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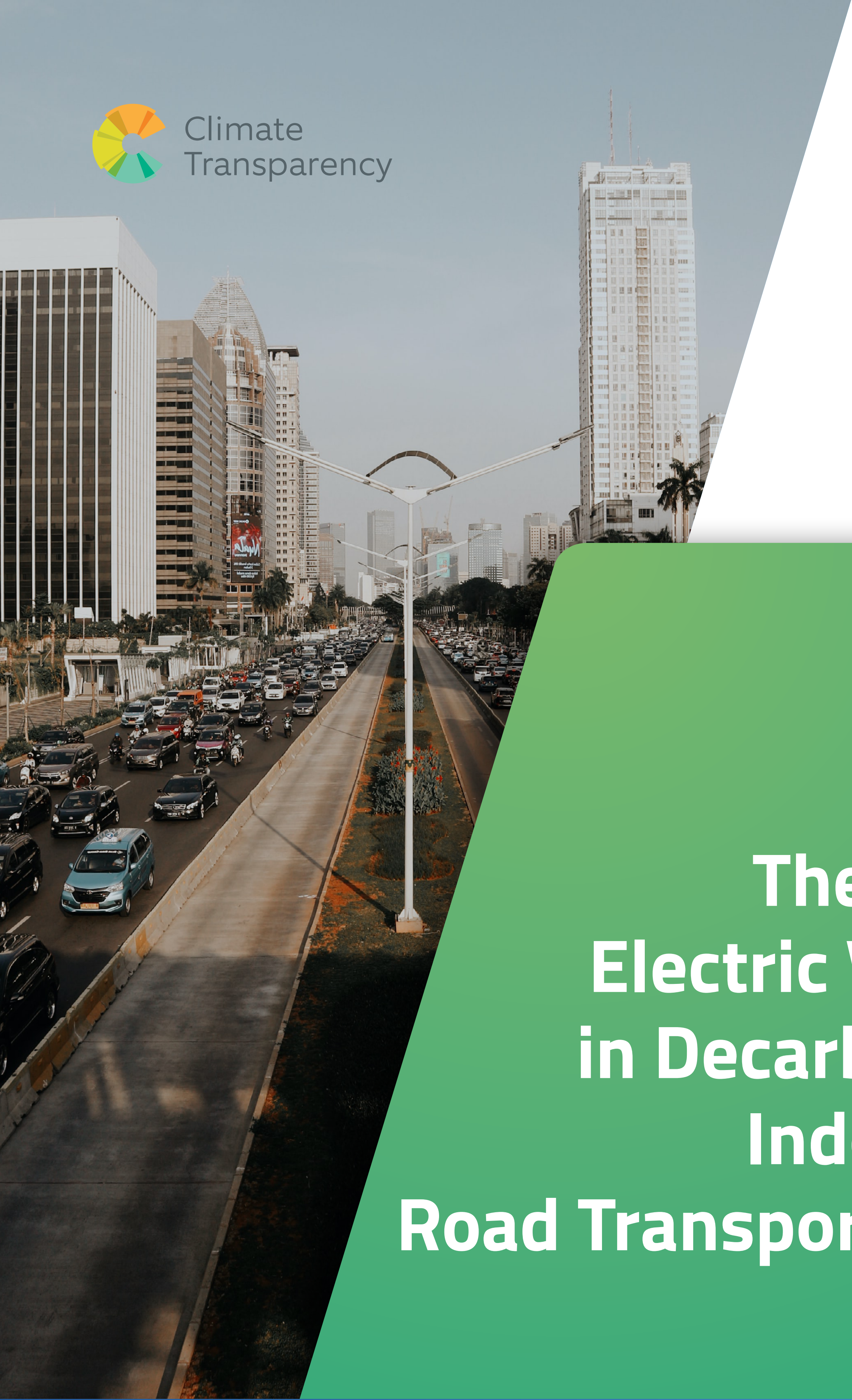

The Role of Electric Vehicles in Decarbonizing Indonesia's Road Transport Sector

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Foreword

Readers, IESR proudly presents our new report: The role of electric vehicles in decarbonizing Indonesia's road transport sector. This report has two objectives. Firstly, to evaluate existing policy and regulatory framework on the development of electric vehicles in Indonesia; secondly, to find the impact of electric vehicles penetration in GHGs emissions reduction to increase Indonesia's climate ambition to meet the Paris Agreement's goals.

Indonesia's government has pledged to reduce its GHG emissions in order to contribute to meet the Paris Agreement's goal in keeping the temperature below 2^{o}C and to reach 1.5^{o}C. In 2019, the transport sector contributes around one-third from total GHG emission in Indonesia. It is projected under business as usual that the emission will increase dramatically. Current Indonesia NDC lacks mitigation action from the transport sector. The measures so far are to increase the use of biofuel and natural gas to substitute petroleum. However, many studies suggested that the use of electric vehicles should become a key strategy to reduce GHG emissions from this sector.

Few countries have shown quite a remarkable growth in the electric vehicle market, such as Norway, Sweden, the United States, China, etc. Many more countries have announced their intention to electrify their transport system, including banning conventional vehicles in 10-20 years from now. Indonesia has just started to move into the deployment of electric vehicles. Last year, the government of Indonesia stipulated the Presidential Regulation that aims to accelerate electric vehicle deployment. However, this regulation alone is not sufficient. Without right and consistent policies, transparent planning and target, inter-sectoral coordination and incentives, it will be hard for Indonesia electric vehicle market to take-off.

Against this background, we build a model to project the electric vehicle market in Indonesia under different sets of policy instruments. The model focuses only on private passenger vehicles, i.e motorcycles and cars. These two types of vehicles now dominate Indonesia's motorized vehicle market. Furthermore, based on the projection, we analyzes the impact of electrification of transport on Indonesia's GHG emission reduction and the potential of electric vehicles to be included in the NDC.

