



Challenges in Connecting the Elements of Sectoral SYSTEM OF Innovation for the Development of Indonesia's Electric Vehicle Industry

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ABSTRACT

This study discusses industrial development of electric vehicle (EV) di Indonesia, viewed from sectoral system of innovation (SSI) perspective, with aim to map challenges in connecting the elements of SSI for developing EV industry. This study employed a desk research. The information input was obtained through secondary sources: statistical data, official documents, and scientific references. This study found eight challenges for developing EV industry. First, the institutional challenges: i) fiscal incentives are still insufficient to promote industrial collaboration on EV innovation with universities and R&D institutions; ii) domestic content provision target is still difficult to meet; iii) unreadiness of domestic industry to be involved in the EV supply chain; and iv) slow consumers' response towards EV program incentives. Next, the knowledge and technological challenges: i) the quality and standards of EVs from domestic R&D efforts are still considered unsatisfactory for commercialization scale; and ii) potential investors have not yet developed adequate interest in domestic EV development. Finally, challenges from the demand aspect: i) the plan to make Indonesia as EV hub in ASEAN region has been hindered due to lack of investors' participation; and ii) the lack of Electronic Charging Station (ECS) accessibility for EV.

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I. INTRODUCTION

Indonesia government is committed to electric vehicle (EV) program to reduce the burden of emission and fuel subsidy. Building its ecosystem is important to the successful implementation of this program. Sectoral system of innovation (SSI) has been widely applied as a model for explaining how automotive industry have been developed by several countries. The SSI perspective comprises three elements: institution and demand, actors and network, and knowledge and technology,. On the basis of SSI perspective, the scientific explanation by several previous studies focused on the specific aspects or combination of system components of SSI. Qi et al. (2016) observed knowledge and technology element in China, especially on innovation process, which was divided into three phases, namely accumulation process, transformation process, and diffusion process. Likewise, Ibusuki et al. (2020) analyzed the knowledge and technology component in terms of investment in R&D and the number of patents performed by automotive companies in Brazil.

The significance of innovation from demand perspective was revealed by Adams et al. (2013) that the magnitude of innovation by user firms, as measured by patents is high, and the innovative user firms are quite active in entrepreneurial activity. Feng & Li (2019) studied the connection between innovation and institution elements in China, and revealed that the central government there has provided long-term and consistent support for domestic innovation in EV, and the rise of EV also benefited from the policy actions of provincial governments. The position of institutions' element related to environmental and innovative policies as an integrated elements influence both technology advance and demand in automotive industry (Oltra & Saint Jean, 2009). Likewise, the role of institution by multilevel proactive state supervision in South Korea and Turkey is crucial to accelerate the industrial transformation in automotive industry through technological upgrading (Tuncel, 2014).

The role of central actors, especially the “leading” firms that invest in R&D and related activities, can facilitate positive collaboration with other actors, especially the first-tier foreign

suppliers and several domestic suppliers; all of which can elevate automotive industry to become stronger, more coherent, and product-specific (Intarakumnerd & Gerdri, 2014). Actors from academic background, such as universities and research institutes, can provide automotive-specific teaching, research programs, and closer collaboration with the industry, while actors from automotive-specific government promotion agency can act as an ‘intermediary’ party (Intarakumnerd & Chaoroenporn, 2013; Intarakumnerd, 2017). The role of actors as the innovation resource for the automotive industry in Indonesia can be quite vary between individual and organizational actors, as well as between internal and external resources. The internal resources of innovation mostly emerge from the internal organization of the firm, while the external resources of innovation mainly emerge from competitors that stimulate the creation of new products in a highly competitive market of automotive industry in Indonesia. Meanwhile, the role of university and public research institutions as external resources of innovation in the Indonesian automotive industry was still considered small (Aminullah & Adnan, 2012).

The automotive sector can be considered a complex system as it requires innovation that involves a large variety of actors, including ones both directly and indirectly engaged in the innovative processes (Xi et al., 2009). Therefore, SSI framework is introduced as a useful perspective for understanding the complexity of the sector (Ndou et al., 2012) to better understand the innovations and industrial dynamics in EV sector.

Considering the aforementioned previous studies on SSI in automotive sector, there were no studies to this day that specifically investigate EV sector in Indonesia using SSI perspective. It is because study on EV sector viewed from SSI perspective in Indonesia was considered new topic. For this reason, we conduct this study by doing a comprehensive mapping of the system, especially on each element of EV sector and the interaction among those elements within SSI. Therefore, this study aimed to to map challenges in connecting the elements of SSI for developing EV industry in Indonesia.

II. ANALYTICAL FRAMEWORK

The SSI model consists of three main elements: (i) institutions and demand (ii) actor and network, and (iii) knowledge and technology (Malerba, 2004). The interaction of these three elements in the system are explained as follows: The learning process, through internal and external resources, is conducted in order to accumulate knowledge and technological capability. The actors, both individual and organizational, have the role as external and internal resources in this learning activity. Next, demand is the resources of external learning to accumulate knowledge and technological capability. The individual and organizational actors interact through networks, namely market and non-market networks. The relations in the network are created and influenced by institutions, namely market and non-market institutions. The whole processes of innovation in SSI always consider and analyze the influence of actors, networks, institutions, and demand, where the demand functions as pull factor to facilitate innovation (see Figure 1).

Institution and demand is the first element of SSI. They are defined as the laws, rules, standards, norms, traditions, and conventions that shape and influence the actors' interactions in the system. These interactions occur through binding contracts and non-binding agreements. The binding contracts consist of formal law (intellectual property right/IPR, patent, and trademark) and government regulation (incentive, procurement, preference, deregulation, and facility), while non-binding agreements comprise convention. Beside that, there are market institutions, such as monopoly, oligopoly, and competition. Meanwhile, non-market institutions comprise the socio-political factors, namely political guidance, collusion, and nepotism, that could affect the actors' interaction in the system. Domestic institution may influence the patterns of sectoral development in a country (i.e. sectoral shift of national planning and policy directed by national agencies). Furthermore, demand is an agent that interacts with producers. The agent is represented by consumers, corporations, and the government sector. The interactions of agents with producers are shaped and influenced by both market and non-market institutions. The demand functions

as the pull factor to trigger innovation, especially problem-solving innovation in order to meet certain demands (i.e. innovation based on input from users and suppliers).

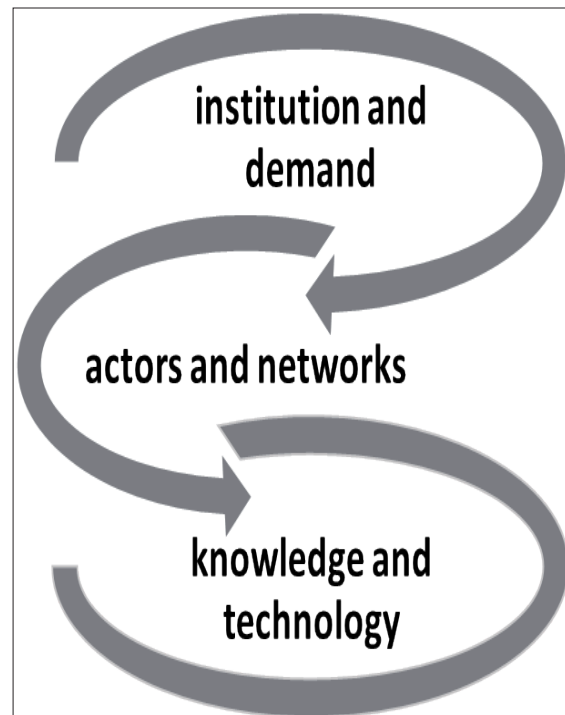


Figure 1. Three elements of sectoral system of innovation (SSI)

Actor and network is the second element of SIS. The actors, as the agents of system, are categorized into individual and organization. Individual actors include consumers, businessmen, and scientists, while organizational actors comprise firms with their internal units (i.e. R&D, production, and marketing) and external units (i.e. users, suppliers, universities, research institutions, financial institutions, government agencies, business associations, and business principals). The network describes the ways various actors are connected in the system. The network provides a path to access knowledge and technology in the system. The variations of access are characterized by market and non-market relationships. Market relationships can occur through licensing, joint venture, contract, subcontract, integration, acquisition, alliance, collaboration, cooperation, and competition. Meanwhile, non-market relationships can occur through consultation, dispatching of personnel to learn, training, meeting, service, lobbying,

information exchange, command, collective action, and partnership.

