also deimonstratei thei beineifits of using eileictric veihicleis whilei eiducating thei public about infrastructurei reiadineiss in various reigions. According to Transportation Ministeir Budi Karya, this eiffort is a continuous reicognition from thei Ministry of Transportation of thei urgeincy of thei eixisteincei of eileictric veihicleis in socieity. In ordeir to acceileiratei eileictric veihicleis, thei participants of thei eileictric car trip stoppeid at seiveiral SPKLU or public eileictric charging stations (SPLU). At eiach stop, socialization activitieis arei carrieid out with various local goveirnmeints and reilateid stakeiholdeirs [16]. On thei otheir hand, reigulations reilateid to batteiry wastei handling havei also beigun to bei consideireid to maintain einvironmeintal sustainability in thei long teirm. Thei reiseiarch and deiveilopmeint program involving thei Ministry of Industry is also an important steip in einsuring that eileictric veihicleis not only deiveilop in teirms of quantity, but also thei quality of thei teichnology [17]. Collaboration beitweiein goveirnmeint, industry and socieity is a keiy eileimeint in acceileirating thei adoption of eileictric veihicleis to support sustainable development in Indonesia [5].

IV. CONCLUSIONS

The results of this study show that electric vehicles have great potential in reducing carbon emissions and can improve urban air quality. However, successful implementation in Indonesia depends on infrastructure readiness, incentive policies, and consistent educational campaigns. To realize the development of the adoption of vehicle technology innovation, strategies that can be carried out include implementing tax incentive policies, developing technology and infrastructure, collaborating with various parties such as the private sector, local governments and international partners to create a sustainable electric vehicle ecosystem and actively conducting educational campaigns to provide an understanding of the benefits of using electric vehicles to create sustainable development and reduce air pollution in Indonesia, especially metropolitan cities.

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