IESR would like to thank to Humboldt Viadrina Governance Platform for their excellent coordination and assistance for this project, all Climate Transparency's partners for excellent discussion and ideas for this thematic paper, and to all reviewers for their excellent feedback and input to improve this report.

We expect this study can provide direction for policy makers to explore suitable policy instruments to facilitate deployment of electric vehicles technologies and to build the electric vehicle market in Indonesia, as well as to maximize its potential to contribute to climate mitigation ambition.

Jakarta, 29 March 2020

Fabby Tumiwa
Executive Director

Abbreviation

APBN	State Income and Budget Allocation
BAU	Business as Usual
BAPPENAS	Ministry of National Development Planning
BEV	Battery Electric Vehicle
BNEF	Bloomberg New Energy Finance
BRT	Bus Rapid Transit
CAGR	Compound Annual Growth Rate
CAFE	Corporate Average Fuel Economy
CAT	Climate Action Tracker
CO_2 / CO_2-e	Carbon Dioxide / Carbon Dioxide equivalent
CMEA	Coordinating Ministry of Economic Affairs
ECU	Electronic Control Unit
EIA	US Energy Information Administration
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FCEV	Fuel Cell Electric Vehicle
gCO_2	Gram of Carbon Dioxide
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emission
GW	Gigawatt
HEV	Hybrid Electric Vehicle
HOV	High Occupancy Vehicle
IC	Integrated Circuit
ICCT	The International Council on Clean Transportation
ICEV	Internal Combustion Engine Vehicle
IDR	Indonesian Rupiah
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
km	kilometer
kWh	kilowatt hour
LCEV	Low Carbon Emission Vehicle
LCGC	Low Cost Green Car
Lge	Liter of gasoline equivalent
LULUCF	Land Use, Land-Use Change, and Forestry
MASKEEI	Indonesia Energy Conservation and Efficiency Society

MBOE : Million Barrels of Oil Equivalent

MEMR : Ministry of Energy and Mineral Resources

MoEF : Ministry of Environment and Forestry

MoF : Ministry of Finance

MoHA : Ministry of Home Affairs

MoI : Ministry of Industry

MoT : Ministry of Transportation

MPWH : Ministry of Public Works and Housing

MPV : Multi-purpose Vehicle

MSOE : Ministry of State-Owned Enterprise

$MtCO_2$: Million Ton of Carbon Dioxide

MW : Megawatt

MWh : Megawatt per Hour

NDC : Nationally Determined Contribution

NMNL : Nested Multinomial Logit

PHEV : Plug-in Hybrid Electric Vehicle

PLN : State-Owned Electricity Company

ppm : Parts per million

RENSTRA : Strategic Plan

RKP : Government Work Plan

RON : Research Octane Number

RPJMN : National Mid-Term Development Plan

RUEN : General Planning of National Energy

RUPTL : General Planning of Electricity Supply

R&D : Research and Development

SUV : Sport Utility Vehicle

TCO : Total Cost of Ownership

TOU : Time-of-Use

TWh : Terawatt Hour

US : United States

USD : United States Dollar

VAT : Value Added Tax

VRI : Vehicles to Refueling Stations Ratio

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Executive Summary

In Indonesia, the transport sector contributed 28% of energy-related greenhouse gas (GHG) emissions in 2018, mostly from road transport. Unfortunately, the mitigation plan in this sector is currently limited to biofuel blending. The adoption of electric vehicles (EVs) has been viewed by many as an important strategy to reduce emissions in the transport sector. This study has been conducted by the Institute for Essential Services Reform (IESR), to provide an assessment of GHG emissions reduction potential in the transport sector through increased penetration of EVs in Indonesia and of the tools required to realize this potential. A nested multinomial logit model is used to project the EV penetration in different policy scenarios. The effect of various policy instruments on EV penetration are evaluated using the model.

In 2018, transport contributed 45% of the final energy consumption. About 94% of this energy consumption comes from petroleum fuel combustion. Mobility in Indonesia is dominated by road transport, with 90% of passenger and freight transport served by this mode. Within road transport, private passenger vehicles (motorcycles and cars) dominate the fleet. Given the growth of motorcycles and cars, there is an opportunity to GHG reduce emission through electric vehicles adoption in these modes.

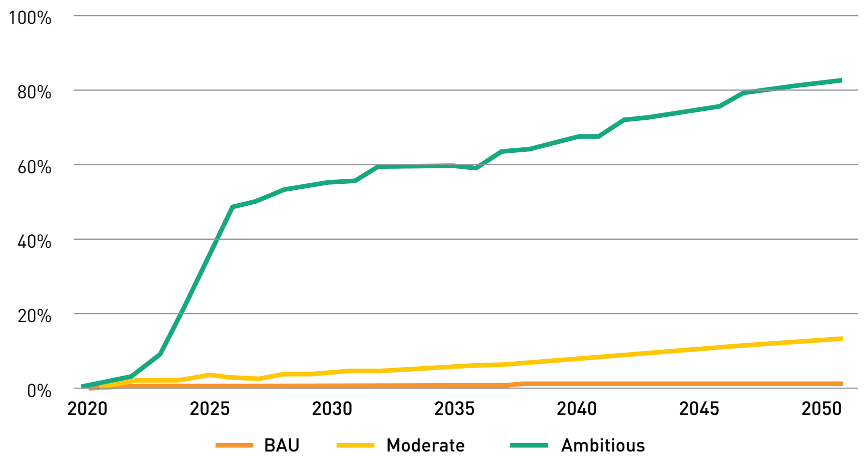
Many countries have experienced high penetration rates of EVs and provide others with examples of policy instruments that are important in driving the adoption, especially through demand-side policy instruments. These instruments can be categorized into one-time fiscal incentives (e.g. tax exemptions, carbon cost to vehicle price); recurring fiscal incentives (e.g. carbon price as fuel tax, dynamic electricity tariff for EV charging); regulatory incentives (e.g. mandatory fuel economy, exhaust gas standards); and non-financial incentives (e.g. charging infrastructure development, access to special lanes, road toll exemptions, free parking, and access to low-emission zones).