Knowledge and technology (covering areas such as knowledge, technology, engineering, design, and operation) is the third element that essentially determine the boundary of SSI. Knowledge in SSI is viewed from the perspective of access and accumulation of knowledge. The access of knowledge can occur through both internal and external resources. The access through internal resources (i.e. it is accessed by a competitor) will reduce the appropriateness, while access through external resources (i.e. universities, research institutions, suppliers, users) affects the sector's opportunities in innovation. Meanwhile, the accumulation of knowledge and technological capability are the results of knowledge creation and acquisition of knowledge in the long run that resulted from the whole process of innovation. The mechanism of knowledge accumulation occurs through the process of creation, absorption, acquisition, and utilization of knowledge. Likewise, the accumulation of technological capability is the result of learning through internal resources (learning by doing, using, and searching) and external resources (learning through the progress of S&T, actors' interaction, and technology spillover).

In this study, the type of EV are cars with battery electric vehicles (BEV), not include hybrid electric vehicles (HEV) and plug-in hybrid electric vehicles (PHEV). A battery electric vehicle (BEV) is considered to be an 'all-electric' or 'full-electric' car. BEVs are powered exclusively by electricity, with their electric motors drawing current from onboard battery packs. BEVs need charge to be driven. This can be done through either a home charger or fast charging station, or energy recouped by regenerative braking. The rationale behind this approach stems from the fact that both HEVs and PHEV remain to generate emissions. However, the primary focus of this study centres on the government's commitment to reduce the emission levels.

III. METHODOLOGY

This study employed a desk research, in which the information input were obtained through

secondary sources: statistical data, official documents, and various previous studies and references on EV since 2011. This study adopted the SSI model, the information collected were then categorized into three groups: (i) institutions; (ii) knowledge and technology; and (iii) demand. Actor and networks will be elaborated in discussion section. Detailed information on each group was elaborated based on the scope of this study, namely the development of EVs industry in Indonesia. The mapping results on the elements of SSI for developing EV industry in Indonesia were then analyzed using an analytical framework that will be explained in the following chapter. The analysis was intended to figure out the relationship among several elements of SSI for developing EV industry, covering the existence of links and obstacles based on the available references. Finally, this study presents several conclusions regarding the challenges in connecting the elements of SSI for developing EV industry in Indonesia.

IV. RESULTS: MAPPING THE SSI ELEMENTS OF EV INDUSTRY

A. Institutions

The Indonesian Government has started movement towards EV transition since 2012 through the initiative from the Ministry of State-Owned Enterprise (MSOE) to develop national EV cars, but the developed cars have never been able to reach the commercialization stage due to the failure in emission test and roadworthiness permit (Suwandono & Nadya, 2021). A number of initiatives to encourage national EV R&D were also taken by the Ministry of Research, Technology and Higher Education during that time especially to promote EV R&D collaboration among universities (Suwandono & Nadya, 2021). However, a stronger commitment to the transition to EVs has emerged since 2017, with the presidential mandate through the enactment of the National Energy General Plan (RUEN) through the Regulation of the President of the Republic of Indonesia No. 22/2017. The document outlines plans for the advancement of electric/hybrid vehicles, implementation of fiscal incentives for

the EV sector, and utilization of EV for public transportation in urban regions.

The policy direction for national EV adoption and development has become clearer since the enactment of the Regulation of the President of the Republic of Indonesia No. 55/2019, which focuses on the EV acceleration program for transportation. This regulation demonstrates the government's dedication in decreasing carbon emission and promoting the growth of domestic EV industries. This regulation serves as the overarching framework for other government policies and program pertaining to domestic EV. This regulation outlines five key guidelines: 1) promoting the growth of the domestic EV industry, 2) offering incentives, 3) establishing electric charging stations, 4) specifying technical requirements for EV, and 5) ensuring environmental protection. This regulation also provides the investment opportunities in the EV sector (Ministry of Industrial Data and Information Center, 2021).

In addition, the government has implemented a national EV industrial road map through the Regulation of the Minister of Industry No. 6/2022. This regulation aims to promote domestic production of two-wheeled EV, with a target of 5,000 units by 2020 and it is projected to reach 12 million units by 2035. In addition, this regulation also stipulates that the production target for four-wheeled EV is projected to reach 400,000 units by 2025 and 1 million units by 2035. Table 2 displays the summary of the 5-years EV domestic production target. This objective has grown substantially, while previously in RUEN the government had set a target of only 2,200 units for four-wheeled EV and 2.1 million for two-wheeled EV by 2025.

In order to promote the adoption and the development EV industry at the national level, the government has implemented a series of regulations and policies, as outlined in Table 1. In this study, the policies are grouped into five categories, namely those related to 1) domestic EV R&D, 2) batteries raw materials and final products downstreaming, 3) domestic component, 4) charging infrastructure, and 5) users incentives. These categories will be discussed in detail in the following sub-chapter.

1) EV R&D incentives

The government promotes active participation of industry, universities, and research institutions in EV research, development, and innovation. This cooperation covers various aspects that aim to facilitate 1) the advancement of EV key components; 2) the streamlined development of charging facility; 3) the development of EV industry that conform with current technological advancements; 4) the establishment of EV industry with notable achievements in domestic content; and 5) the creation of EV that adheres to technical standards and exhibits environmental sustainability, as outlined in the Regulation of the President of the Republic of Indonesia No. 55/2019.

In order to promote R&D within EV industry, the government has committed to providing both fiscal and non-fiscal incentives for industry players, universities, and research institutions. Through the Regulation of the Minister of Finance No. 153/2020, the government has granted the opportunity for industrial participants to obtain a reduction in gross income—referred to as super deduction tax—of up to 300%. The reduction in gross income can be divided into two components: i) a reduction of 100% of the entire costs incurred, and ii) an additional reduction of up to 200% of the total costs incurred. The additional reduction is described as follows: i) a 50% reduction if R&D activities generate acquisition of intellectual property rights in the form of domestically registered patents; ii) a 25% reduction if R&D activities generate patents other than the domestically registered ones; iii) a 100% reduction if R&D activities proceed to commercialization stage; and/or iv) a 25% reduction if R&D activities at the commercialization stage are conducted in collaboration with government R&D institutions or Indonesian higher education institutions.