This study simulates the implementation of several demand-side policy instruments and evaluates their impacts on EV penetration in Indonesia. The EV penetration is modelled using a nested multinomial logit model. This model estimates the market share of each vehicle technology based on consumers' preference and technology diffusion characteristics of a disruptive technology. For passenger cars, the technology options are conventional cars (ICEV), low-cost green cars (LCGC), hybrid cars (HEV), plug-in hybrid cars (PHEV), and battery electric cars (BEV). For motorcycles, there are only two options: conventional and electric motorcycles.

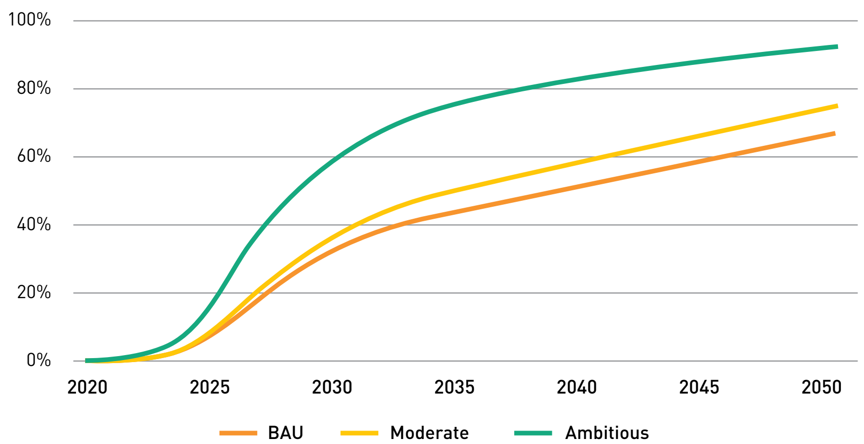
This study evaluates the EV market share in three policy scenarios. In each scenario, five policy instruments are applied with different values: tax incentives, fuel quality standard, carbon price on fuel, charging infrastructure provision, and dynamic electricity pricing. The "business-as-usual" (BAU) scenario simulates market share if the current policies and trends continue until 2050. The moderate scenario introduces some policy interventions with a rather conservative value (mostly policies that are already in the government's pipeline). Under the ambitious scenario, the chosen policy instruments are being implemented aggressively.

The model simulation of those three scenarios is presented in the figures below. The

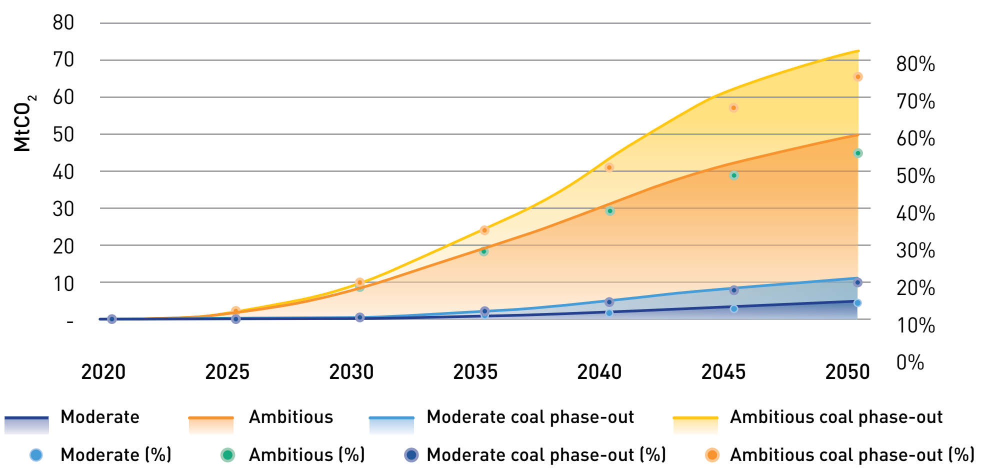
Electric vehicle penetration in different scenarios



Electric motorcycle penetration in different scenarios



CO_2 emission reduction through passenger EV penetration in different scenarios



simulation indicates that tax incentives and availability of public charging infrastructure are the most important instruments for pushing up EV penetration. For the passenger cars market, tax incentives play the major role, without which the adoption of EV will not exceed 1% by 2050. For the motorcycles market, public charging provision is the more influential instrument to accelerate EV penetration. In addition, the simulation shows that the current incentives planned by the government are not sufficient to increase EV penetration significantly.

In terms of GHG emissions reduction, the impact of EV penetration is more significant in the long run (after 2030) as shown in the figure below. Even under the ambitious scenario, only 9 to 10 $MtCO_2$ will be avoided in 2030, compared to 30 to 40 $MtCO_2$ in 2040, and 50 to 70 $MtCO_2$ in 2050. To accelerate the GHG emissions reduction, it will be necessary to ban conventional vehicle sales by 2035. The GHG emissions reduction is also more significant when complemented with the decarbonization of the power generation mix, through a coal phase-out policy that replaces coal power plants with renewables.