2) Downstreaming battery raw material policy

The overall success of EV development is heavily dependent on the advancement of battery components and the establishment of charging stations (Fitriana et al., 2020). Indonesia is considered a highly potential nation due to its natural resource

Table 1. EV Regulations and Policies in Indonesia

Regulation & Policies	Description
Legal framework	
The Regulation of the President of the Republic of Indonesia No. 22/2017	Acceleration target for the utilization of electric power for motorized vehicles
The Regulation of the President of the Republic of Indonesia No. 55/2019	Acceleration of domestic EV industry development, provisions of incentives, provisions of electric charging stations, technical requirements of EVs, and environmental protection
The Regulation of the Minister of Industry No. 6/2022	Specifications, national EV production targets, strategic plan of EV industry development, and provisions for calculating the value of EV domestic component levels (DCL)
R&D incentives policy	
The Regulation of the President of the Republic of Indonesia No. 55/2019	Incentives and requirements for R& D and innovation activities EV-related R&D and innovation plan
The Regulation of the Minister of Finance No. 153/PMK.010/2020	Super deduction tax or gross income reduction of up to 300% for industrial companies carrying out R&D and related innovation activities
Downstreaming battery raw material policy	
The Regulation of the Minister of Industry No. 6/2022	Battery technology and industry development strategy
The Regulation of the Ministry of State-Owned Enterprises	The national battery industry consortium consists of four state-owned companies: Mining Industry Indonesia (MIND ID), PT. Pertamina, PT. Perusahaan Listrik Negara (PLN), and PT. Aneka Tambang Tbk. (Antam) as the main shareholders of Indonesian Battery Corporation (IBC).
The Regulation of the Minister of Energy and Mineral Resources No. 11/2019	Prohibition of nickel ore exports from January 1, 2020
The Regulation of the Government No. 49/2022	Exemption of nickel ore from the imposition of value added tax
The Regulation of the Minister of Finance No. 130/2020	The amount of corporate income tax deduction and tax reduction period
The Regulation of the Government No. 1/2014	The obligation of purifying and processing the mineral and coal domestically
Domestic component policy	
The Regulation of the President of the Republic of Indonesia No. 55/2019	Target for fulfilling EV DCL for two, three, four-wheeled, and more. Import conditions for main components, supporting components and complete products Incentives for industrial companies DCL compliance
The Regulation of the Minister of Industry No. 6/2022	DCL calculations based on main component manufacturing aspects, supporting component manufacturing aspects, assembly aspects, and development aspects
Charging infrastructure policy	
The Regulation of the President of the Republic of Indonesia No. 55/2019	Electric charging infrastructure for EV, assignment to PT. PLN for providing initial electricity charging infrastructure, determination of the location of public electric vehicle charging station (PEVCS) infrastructure
The Regulation of the Minister of Energy and Mineral Resources No. 13/2020	Electric charging infrastructure, private installations, PEVCS specifications, battery exchange facilities (BEF), tariffs, connection fees reductions and electricity subscription guarantees, and infrastructure safety
EV user incentives policy	
The Regulation of the Minister of Finance No. 38/2023	Value added tax (VAT) reduction of 10% for EV with a minimum 40% DCL.
The Regulation of the Minister of Home Affairs No. 6/2023	EV exemption from motor vehicle tax (PKB) and motor vehicle title transfer fee (BBNKB).
The Regulation of the Government No. 74/2021	EV exemption from sales tax on luxury goods (PPnBM). The basic tax imposition of EV is 0% of the selling price.
Specification and standard	
The Regulation of the Minister of Industry No. 6/2020	EV specifications of two, three, four-wheeled, and more.

Regulation & Policies	Description
SNI 8927:2020	Category L electric motor vehicle battery systems - Removable and swappable battery system safety requirements.
SNI 8928:2020	Category L electric motor vehicle battery system - Specification of removable and exchangeable batteries for electric motor vehicles.
SNI 8608:2018 ISO/TR 13062:2015	Electric mopeds and motorcycles -Terminology and classification
SNI IEC 62893-2:2017	Charging cables for electric vehicles of rated voltages up to and including 0,6/1 kV – Part 2: Test methods
SNI IEC 62893-3:2017	Charging cables for electric vehicles of rated voltages up to and including 0,6/1 kV – Part 3: Cables for AC charging according to modes 1, 2 and 3 of IEC 61851-1 of rated voltages up to and including 450/750 V
SNI IEC 62893-1:2017	Charging cables for electric vehicles of rated voltages up to and including 0,6/1 kV – Part 1: General requirements
SNI IEC 62196-1:2014	Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 1: General requirements
SNI IEC 61439-7:2018	Low-voltage switchgear and controlgear assemblies – Part 7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicle charging stations
SNI IEC TS 62196-3-1:2020	Plugs, socket-outlets, vehicles connectors and vehicles inlets – Conductive charging of electric vehicles – Part 3-1: Vehicles connector, vehicle inlet and cable assembly for DC charging intended to be used with a thermal management system
SNI 0225-7-722: 2020	General Electrical Installation Requirements (PUIL) 2020 – Part 7-722 – Requirements for special installations or locations – Supplies for electric vehicles
SNI IEC 62196-3:2014	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c.pin and contact-tube vehicle couplers
SNI IEC 62196-2:2016	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories
SNI IEC 62893-1:2017	Charging cables for electric vehicles of rated voltages up to and including 0,6/1 kV – Part 1: General requirements
SNI IEC 61439-7:2018	Lowvoltage switchgear and controlgear assemblies – Part 7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicle charging stations
SNI IEC 61851-21-1:2017	Electric vehicle conductive charging system - Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply.
SNI IEC 61851-24:2014	Electric vehicle conductive charging system - Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging
SNI IEC 61851-23:2014	Electric vehicle conductive charging system – Part 23: DC electric vehicle charging station.
SNI IEC 62660-3:2016	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 3: Safety requirements
SNI IEC 62196-1:2014	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements
SNI IEC 62660-1:2017	Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 1: Performance testing
SNI IEC 62660-2:2017	Secondary Lithium-ion cells for the propulsion of electric road vehicles – Part 2: Reliability and abuse testing

Table 2. EV Production Target in Indonesia

	Variable		2020	2025	2030	2035
Four-wheeled and more EV	Production	Total (Unit)	0	400,000	600,000	1,000,000
Two and three-wheeled EV	Production	Total (Unit)	5,000	6,000,000	9,000,000	12,000,000

reserves. Notably, it possesses abundant quantities of nickel, a primary raw material utilized in the production of batteries for EV. According to the Ministry of Energy and Mineral Resources (2020), Indonesia, the foremost producer of nickel, currently possesses around 52% of the global nickel reserves. This implies that Indonesia has the capability to not only participate in the EV global production network, but also has the capacity to emerge as a significant contributor in the supply of nickel-based EV batteries (Febrianto et al., 2020).

The government through the Ministry of Industry has formulated a strategic plan (also known as a roadmap) that particularly focuses on the advancement of EV raw materials and components sector. The government also has implemented a technology development strategy that primarily focuses on the advancement of battery technology. This strategy encompasses four key areas related to batteries development: 1) the development of battery cells and packs; 2) the development of battery management systems; 3) the exploration of battery raw materials; and 4) the consideration of battery end-of-life issues.

The government subsequently established a task force, under the Ministry of State-Owned Enterprises (MSOE), with aim to expedite the advancement of EV batteries. This task force comprised four state-owned enterprises, namely Mining Industry Indonesia (MIND ID), PT. Pertamina (Persero), PT. Perusahaan Listrik Negara (PLN), and PT. Aneka Tambang Tbk (Antam). Subsequently, these four business entities consolidated in order to establish and hold primary ownership of the Indonesian Battery Corporation (IBC), with aim to bolster the domestic battery sector across its whole value chain. The establishment of the IBC is intended to facilitate Indonesia's transition into a comprehensive battery manufacturer, encompassing activities such as mining, smelting, refining, component production, and EV battery manufacturing. Moreover, in July 2021, IBC achieved a collaboration agreement valued at US\$ 1.1 billion. The agreement involved a South Korean consortium comprising Hyundai Motor Company and LG Energy Solution, with aim to establish a joint venture for

the construction of an EV battery cell facility in Karawang, West Java.

In contrast, in an endeavor to promote the domestic industry and facilitate the downstream activities of nickel commodities, the Indonesian Government, through the Ministry of Energy and Mineral Resources (MoEMR) implemented nickel ore exports ban started in 2020, as stipulated in The Regulation of the Minister of Energy and Mineral Resources No. 11/2019. This regulation aims to promote the enhanced value of nickel commodities, particularly through the production of EV batteries. The restriction enactment on the exportation of nickel ore minerals has faced significant opposition from the European Union, prompting this organization to file a lawsuit through the World Trade Organization (WTO). If the lawsuit succeeds and Indonesia suffers a loss as the consequence, the Indonesian Government would be required to revise the regulations pertaining to the export prohibition. Nonetheless, considering the importance of nickel ore as a key resource in the production of EV batteries, the government has implemented the value-added tax (VAT) exemption provisions for nickel ore through the Regulation of the Government No. 49/2022.

Several regulations were also enacted to promote the downstream process in order to convert nickel into value-added products. For example, it is stipulated in Law No. 4/2009 and the Regulation of the Government No. 1/2014 that domestic mining companies are required to conduct processing and refining activities, and they must be equipped with smelting facilities to process raw materials into semi-finished and finished products.

In addition, to ensure the smooth downstream activities in the domestic EV industry, the government has formulated a series of policies to encourage the growth of investment in this industry. For example, through the Regulation of the Minister of Finance No. 130/2020, the government offers incentives to pioneer industries, including EV battery industries, with aim to undertake new capital investments. The incentive offered is a tax reduction or tax holiday of up to 100% for a maximum duration of 20 years. The

government also provides fiscal incentives in the form of import duty for imports for the purposes of undertaking new capital investments and production processes. Moreover, incentives are also offered through the suspension of import duties for the purpose of exports financing. Additionally, the government also offers assistance in the form of professional competency certification for human resource development, as well as product certification and technical standards for the EV industry and its related sectors.

3) Domestic component policy

Through the Regulation of the Minister of Industry No. 2/2011, the government has implemented policies pertaining to the inclusion of domestic components in goods manufacturing. These activities encompass several aspects in subsequent order, namely the use and selection of raw materials, the designing, the fabrication, the assembling, and the completion stage. All of these are required to be carried out domestically using domestic components. Accordingly, the four-wheeled EV industry is subjected to government regulations regarding the domestic component level (DCL). The minimum DCL target is set at 40% for the 2022–2023 period, 60% for 2024–2029, and a minimum of 80% for 2030 and beyond. The DCL percentage also affects the fiscal incentives for VAT deductions. For instance, the government offers a 10% VAT discount to four-wheeled EV companies that have achieved a minimum of 40% DCL.

Furthermore, the government offers concessions and import duty incentives to component industries that are unable to produce all their components domestically. These incentives apply to the import of KBLBB components in either incompletely knocked down (IKD) or completely knocked down (CKD) form, as well as EV in completely built-up (CBU) form.

4) Charging infrastructure policy

Charging facilities play a crucial role in facilitating the transition from internal combustion engine vehicles (ICEV) to EV in Indonesia. Through the Regulation of the President of the Republic of Indonesia No. 55/2019, the government

formulated a policy to encourage the development of electricity charging infrastructure for EV. Furthermore, through this regulation, the government has designated PT. PLN (Persero) as the initial provider of public electric vehicle charging station (PEVCS) infrastructure.

The government facilitates the modification of electrical installations to accommodate the construction of PEVCS. The government also offers financial support and incentives to promote the economic value of the PEVCS business. This includes assistance for the construction of PEVCS facilities and incentives for the production of PEVCS equipment.

Furthermore, the government through the MoEMR has issued a policy (The Regulation of the Minister of Energy and Mineral Resources No. 13/2020) concerning the provision of electricity charging infrastructure for EV. This regulation governs the infrastructure, tariffs, and safety factors associated with electric charging infrastructure. In addition, the National Standardization Agency (BSN) in Indonesia has implemented regulations for standardizing EV charging stations. These regulations cover various components, such as plugs, sockets, vehicle connectors, and vehicle inlets (Dharmawan et al., 2021).

5) EV user incentives

The government is implementing both fiscal and non-fiscal policies in order to encourage the public adoption of EV. These policies play a crucial role in stimulating public interest in EV. The government, specifically the Ministry of Finance, has recently enacted the Regulation of the Minister of Finance No. 38/2023 concerning the subsidies for EV in the form of cars and buses. This regulation entails a reduction of 10% in value added tax (VAT), resulting in customers only being required to pay 1% VAT when purchasing EV cars that meet the minimum requirement of 40% DCL. The price of EV is significantly reduced, ranging from IDR 27 to 70 million.

Furthermore, the government through the Ministry of Home Affairs (MoHA) has enacted a policy (The Regulation of the Minister of Home Affairs No. 6/2023), which grants an exemption

for EV from motor vehicle tax (MVT/PKB) and motor vehicle title transfer fee (MVTTTF/BBNKB). In addition, this regulation also stipulates that the government i) grants a sales tax exemption on luxury goods (STELG/PPnBM) for EV, and ii) provides relief by setting low interest rates and eliminating the minimum down payment requirement for EV credit.

In terms of charging services, PT. PLN offers a 30% discount for home charging services. The government offers supplementary electricity discounts to individuals interested in installing home charging facilities. Additionally, regional government also provides regulations pertaining to EV. For example, in Jakarta, the government has recently implemented a relaxation regarding the odd-even regulation for EV. In addition to promoting the use of KBLBB among individuals, the government is also encouraging EV adoption for public transportation and government service vehicles.

6) *Standard*

In terms of standard, until 2023, Indonesia has issued Indonesian National Standards (SNI) relating to electric vehicles, consisting of 38 SNIs regarding electric vehicles, 9 SNIs for electric vehicle batteries and 15 SNIs regarding electric vehicle charging infrastructure as mentioned in Table 1. However, each country has different standards related to EVs producer including electric energy utility standards for variations in driving pattern/driving cycles (Brady and O'Mahony, 2016), battery standards (Ruiz et al., 2018), design standards for battery management systems (Hauser and Kuhn, 2015), electric charging standards integrated with electric vehicle rules (Shareef et al., 2016; Knezovic et al., 2017; Habib et al., 2015; Shaukat et al., 2018), spare parts (Ruiz et al., 2018; Habib et al., 2015), as well as electricity infrastructure standard platforms in order to protect consumers (Ahmad et al., 2018; Habib et al., 2015). Future standards development of EV in Indonesia will require closer collaboration between standardization organizations (SAE, IEC, and ECE), researchers, and manufacturers. Moreover, standardisation has also been implemented with respect to ion cells of electric vehicle

batteries and electric motorcycle, as detailed in Table 1.

B. Knowledge and Technology

1) *Domestic EV development*

R&D and academic institutions in Indonesia, including LIPI, BPPT (now they are merging into BRIN – National Research and Innovation Agency), ITB, ITS, UNS, UI, and others, have been undertaking initiatives for over a decade to promote R&D and innovation activities in the EV sector (Aminullah & Adnan, 2011; Asfani et al, 2020; Sutopo et al., 2018). These activities are crucial for implementing the EV Program as outlined in the Regulation of the President of the Republic of Indonesia No. 55/2019, specifically Article 7.3, which focuses on research, development, and innovation. These activities include battery development, construction of an efficient public EV charging station, EV production with predetermined domestic content requirements, and environmentally friendly EV manufacturing that adheres to technical standards (Investment Coordinating Agency, 2017).

Several R&D outputs, such as pilot projects or patented inventions, still have not been fully incorporated into industrial scales. In 2018, the government introduced an automotive roadmap that prioritizes EV due to Indonesia's significant market potential in this sector. Through this plan, domestic EV production is expected to expand and able to meet the domestic market demands, before entering regional and international market competition. The government offers appealing incentive schemes to both EV producers and customers. On the other hand, Nurhadi et al (2021) suggested that successful R&D and innovation efforts in EV program could lead to a reduction of approximately 30% in component suppliers in Indonesia due to the relatively lower number of components required for EV compared to ICEV.

Before BRIN was formed in 2021, the development of electric vehicles focused on mastering key component technology such as electric motors, batteries, control systems/power electronics, platforms, and charging systems, while after that it focused on mastering key autonomous vehicle technologies, such as object/sensor detection

systems, telecommunications systems, human to vehicle interaction, computer vision, etc (National Research and Innovation Agency, 2022).