In conclusion, the study recommends several policy interventions to be adopted to foster EV growth in Indonesia:

- Increasing **public charging** infrastructure investment, both by public and private funds.
- Transforming the **taxation scheme** into one based on tailpipe CO_2 and pollutant emissions.
- Providing **purchase incentives** that can create EV competitiveness, e.g. tax exemption.
- Providing **non-financial incentives** for EV users, such as road toll exemptions, free parking, allowance to use bus lanes, exemption from odd-even policy, and establishment of low-emission zones.
- Creating an initial market through **public procurement of EVs** such as for public buses and official vehicles for government officials.
- **Increasing the fuel price** through fuel quality standard improvement and implementation of a carbon price.
- Establishing a **mandatory fuel economy standard** to reduce transport emissions while EVs are not yet competitive.
- Putting a **ban on internal combustion engine (ICE) vehicles** sales by 2035.
- **Increasing renewable energy** and reducing coal consumption in electricity generation.
- Introducing **different electricity tariffs** for peak and off-peak periods.

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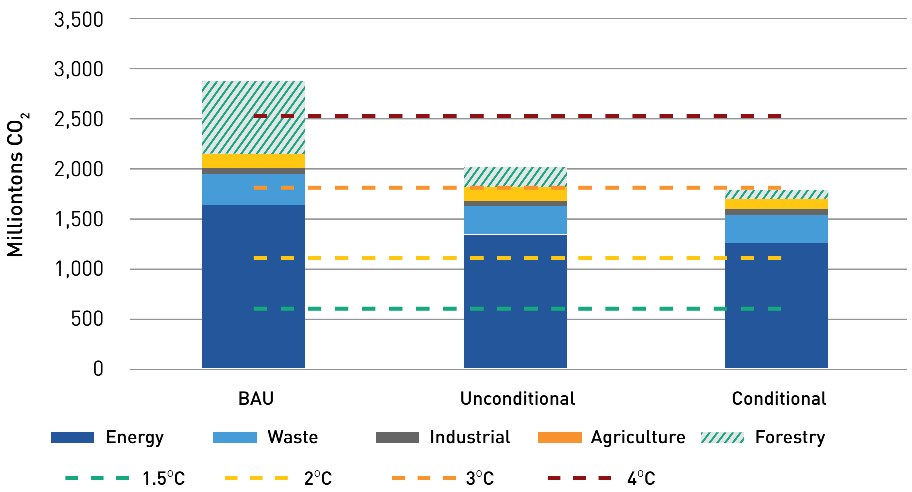
1. Introduction

Indonesia has pledged to reduce its greenhouse gas (GHG) emissions by 29%, unconditionally, against the “business-as-usual” (BAU) scenario, and up to 41% with international support by 2030 as stated in its Nationally Determined Contribution (NDC). However, this target is deemed to be “highly insufficient” by Climate Action Tracker (CAT)[1] as depicted in Figure 1. This is because it allows Indonesia to emit 1,817 MtCO_2e/year and 1,629 MtCO_2e/year to comply with the 29% and 41% reduction pledge respectively; this would be in line with a global temperature increase of 3°C to 4°C (Climate Action Tracker, 2019a). This target is much higher than the maximum emissions of 622 MtCO_2e/year required to meet the 1.5°C pathway. Consequently, to be in line with the 1.5°C pathway, Indonesia needs a more ambitious emissions reduction plan and effort.

In Indonesia, the transport sector contributes 28% of national energy-related GHG emissions (Climate Transparency, 2019). The highest emissions come from road transport (mainly cars and motorcycles), which accounts for 85% of total emissions in the sector (Setiawan et al., 2019). With car ownership increasing in Indonesia, the transport sector is predicted to continue as one of the main emitters in the country (Erahman et al., 2019). Under its current pledge in NDC, the Indonesian government has, however, limited

1 Climate Action Tracker is an independent scientific assessment that tracks countries’ NDCs and climate actions, and then measures these against the target set in the Paris Agreement. The methodology used by CAT does not take into account emissions from LULUCF, mainly because it wants to highlight the importance of decreasing emissions from industry, agriculture, fossil fuel combustion and waste sources.

Figure 1. Indonesia's GHG emissions in 2030 based on NDC target, and CAT's allowed emissions in 2030 for each temperature increase scenario[2]



Source: Authors' own, based on data from Climate Action Tracker (2019a) and Government of Republic of Indonesia (2016)

the mitigation plan for the transport sector only to fuel-shifting to biofuel and expansion of natural gas refuelling stations (Government of Republic of Indonesia, 2016). Meanwhile, the role of electric vehicles (EVs) (including hybrid, plug-in hybrid, and battery electric vehicles), which many see as key to reducing GHG emissions in the sector (Agora Verkehrswende, 2017; IEA, 2017), is still missing from Indonesia's NDC.

The Climate Action Tracker outlined a 1.5°C compatible scenario for Indonesia which curbs the emissions from the transport sector to 2 $MtCO_2e$ by 2050. This scenario includes an increase in public transport use, fuel economy improvement of conventional vehicles, and 100% electrification of passenger road vehicles (cars, motorcycles, and buses) by 2050. To achieve 100% electrification by 2050, Indonesia needs to stop selling fossil-fueled vehicles between 2035 and 2040, assuming vehicles have a lifetime of 15 years (Climate Action Tracker, 2019b). Other studies also reported that EVs can provide an important contribution in emission reduction efforts (EEA (European Environment Agency), 2018; IEA, 2019b; Qiao & Lee, 2019). As the current market penetration of EVs in Indonesia is virtually zero, it is necessary to establish a supportive policy framework and instruments to accelerate EV adoption.

This study aims to assess the GHG emissions reduction potential in the transport sector through increased penetration of EVs in Indonesia and how this can be achieved. It provides a projection of electric passenger vehicles (cars and motorcycles) penetration with several policy alternatives. The projection is based on a model developed by the Institute for Essential Services Reform (IESR) that captures consumer preferences on cars and motorcycles (see Appendix A for more details), thus, it focuses on the demand-side driver of market penetration. The implications of EV penetration on the power sector, oil consumption and domestic automotive industry will also be discussed.