2) *EV manufacturing*

The Ministry of Industry's 2018 Automotive Roadmap towards 2035 received supports from domestic and foreign companies due to its promotional policy pertaining to the production of electric vehicles, including battery-powered electric vehicles (BEVs), hybrid electric vehicles (HEVs), and low carbon emission vehicles (LCEVs). The production of two distinct types of electric vehicles, namely EVs and BEVs, is projected to reach a total of 9,847 units by 2023. This represents a notable growth of 23% compared to the previous year. However, the production volume represents a mere 0.5% of the total number of ICEV. Since 2022, two foreign companies, Hyundai and Wuling, have been operating EV assembly factories in the Cikarang industrial estates. The EV products from these two companies have gained significant market share in Indonesia. In addition to automobiles, Indonesia has also produced electric motorcycles, commercial EVs such as buses and trucks, battery materials, and complementary infrastructure, such as charging stations and battery swap stations.

Throughout EV development, Indonesia has been facing challenges regarding several aspects: technical and technological capabilities, establishment of charging infrastructure, battery technology expertise, and standardization (Zulkarnain et al., 2014; Regina & Ulmi, 2023; Nuryakin et al., 2019). The development of EV necessitates human resources and technological capabilities in various areas, such as EV manufacturing, battery industry, EV component suppliers, and supporting services (Zulkarnain et al., 2014; Marciano, 2021). For this reason, the government has implemented a battery program to support the EV industry. This program includes various facilities, such as incentives and subsidies, as outlined in the Regulation of the President of the Republic of Indonesia No. 55/2019.

3) *EV investment*

Capital investment with aim to facilitate technological advancement is a prevalent approach for

EV development in Indonesia, as the progress in this sector apparently is still in the nascent phase (Amir & Prabawani, 2022; Habiburrahman & Nurcahyo, 2022; Maghfiroh et al., 2021). According to Cyrill (2023), many investors have been involved in the development of EV and the EV supply chain in Indonesia, which can be categorized into several sectors as follows.

- a) Car production, is being expanded by i) MM Motors, which includes the upcoming production of the Minicab-MiEV electric car.; ii) Neta, a subsidiary of China's Hozon New Energy Automobile, that plans to produce cars domestically in 2024; iii) foreign private manufacturers W and H that have moved their EV production facilities to Indonesia and have received full incentives.
- b) Nickel-related industries, which includes: i) a foreign investor that involved in two nickel mining and smelting located in Sulawesi (Morowali Industrial Park and Virtue Dragon Nickel Industry); ii) one private company that constructs a smelter in Central Java Province with annual production capacity of approximately 150,000 tonnes of nickel sulphate.
- c) EV supply chain, which includes: i) South Korean companies and three other manufacturing companies that have signed a Memorandum of Understanding (MoU) with The Ministry of Investment (MoIn) to focus on battery manufacturing, e-mobility, and other related industries; ii) Two South Korean companies that have invested in the establishment of Indonesia's first EV battery factory, which is designed to bear a battery cells' capacity of 10 GWh; iii) Indonesian mining companies that collaborates with foreign counterparts to establish facilities for EV manufacturing, battery recycling, and nickel mining; and iv) VI and ZHC that collaborates with FM to establish a hydroxide precipitate (MHP) facility in Southeast Sulawesi Province. The first factory is projected to has a production capacity of 120,000 tonnes, while the second factory is estimated to reach a production capacity of 600,000 tonnes.

4) EV import

Currently, Indonesia can still be considered a technology adopter nation, as evidenced by the importation of EV. Customers have the option to purchase EV that are currently unavailable in domestic market. In this regard, foreign cars are typically imported into Indonesia in completely built-up (CBU) form through general importers. According to data from Gaikindo (2023), the number of imported EV cars is 2,381 units.

There are seven domestic companies or joint ventures serving as EV importers. The predominant types of EV in Indonesia are battery electric vehicles (BEVs), which are primarily imported from Japan, Germany, England, South Korea, and China. Imports of four-wheeled EV accounted for approximately 0.72% of the total import value of motor vehicles, reaching US\$3.89 billion in 2022 (Central Bureau of Statistics, 2022). The predominant model of imported EVs in Indonesia is station wagon, mainly in completely knock down (CKD) form.

5) EV battery

The battery is a vital and costly component in EV, serving as the primary power source for the vehicle propulsion. Currently, battery accounts for approximately 40% of the total EV price. Fortunately, the percentage is projected to decrease to approximately 25% by the 2030s (König et al., 2021). Nonetheless, there are several other challenges pertaining to battery technology in EV development, namely the imperative to decrease its weight, volume, and charging duration, the reliance on operating temperature, and the management of its toxic components (Zulkarnain et al., 2014).

EV batteries are primarily composed of three main components: cathode, anode, and other additional materials. Approximately 66.7% of batteries total production cost is allocated to cathode manufacturing, while the remaining (33.3%) dedicated to other materials. The cathode material typically comprises nickel sulphate (NiSO_4), cobalt sulphate (CoSO_4), manganese sulphate (MnSO_4), lithium carbonate (Li_2CO_3), sodium carbonate (Na_2CO_3), and water (H_2O). Until 2021, nickel material costs were dominant, but nowadays lithium material costs are the highest (IEA, 2023). Indonesia possesses abundant domestic reserves of nickel, cobalt, and manganese, making these battery components domestically available. However, this country still relies on imports for lithium and sodium provision. Despite that, it cannot be denied that Indonesia is still the world's leading producer of nickel as it possesses the world's largest nickel reserves at approximately 21 million tonnes (International Nickel Study Group, 2021).

The battery's production chain is summarized in Figure 2. Many companies have been involved in the upstream value chain, such as nickel mining, smelting, and the production of nickel-based chemicals. These companies comprise State-Owned Enterprises (SOE), national private companies, and foreign private companies. The technologies employed in this process include high pressure acid leach (HPAL), rotary kiln-electric furnace (RKEF), step temperature acid leaching (STAL), circular type electric furnace, rectangular type electric furnace, and various other technologies. These technologies have mostly been mastered and developed by research and development institutions and universities (Prasetyo, 2011; Setiawan, 2016; Yoesgiantoro et al., 2022), as well as by Indonesian companies (TBP, 2023; Deloitte, 2022).

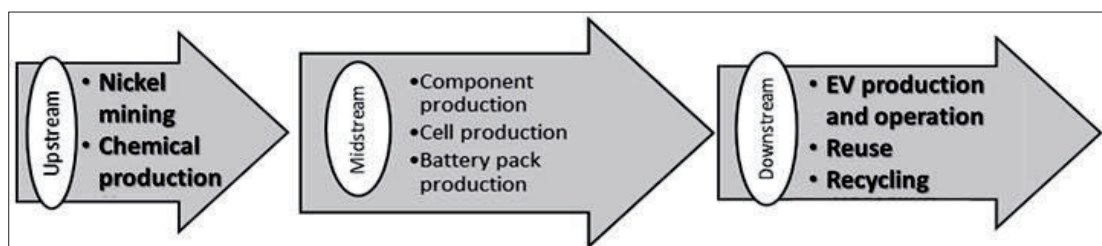


Figure 2. Battery's production chain: upstream, midstream, and downstream (Source: modified from IESR, 2023)

Next, several key components, such as cathodes, battery cell, and battery pack, are produced in the midstream value chain. There are several companies that produce EV batteries in Indonesia; for example, i) PT HLI Green Power (a collaboration company between the Hyundai Group and LG), which produces battery cells with a capacity of 10 GWh and an investment value of USD 1.1 billion, ii) PT International Chemical Industry (ABC) with a production capacity of 100 MWh per year and a total target production capacity of 256 MWh per year, equivalent to 25 million cells (Ministry of Industry, 2023), and iii) the Indonesian Battery Corporation (IBC) consortium, as an electric battery holding company and synergize the end-to-end EV battery value chain from upstream projects to battery derivative products (Tjahajana, 2021).

The production of EV batteries necessitates the presence of complementary industries, particularly those involved in the manufacturing of key raw materials like cathode, anode, and other related materials. Indonesian companies are already capable to produce raw materials for separators, such as porous polyethylene, as well as to produce anode and other components (Ramdhan et al., 2023). Likewise, R&D activities for developing the batteries along with the components have been carried out by several research institutions: PUI Lithium Batteries, UNS; the National Battery Research Institute; the Battery Research Group in Advanced Materials Research Center of BRIN; and others (Kartini & Drew, 2021).

The downstream value chain comprises EV production and operation, reuse dan recycling, as reflected in EV and battery industry development roadmap in Indonesia (2020–2030), in which the battery development consists of battery pack assembly, battery cells production, battery management system, battery material, and includes end-of-life (EOL) recycling at the downstream stage (Deloitte, 2022).

6) EV component supply

EV components, apart from the battery, consist of a traction motor, controller, inverter, steering system, wheels and axle, suspension, braking system, integrated vehicle computer, battery management system, and platform (frame, body, chassis). There are several companies that have developed electric motorbikes in the form of in-wheel motor, namely an electric motor that is directly installed in the wheel rim (velg). Since EVs do not require a combustion engine, gearbox, propeller shaft, cross joint, or exhaust gas system, their platform components or construction are typically almost identical to those of ICEV with relatively lower loads. Indonesian automotive suppliers are already able to provide parts for interior and exterior cars, braking and suspension systems, steering systems, and different electrical and electronic components that are the same as those used in ICEV (JICA, 2021).

R&D activities for the development of four-wheeled vehicle and bus components, such as traction motors, inverters, and several other EV components, have been carried out by domestic R&D institutions and universities, and have been incorporated in the National Research Priority Program (PRN) coordinated by the Ministry of Research and Technology (Yuniarto et al., 2016). In addition, domestic manufacturers also has the potential to produce parts intended for two-wheeled EV, including rolling chassis, electric motors, controllers, display and electronic systems, battery packs, battery management systems, bodywork, and accessories (Sudibyo et al., 2021). In estimation, the domestic production of these components accounts for 95% of total production cost, with the remaining expenses are 3% for labor and 2% for work facilities.

The state of knowledge and technology in Indonesia is depicted in Table 3.

Table 3. The state of EV knowledge and technology in Indonesia (Author's own elaboration)

Component	R &D	Manufacturing	Investment	Import
Battery	Battery development, (UNS, NBRI, BRIN)	Local: will be built (IBC consortium of MIND ID, PT Pertamina, PT PLN, dan PT Antam Tbk) Foreign/JV: production (PT HLI Green Power, PT International Chemical Industry)	Morowali Industrial Park and Virtue Dragon Nickel Industry Investment from several foreign companies, with values more than USD 1 million each (LG, CATL, Britishvolts, BASF, Foxconn)	
Other components	Development of traction motor, controller, inverter, steering system, wheels and axle, suspension, braking system, integrated vehicle computer, battery management system, and platform (before 2021) mastering key autonomous vehicle technologies, such as object/sensor detection systems, telecommunications systems, human-to-vehicle interaction, computer vision. etc (after 2021) (PRN Program, ITS, UNS, ITB, UI)	Provide parts for interior and exterior cars, braking and suspension systems, steering systems, and different electrical and electronic components that are the same as those used in ICEV (existing vehicle component supplier companies)		
Charging station	Construction of an efficient public EV charging station, (BPPT, LEN)	PLN builds charging stations with import components (PLN)		
Integration	Motorcycle: Gesits (ITS) Cars: Molina, Selo, Gendis, Evina, Tucuxi, Hevina, Maung Electric, Bimasena, Fin Komodo, Blits (EV production with predetermined domestic content requirements, environmentally friendly EV manufacturing that adheres to technical standards) (LIPI, BPPT, ITB, ITS, UNS, UI, Pindad) Bus: Molina, Merah-Putih (UI, ITB, UGM, UNS, ITS, INKA)	Local: Motorcycle: Gesits, Alva One, Selis, Smooth, Rakata, Elvindo, Eider, Nusa Khatulistiwa (some components are still imported) (WIMA, IMG, Juara Bike, TDI, SEI, Artas Rakata, Goodrich, Indo Jaya, REA, Nusa Motor) Cars: Ioniq 5, Air-EV, Gelora E (some components are imported, production domestically) (Hyundai, Wuling, DFSK) Bus: MD12E-NF, E-Inobus, (some components are still imported) (MABI, INKA) Foreign: Motorcycle: Cars: production of two distinct types of electric vehicles (EVs and BEVs) projected to 9,847 units by 2023 (Hyundai, Wuling) Bus: NJL6126BEV (PT KLI-Skywell)	Local investment Foreign investment (MM motors, Neta, Wuling, Hyundai)	BEVs (MB ESQ SUV, eC3, C40, EV6-GT, Mifa-9, Neta-V, ZS-EV) are imported from Japan, Germany, England, South Korea, and China (US\$3.89 billion) in 2022
Output	Pilot projects, patented inventions,	Battery, components, and electric vehicle	Value of investment	Number of imported electric vehicles

C. Demand

1) EV market demand

The EV sales in Indonesia has experienced significant growth, namely from 120 sold units in 2020 to 10,327 sold units in 2022. Based on data by Gaikindo (2023), approximately 19,384 electric cars were sold in Indonesia from 2020 to 2023. The EV market is primarily dominated by two car brands namely Hyundai from South Korea and Wuling from China, specifically with Hyundai Ioniq 5 Signature Extended model and Wuling Air EV Long Range. In addition, the Indonesian market offers various brands that are imported or built completely in Japan, Europe, and China. These brands have collectively sold 2,381 units as of September 2023 (Gaikindo, 2023).

The Indonesian government strongly supports the growth of EV through the Battery-Based Electric Motor Vehicle (KBLBB) program. This program offers various incentives, including sales price discounts, purchase tax exemptions, annual tax exemptions and reductions, as well as policies for exemption from odd-even traffic regulations. Additionally, the government is also focusing on the development of charging infrastructure for EV, as outlined in the Regulation of the President of the Republic of Indonesia No. 55/2019. The electric motorbike sales in Indonesia is projected to reach 25,782 units by 2022. Based on a projection by Deloitte and Foundry (2023), the number of electric motorbikes in Indonesia is expected to reach 13.5 million units by 2030, while the number of electric cars is projected to reach 2.2 million units by that period.

In addition, the future market for EV sales in Indonesia is considered highly potential due to the following factors: i) Indonesia, with its substantial population ranking fourth globally, exhibits significant potential in the EV market (Pandyaswargo et al., 2021; Utami et al., 2020); ii) Indonesia possesses a significant amount of natural resources that can be utilized as raw materials for batteries; iii) Indonesia's basic electricity tariff (TDL) is among the lowest globally, at 0.1 USD/kWh, which is considered a contributing factor to the uptake of EV (Veza et al., 2022).

2) Perception and adoption of EV

Several previous studies regarding public perceptions on the adoption of EVs in Indonesia reveals the following findings: i) Apparently, the Indonesian citizens still have limited interest in adopting EV as their daily transportation means; ii) The majority of them perceive that the price of EVs and EMs is still higher than ICEV; iii) The travel mileage of EV and EM are relatively shorter, which poses challenges for long-distance travel; iv) Currently, the number of public facilities for electric charging station in Indonesia are still limited, and v) The public still have doubts regarding the durability and reliability of EVs and EMs (Damayanti et al., 2020; Gunawan et al., 2022; Maghfiroh et al., 2021; Murtiningrum et al., 2022; Pandyaswargo et al., 2021; Veza et al., 2022).