2 Emissions from forestry are put in stripes since these are not included in CAT's calculation of allowable emissions.

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2. Overview of the transport sector in Indonesia

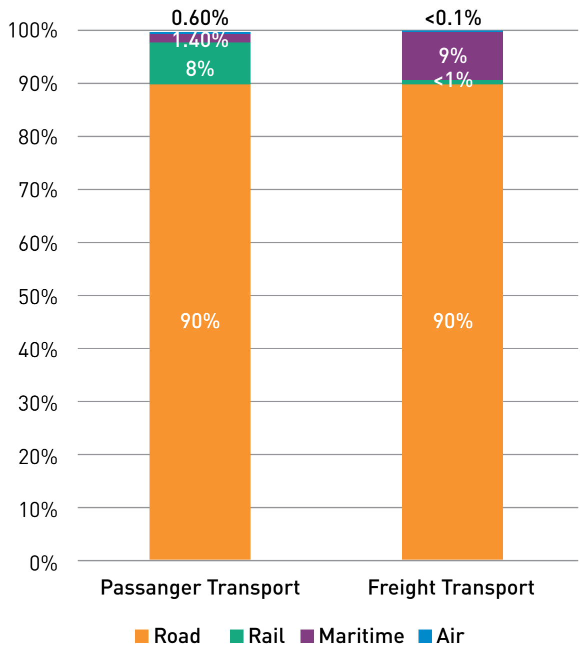
2.1. General overview

As an archipelagic country, Indonesia depends on air and maritime transport systems to connect one island to another. However, the land transport system (road and rail) dominates the means of mobility for people and goods. The modal shares for both passenger and freight transport, are depicted in Figure 2.

The increasing demand for mobility contributes significantly to energy consumption and GHG emissions. Since 2012, the transport sector has been the highest final energy consumer, replacing the industrial sector. In 2018, transport contributed 45% of final energy consumption. Almost all the energy consumed in the transport sector comes from petroleum oil; only about 5% comes from biofuel and less than 1% from natural gas and electricity (Ministry of Energy and Mineral Resources Republic of Indonesia, 2018).

The energy consumption in the transport sector grew by 5.9% Compound Annual Growth

Figure 2. Passenger and freight transport modal shares



Source: Authors' own, based on data from Asian Development Bank (2012)

Rate (CAGR) from 2000 to 2018 (Ministry of Energy and Mineral Resources Republic of Indonesia, 2018). It is expected to grow by 5.2% annually until 2040 under the BAU policy (Malik, 2016), leading to more GHG emissions. The General Planning of National Energy (RUEN) projected that GHG emissions from the transport sector will increase from 143 $MtCO_2e$ in 2015 to 218 $MtCO_2e$ in 2030 and to 394 $MtCO_2e$ in 2050. According to the latest data from the Ministry of Environment and Forestry (MoEF), in 2017 transport emitted 147 $MtCO_2e$, contributing 26% of the total GHG emissions from the energy sector. Land transport contributes to 90.8% of these transport emissions (emissions from rail transport are negligible), followed by aviation (9.1%), and sea transport (0.1%) (Ministry of Environment and Forestry, 2019).

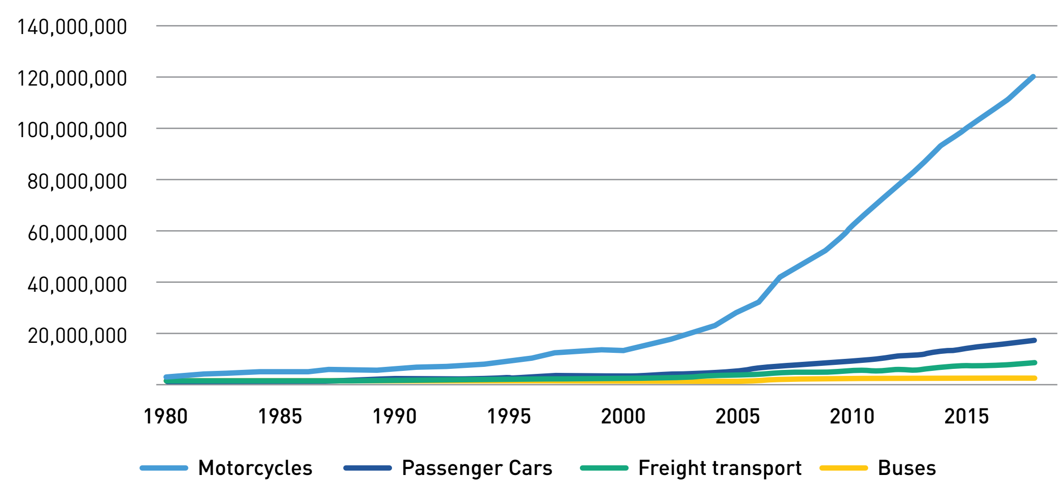
The road transport system, the main emitter within land transport, comprises cars (11%), motorcycles (82%), buses (1.7%) and freight transport (5.3%). From 2000 to 2018, motorcycles had grown the fastest by 13.7% CAGR, followed by passenger cars by 10.3%, while buses and freight vehicles grew at a slower rate at 8.6% and 9.3% respectively (Badan Pusat Statistik, n.d.). By 2018, there were 120 million motorcycles and 16 million passenger cars registered; in other words, 450 and 60 motorcycles and passenger cars owned per 1,000 citizens (see Figure 3).

Passenger cars are the main cause of high CO_2 emissions in the road transport sector (Erahman et al., 2019). Moreover, as can be seen from the figure, the high number of cars and motorcycles in the road transport sector justifies the need to address passenger vehicles as one of the main contributors of carbon emissions in Indonesia's transport system. Given the growth of the transport sector, there is an opportunity to build cleaner and more sustainable road transport systems to avoid a significant amount of future GHG emissions.