In 2023, PwC consultants have mapped the adoption of electric vehicles (EV and EM) into everyday life (PwC Indonesia, 2023). Based on the survey, the majority of respondents (72%) view EVs and EMs as supplemental vehicles rather than as primary vehicles. According to the survey's results, the majority of participants (52%) said they will eventually adopt EVs and EMs due to their cheaper operating costs, technological features, and environmental friendliness. The primary obstacles to the widespread use of EVs, particularly plug-in hybrids (PHEVs), are their high retail price, long charging duration, and limited availability of charging stations (PwC Indonesia, 2023). The results of this survey are consistent with several previous studies, showing that in order to encourage public interest in adopting EV, there must also be a greater public understanding of EVs. This is particularly important when it comes to EVs, considering the majority of Indonesian consumers are actually able to access information from various sources, such as television, social media, and the internet (PwC Indonesia, 2023).

3) Public Electric Vehicle Charging Station (PEVCS)

EV has the potential to gain popularity as a substitute for other advanced technologies and to be developed into a necessary mode of

transportation in the long term. Miele et al. (2020) and Thompson et al. (2018) classified EV into three main types based on the power source: i) Battery Electric Vehicle (BEV), is a vehicle that runs solely on electricity and does not have internal combustion engines. BEVs also does not emit pollutants and can be charged quickly; ii) Hybrid Electric Vehicle (HEV), is a low-emission vehicle that combines an internal combustion system with an electric propulsion system. It uses both petrol and battery as its energy source, but it cannot be plugged in to charge the battery; and iii) Plug-in Hybrid Electric Vehicle (PHEV), is hybrid-like vehicle but has a bigger electric motor and battery. It can be plugged in to charge the battery since it has charging outlet.

Adoption of EV will be facilitated by PEVCS infrastructure, quantity, quality, and standards of connectors (ports) in order to meet the established standard (Miller et al., 2012). There are three charging methods for EV: conductive, inductive, and battery exchange. Currently, the Indonesian Government focuses on developing PEVCS based on conductive charging for electric cars. Conductive charging uses a charging cable as the direct connector between the power supply and the electric car (Sutopo et al., 2018). This method is more widely recommended owing to its large economic feasibility, ease of operation, faster charging duration, and better power efficiency (Mastoi et al., 2022; Setiawan et al., 2020). According to Mastoi et al. (2022), there are three types of electric car charging infrastructure: a) residential charging, b) work and public charging, and c) DC fast charging, which has the fastest charging duration.

The Indonesian Government has appointed PT. PLN—the largest state-owned electricity provider—to accelerate the preparation of EV infrastructure in Indonesia. Its designated mission is to provide reliable, easily accessible, and cost-effective EV charging station infrastructure in Indonesia (Amilia et al., 2022). Based on data from the MoEMR, the number of PEVCS in Indonesia was 842 units as of April 18, 2023, which spread across 388 locations domestically. Based on the type of charging technology, these PEVCSs are further grouped as follows: a) 32 units adopt ultra-fast charging technology; b) 91

units adopt fast charging technology; c) 267 units adopt medium charging technology; d) 162 units adopt medium-slow charging technology, and; e) 290 units adopt slow charging technology (The Regulation of the Minister of Energy and Mineral Resources No. 1/2023).

V. DISCUSSION: CHALLENGES IN CONNECTING THE SSI ELEMENTS OF EV INDUSTRY

This section explores the role of actors, agents, and intermediaries in structuring the interactions among three main elements, namely institutions, knowledge and technology, and demand, within the SSI model.

A. Institutions

Institutions are key elements that shape the interactions of the entire system. This study has identified six institutional factors that impact various components from the SSI perspective. *First*, fiscal supports from government to promote domestic EV investment, including the development of the entire value chain of battery industry. This policy has positively influenced the battery industry's growth, as evidenced by the establishment of the IBC consortium and the influx of international investments for the domestic EV development.

Moreover, several studies (Akbar, 2022; Gunawan & Nadir, 2022; Pirmana et al., 2023) underline the decision to impose restrictions on nickel exports as Indonesia's strategic movement as a means to enhance the value-added aspect of domestic commodities and foster national economic development. Although, it is worth noting that concrete outcomes of this policy have yet to materialise. Nevertheless, it is crucial to underscore the importance of considering various factors to guarantee such success, particularly in enhancing human resource capability, maintaining policy and programme consistency despite shifts in political and leadership dynamics, and fostering coherence between central and regional governments in policy formulation (Akbar, 2022). However, Indonesia should diversify its focus beyond nickel-based batteries and explore other potential natural resources which will allow for

the identification of cost reduction opportunities in battery production (Pandyaswargo et al., 2021).

Second, the government fiscal policy that aim to foster domestic R&D capacities by generating EV inventions and innovations. Currently, the only identifiable governmental policy is super tax deduction. This policy has been implemented in various countries to promote R&D and foster collaboration among industries and universities (Makeeva et al., 2019). However, to this day, no study has been conducted to assess the efficacy of this policy pertaining to Indonesia EV program. *Third*, the domestic components utilization program has been intended to decrease the reliance on imported components. While there is flexibility in importing EV as IKD, CKD, or CBU form, the government also imposes DCL targets for EV industry. However, the DCL is currently a subject of debate as Indonesia is conducting several ongoing preparations for the transition to EVs (Krisnowo et al., 2020). *Fourth*, the readiness of domestic component industries is crucial to support domestic EV production and diminishing competitiveness due to inefficiencies of EV supply chain. However, the level of readiness is still low.

Fifth, the availability of electricity charging facilities to boost the growth of market demand. The government has enacted policies pertaining to the establishment of electricity charging infrastructure. PT. PLN—due to its economically significant role in providing the domestic electricity—has been designated as the initial provider of PEVCS, in partnership with third parties. PT. PLN also offers various benefits and discounts for public and private electricity charging infrastructure. The majority distribution of PEVCS in the Java region (Ministry of Energy and Mineral Resources, 2023) is considered sufficient due to the concentrated demand growth in this region. *Sixth*, the consumers' responses towards user incentive policies. The government has implemented policies on this matter, one of which involves providing tax incentives for consumers, resulting in significant EV price reductions of up to IDR 70 million. Nonetheless, despite substantial price reductions, the base price of EV is still more expensive. Therefore, the electric car prices in Indonesia still remain uncompetitive compared

to ICEVs, which have been more favored (Tan et al., 2023). Moreover, the Indonesian citizens still possess relatively lower level of understanding—compared to citizens in developed countries like Europe and Japan—about the advantages of EVs over ICEVs, and the potentially long-term favorable impact of EVs on the environment (Tan et al., 2023).

Indonesia and other ASEAN countries exhibit a relatively slower tendency towards endorsing EV in comparison to countries like China (Schröder et al., 2021). Therefore, Indonesia has implemented similar policies to those implemented by pioneering countries in EV transformation. This includes attractive policies for EV adoption through purchase incentives as implemented in several European countries and China; incentives related to charging facilities as implemented in China and Korea; and provision of several privileges to EV owners as implemented in China (Maghfiroh et al., 2021). Indonesia and Thailand, also adopts comparable corporate tax exemption to encourage investment (Schröder et al., 2021). However, it is noteworthy that Thailand offers an additional tax exemption specifically targeted towards domestic manufacturing investment of EV essential components (Schröder et al., 2021).

B. Knowledge and technology

Indonesia's EV manufacturing capabilities are influenced by several factors, such as the capabilities to develop EV industry domestically, the availability of batteries and components, and the presence of appropriate ecosystem. Despite the initiation of R&D activities and EV engineering endeavors by research institutions and universities over a decade ago, domestic EV development is still declared unsatisfactory to proceed towards commercialization stage. This is mainly caused by several key factors as follows.

First, the quality and capability of domestic EV is still unable to meet the established standards. As a consequence, it has caused the continuous dominance of foreign actors in this sector, such as from South Korea and China. In addition, the domestic component companies are currently not yet ready to directly serve as suppliers of EV components.