2.2. Policy, legal and institutional frameworks

Transport policies in Indonesia are formed through complex political and institutional processes within central government. Central government ministries and departments have their own agendas and responsibilities which often create confusion on how to structure planning overall. Transport planning and policy-making involves multiple government agencies, especially at the central government level. However, coordination between the entities is lacking; and moreover, since the decentralisation era (during the 2000s), poor coordination between local government and central government also occurred. For example, if central government devised a plan to introduce toll roads as a solution to congestion in urban regions, this could collide with the infrastructure

Figure 3. Total registered motorized vehicle units (1980 – 2018)



Source: authors' own based on data from Badan Pusat Statistik (n.d) projects already planned within those regions. Local resistance would therefore hinder such projects. As a result, policy planning processes can be scattered and unfocused (Wijaya & Imran, 2019).

The overall planning processes are led by the National Development Planning Agency (BAPPENAS), in direct coordination with the Ministry of Transportation (MoT) and the Ministry of Public Works and Housing (MPWH). The Ministry of Transportation is responsible for national transport policy that provides guidelines for local governments. Within this ministry, the responsibilities are divided between different directorate generals: rail transport, road transport, sea transport and air transport. Various government agencies are directly linked to the transport sector in Indonesia. In Table 1, the different roles and responsibilities from various related agencies are compiled.

Following the division of roles across these ministries, the transport policy framework trickles down from long-term national development targets outlined in the National Medium-Term Development Plan (RPJMN). These targets are set based on the national objective for improving physical and institutional connectivity in the transport sector, and they are authorized by BAPPENAS (ADB, 2016). These targets then serve as a basis for subsequent national planning documents,

Table 1. Roles and responsibilities of different government ministries in the transport sector

Ministry	Role and Responsibility
Ministry of National Development Planning (BAPPENAS)	Construct national development planning, including transport sector
Ministry of Transport (MoT)	Construct national transport policy and manage public transport infrastructure operation
Ministry of State-Owned Enterprise (MSOE)	Manage the national transport infrastructure and operation of public transport services; administer state-owned enterprises, like toll roads and rail
Ministry of Public Works and Housing (MPWH)	Prepare policy for development of national road and bridges network
Ministry for the Environment and Forestry (MoEF)	Prepare national policy for pollution control and environmental impact management of transport sector
Ministry of Home Affairs (MoHA)	Regulate development programs at sub-national level (provincial, city and regency) including for local transport
Ministry for Economic Affairs (CMEA)	Develop national economic and fiscal policy, including for the transport sector; provide economic policies for urban transport proposed by different ministries
Ministry of Finance (MoF)	Prepare state budgeting, including for road and public transport infrastructure
Ministry of Energy and Mineral Resources (MEMR)	Develop energy planning and supply, including for the transport sector

Source: Wijaya & Imran, 2019

which include the government's work plan (RKP), strategic plans (RENSTRA) of the Ministry of Transport and the Ministry of Public Works and Housing, and national budget allocation (APBN). These documents function as foundations and guidelines for the collective effort to achieve the national objectives. The ministries then formulate public policy on transport development in each transport system. In the maritime sector, as described in RENSTRA, several strategies are adopted to increase access to sea transport infrastructure, to improve efficiency of transport technology to anticipate climate change, to enhance marine infrastructure capacity, and other aims. In the road sector, policies are geared towards improving the national road network and increasing cost efficiency among other goals. Other transport systems have their own goals and sets of strategies (ADB, 2016).

While decision-making in the transport sector relies heavily on central and local governments, some non-governmental and international organizations also contribute to shape the policy debates by raising issues related to the transport sector. For example, climate change mitigation issues had been brought up multiple times before and as a result, several alternatives to mitigate the impacts had been considered, of which development of Bus Rapid Transit (BRT) emerged as the popular solution for the urban transport sector (Wijaya & Imran, 2019). As one of the alternatives for mitigating the impact of climate change, EVs could also be integrated into national transport policy. However, producing a formulated policy in the transport sector involves many complexities.

As presented in Table 1, the structure and division of roles between the ministries create several overlapping interests. Coordination between BAPPENAS, the MoEF, and the MoF has proved difficult (Wijaya & Imran, 2019). A closer look at the transport sector in Indonesia reveals that several problems still exist. These include long-neglected policy and institutional reforms, the lack of one integrated plan for all transport modes and regions,[3] insufficient road transport infrastructure (especially for urban public transport such as BRT), and a severe urban mobility crisis (Hang Leung, 2016). These problems breed inefficiency and pollution.

The National Action Plan for GHG Reduction (RAN-GRK) serves as the formal plan for national efforts to reduce emissions, including in the transport sector. Based on this document, several action plans for the transport sector are proposed, like reforming the BRT system, non-motorized transport development, public transport fleet rejuvenation, and other measures. Essentially, the overall plan for the transport sector internalizes a new paradigm, that is the "avoid-shift-improve" approach. "Avoid" means reducing travel needs in general. "Shift" means converting private vehicles to environmentally friendly public transport. "Improve" means increasing the energy efficiency of vehicle technology (Sukarno et al., 2016). As a potential solution, EVs present an opportunity through the "improve" approach by significantly increasing the energy efficiency of vehicles, therefore reducing carbon intensity.

Regarding the target of EV penetration in Indonesia, there are some national documents that state different outcomes. 2017 RUEN foresees 2,200 electric passenger cars and 2.1 million electric motorcycles on the road by 2025. However, these numbers are deemed not ambitious enough to achieve the climate targets.

On the other hand, the Ministry of Industry has a draft roadmap of February 2020 that targets the production of low-emission vehicles (LCEV). This list includes different types of electric vehicles: BEV (battery electric vehicle), PHEV (plug-in hybrid electric vehicle), HEV (hybrid electric vehicle), and FCEV (fuel cell electric vehicle).[4] It is aiming for an annual production of 400,000 LCEV cars and 2 million electric motorcycles by 2025 (Directorate General Metal Machinery Automotive and Defense Industry Ministry of Industry, 2019). In 2018, the Minister of Energy and Mineral Resources planned to stop selling conventional vehicles by 2040 (Rudi, 2018), however it is still unclear whether this would be implemented.

3 Based on a personal interview with Damantoro on February 21, 2020.

4 Details on the difference between EV types can be found in Appendix B.

These objectives are used in this document as the national target for Indonesia in increasing EV penetration.

The Presidential Regulation 55/2019 supports EV development and market diffusion in Indonesia. The regulation acts as an umbrella regulation for EVs, with more derivative regulations expected to be enacted in the future. Other countries, most notably Norway, Iceland, Sweden, and the Netherlands, have seen more than 5% EV penetration (IEA, 2019a). Some major cities in China and the US have also seen high EV uptake with more than 20% market share (Hall et al., 2018). Indonesia could look at lessons learned and implement best-practice policies which align with the country's situation. The next section describes several policy instruments that have been applied and are effectively accelerating EV uptakes in those countries.

Photo by Jan Kaluza on Unsplash

3. Policy instruments for EV deployment and diffusion

The development of an EV industry offers several potential benefits to a country – namely oil consumption reduction, GHG emissions reduction, pollution reduction, health benefits, new industrial development, and job creation. With lots of potential benefits to be tapped, countries around the world are promoting EVs. Sales of EVs have been rising since 2009, led by North America, Europe, and Asia. Studies found that policy support from governments is crucial in driving the early stages of EV market penetration (Coffman et al., 2017; Li et al., 2017; Yang et al., 2016; Zhou et al., 2015).

In the current market, EVs face several hindrances to market entrance, with the main barrier being the high upfront cost of EVs compared to conventional vehicles. A combination of supportive policy instruments and incentives from governments are key to spurring EV market growth (Transportation Research Board & National Research Council, 2015). China, for example, focused on industry development. It provided incentives for manufacturers, followed by purchase incentives for consumers to establish the market and efficiency standards enforcement to further push manufacturers to produce EVs (Qiao & Lee, 2019). Norway gives VAT-free incentives to entice customers into buying large and expensive EV cars. France uses a feebate that is better suited for people favouring the smaller and accessible EVs (Kempton et al., 2014). Therefore, depending on each country's objectives and situation, picking the right combination of policy instruments is crucial to obtain the objectives.

In general, there are two broad categories of policy instruments to promote new technology deployment and market creation:

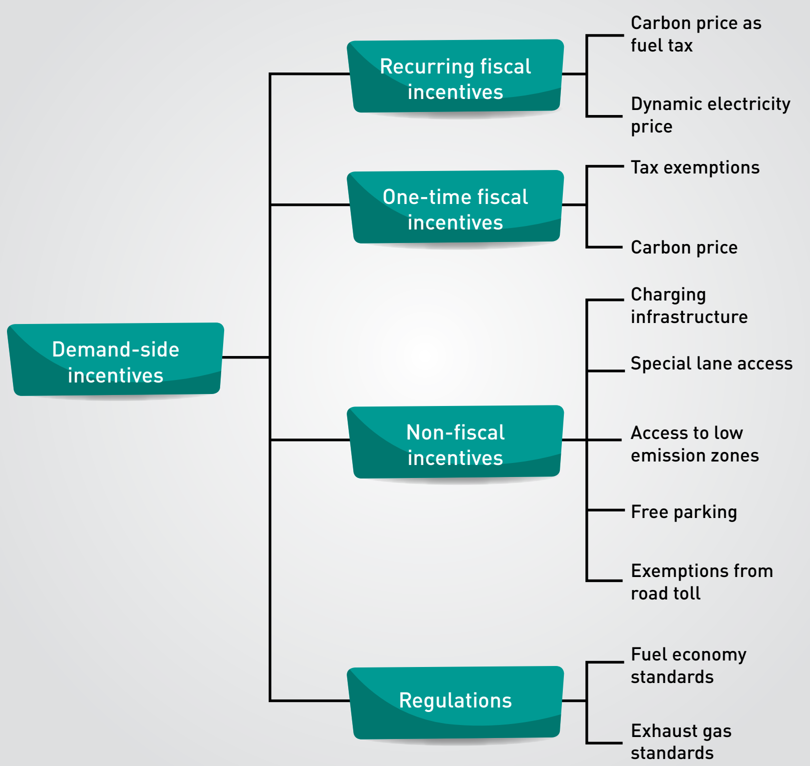
demand-side and supply-side instruments. In promoting an innovation like EVs, supply-side policy focuses on research and development (R&D) and production through for example, financial support, standardized regulations, and infrastructure. Demand-side policy works to stimulate the demand through fiscal (e.g. sales incentives) and non-fiscal incentives like infrastructure provision and public education (Zhang & Liu, 2016).

Supply-side policies tend to be prioritized for countries with strong domestic automotive industries in order to improve their industrial capabilities in producing EVs. This trend is seen in the major car-manufacturing countries such as Germany, Japan, the United States and France. Those countries accounted for 82% of total spending on R&D in the period 2008–2014 by the 13 leading countries in EV development (Wesseling, 2015).

Countries with weaker automotive industries, such as Norway and the Netherlands, spend less on R&D, and instead favor sales incentives to facilitate EV market diffusion. Indonesia's automotive industry acts more as a manufacturing site that focuses on serving the domestic market. Developing the market through demand-side incentives therefore are more appropriate to facilitate early EV deployment in Indonesia. Meanwhile, supply-side incentives that focus on manufacturing will be necessary further down the line to support the industry when the market is ready.