Second, foreign manufacturers that provide the battery and other main components are currently still the significant players in the EV industry in Indonesia. EV production relies heavily on imported battery supplies due to the limited availability of domestic battery manufacturers. The majority of other electric vehicle components, including traction motors, controllers, inverters, and various others, are also imported.

Third, various attempts to attract potential investors in order to encourage domestic EV development still have not generated satisfactory results. Nonetheless, it cannot be denied that several investors have invested in various sectors related to the EV field, for example PT. MABI for commercial bus development, PT. PLN for charging stations, and IBC for battery materials (Nikkei Asia, 2023).

C. Demand

The following several factors within the demand aspect influence the ecosystem involving the interactions among producers, consumers, corporations, and the government sector.

First, the distributor service provided by the EV manufacturer (i.e Hyundai and Wuling), including battery guarantee and regular maintenance services at authorized workshops. This factor has successfully boosted public demand for electric cars in Indonesia, resulting in increased sales of both CKD and CBU form. *Second*, the distributor's level of aggressiveness plays a crucial role in enhancing the public adoption. Based on a survey by PwC Indonesia (2023), EV manufacturers have extensively utilized websites and social media platforms for EV promotion.

Third, the consumers' responses towards government incentives. Despite the ease through the provision of sales tax and annual tax discounts, EV are still perceived by the public as having a high selling price (Damayanti et al., 2020; Maghfiroh et al., 2021; Veza et al., 2022). However, the PwC's survey also revealed that the Indonesian citizens are increasingly considering EV as supplementary modes of transportation as the second or the third car. Hence, the current issue that necessitates particular attention is how to increase the demand from upper-class society

who consider purchasing a vehicle for supplementary needs. Rogers (2003), using the diffusion of innovations perspective, suggested that the experience of the early adopters, represented by the middle-class and upper-class society, can significantly contribute to foster a favorable public perception of EV.

Fourth, the public demand expectation factor is crucial for EV manufacturers to promote greater market penetration. The government can foster collaboration in technological development especially in battery development to reduce the cost of EV.

Fifth, the accessibility for electric charging infrastructure, which is currently limited, may lead to public hesitation on EV adoption. EV electric charging infrastructures are currently limited to urban regions in Java Island (Ministry of Energy and Mineral Resources, 2023). Therefore, to gain a greater market penetration, the government through PT.PLN, in collaboration with other corporations, must construct more PE-VCS that are easily accessible, affordable, faster, and comfortable (Haryadi et al., 2023). Finally, *sixth*, the realization of Indonesia's goal to be a prominent EV hub in the ASEAN region has been hindered by insufficient investor participation.

Finally, from above discussion, we found eight challenges and they can be summarized as follows: i) The institutions exhibit a commendable level to determine the extent of design and comprehensiveness, but challenges persist in the implementation process; ii) The current state of knowledge and technology is centered around capital investment, with few opportunities for technology transfer and assimilation. iii) The market demand has significant potential, which mostly centered within major urban regions that offer comprehensive support infrastructure.

In addition, the role of actors in connecting elements in the SSI model is categorized as follows: i) actors that have performed as connectors to make the interaction among various elements in the SSI run accordingly, and: ii) actors that have *not yet* performed as connectors to make the interaction among various elements in the SSI run accordingly. The connection of each actor and each element in structuring the SSI as whole interaction is depicted in figure 3. In the figure,

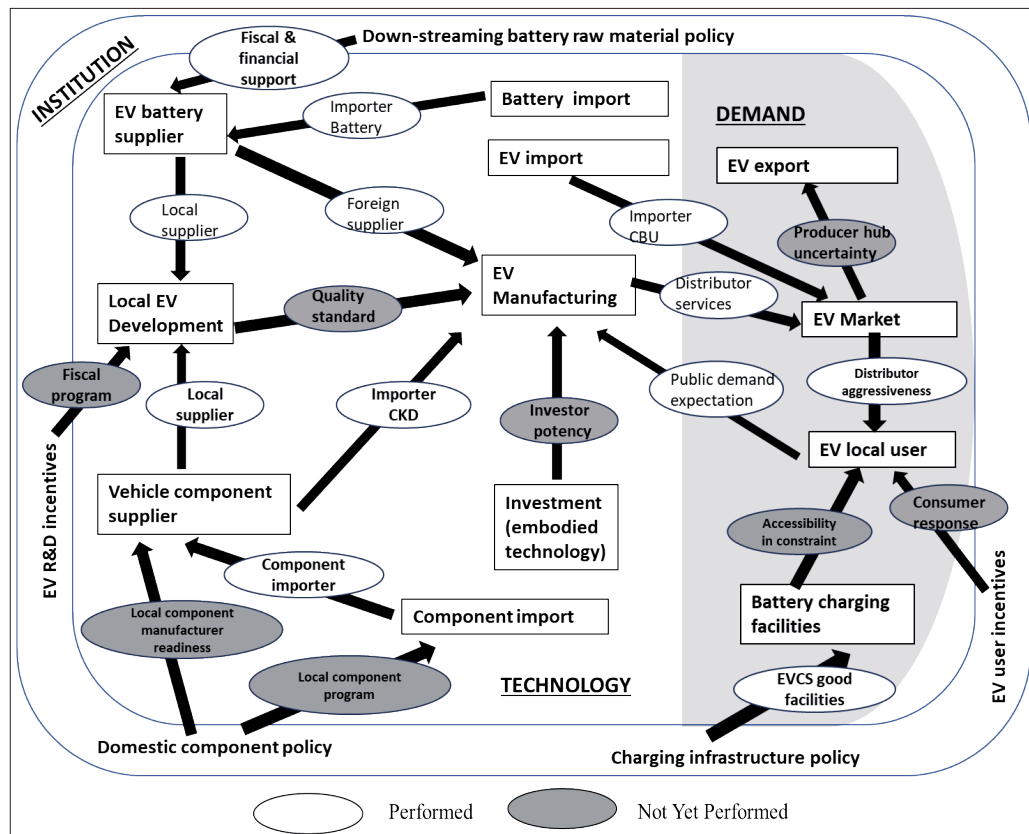


Figure 3. Challenges in connecting the SSI elements with the development of EV industry

the challenges that are found are shaded in darker color.

VI. CONCLUSION

There are eight challenges in connecting the elements of SSI for developing EV industry in Indonesia. First, in the context of the institutional aspect, we have found several issues pertaining to 1) the fiscal incentives programs which is still not effective in facilitating industry engagement with universities and R&D institutions for fostering EV innovation; 2) the fulfilment of DCL, which remains challenging; 3) the unreadiness of the domestic industry to participate in EV supply chain; and 4) the level of public's responses towards EV incentives, which remains insignificant. Next, in the context of knowledge and technological aspects, our findings reveal that 1) the quality and standards of domestic R&D efforts are still declared unsatisfactory to proceed towards commercialization stage; and 2) the domestic EV development still has not generated favorable outcomes in terms of attracting potential investors.

Finally, in the context of demand aspect, it is noteworthy that 1) the realization of Indonesia's goal to be a prominent EV hub in the ASEAN region has been hindered by inadequate investor participation; and 2) the limited accessibility of PEVCS is a significant obstacle to facilitate the growth of the domestic EV market.

This study relies primarily on desk research, wherein a significant reliance is placed on the acquisition of existing supporting documents. Thus, explaining the composition of SSI elements may lead to the lack of explanatory details about occurrences that empirical research could better explain. Furthermore, while the SSI framework has the capability to provide a thorough overview of the EV sector, there is a need for further exploration on the underlying relationships and interactions of elements of the system.

We propose potential research areas, specifically the necessity to conduct empirical investigations regarding the practical functions of SSI, with particular emphasis on two aspects: domestic EV and battery companies, and EV users experience.

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