Demand-side policy instruments can be further broken down into one-time fiscal incentives, recurring fiscal incentives, non-fiscal incentives, and regulations. One-time fiscal incentives aim to lower the gap of upfront costs between EVs and ICEVs, including direct subsidy, tax exemption, and carbon emission-based taxation at the point of sale. Recurring financial incentives can be in the form of vehicle licensing fees waivers or lower annual taxes, for example. Non-financial incentives include those that are not financial in nature, such as giving EVs access to bus lanes, road toll exemptions, free parking, and access to zero-emissions zones. Charging infrastructure development is also a non-financial way of encouraging consumers to purchase EVs.

Figure 4. Demand-side policy instrument types and examples



Regulations such as exhaust gas standards and fuel economy standards are proven to have positive effects on EV sales. Examples of each instrument are given in Figure 4 and described in more detail in the following sub-sections.

3.1. One-time fiscal incentives

Several studies reveal that high purchase price is a powerful barrier to EV adoption (Larson et al., 2014). Thus, upfront purchase price incentive is key to increase EV attractiveness. One-time fiscal incentives act to lower this barrier through several means. Purchase subsidy, tax exemption and vehicle purchase rebate (in the form of carbon price) are among the instruments most commonly used by countries to affect the purchase price (Yang et al., 2016).

3.1.1. Purchase subsidy

This method is most commonly employed by developed countries. They introduce directly tax-funded purchase subsidies to enhance the local EV industry, usually in the form of a direct payment or tax credit (in the case of the United States) to each EV buyer. Several OECD countries like Belgium, Denmark, Spain and Portugal use direct subsidy to promote EVs. Essentially cutting buyers' premiums, the rationale of these purchase subsidies are that they stimulate each country's ability to generate new technology, in this case, EVs (Kempton, 2014).

3.1.2. Tax exemptions

In countries without EV production capability, the government provides exemptions for import duties and taxes. For example, Norway has been providing EVs with exemption from purchase tax and VAT and 80% reduction of registration tax. This could reduce EV purchase cost by 20% to 50% (Bjerkan et al., 2016). This taxation scheme, therefore, makes the EVs price competitive compared to ICEVs, and boosts sales. Other countries where vehicle tax is lower than Norway might need additional incentives to close the gap in upfront costs. Many countries even set direct subsidies on top of tax exemptions, e.g. India, Japan, the Netherlands, Spain, France and the United States (IEA, 2013).

In China, one of the leaders in EV market share, the government provides exemptions from purchases and additional taxes ranging between USD 5,000 and USD 8,500. Local and regional authorities can complement these within the limit of 50% of the central subsidies. As of June 2016, EV sales have increased a staggering 162% compared to the same period the previous year (Giannopoulos & Munro, 2019).

3.1.3. Carbon price for upfront purchase price

A carbon price can be imposed on the vehicle price at point of sale. An example is the feebate system in France. The feebate policy provides a direct price cut for new cars that emit less than 130 gCO_2/km. The price cut amount varies depending on the emissions levels. On the other hand, new cars that emit more than 160 gCO_2/km would have to pay tax of up to EUR 2,600 (Monschauer & Kotin-Förster, 2018). This feebate system is intended to shift consumers' preference towards EVs and also encourage manufacturers to build more EVs. The French government is still using this policy (with different requirements) as one of its main drivers to increase EV sales.

3.2. Recurring fiscal incentives

Another method to promote EVs is through recurring fiscal incentives to lower their total cost of ownership (TCO), including imposing annual tax based on vehicle weight, fuel type, and/or CO_2 emissions (ICCT, 2016). Implementing dynamic electricity pricing could also support EV penetration (Myers et al., 2019).

3.2.1. Carbon price (as fuel tax)

A carbon price can also be imposed on the fuel. One way to give financial incentives to the EV buyers is through fuel cost savings. Several countries have already employed carbon emissions tax on gasoline to promote EVs. Because in most countries the well-to-wheel emissions of EVs are lower than conventional vehicles, EV consumers would benefit by paying lower fuel costs. A study conducted for Singapore (Chua & Nakano, 2013) concludes that as the rate of carbon tax increases, the market share of EVs also increases.

The impact of carbon pricing has already been proven globally. For instance, one study suggests that high fuel tax adopted by Japan and Europe plays a major role in reducing global transport emissions (Sterner, 2007). This phenomenon hints that carbon tax could affect consumers' behavior in nudging them to use fuel more efficiently or to shift their preference towards more fuel-efficient vehicles. Another example is in Sweden, which implemented a carbon tax in 1991. A study on the Swedish carbon tax suggests that carbon taxes influence vehicle purchase decisions of consumers more than oil price fluctuations (Andersson, 2017).

3.2.2. Dynamic electricity price for EV charging

As more EVs are introduced, electricity demand would be expected to rise. If unregulated, that demand could accumulate in peak hours. Local electricity infrastructure therefore must be improved to handle the additional power needed, which potentially pushes up the cost of electricity. This could be avoided by introducing dynamic electricity pricing, such as time-of-use (TOU) pricing, which offers cheaper electricity prices during off-peak hours. This is done to influence consumers to shift towards off-peak charging. At the same time, this instrument could be utilized to attract more people to buy EVs since it offers lower electricity prices.

A US study suggested that time-varying rates will encourage EV adoption by lowering the total ownership cost (Myers et al., 2019). Another study in the United States estimated that switching to a TOU plan could save more than USD 500/year compared to staying with the standard rate plan. Based on electricity tariff data in various US cities presented in the report, most (60%) of the TOU plans could provide 20% to 50% of cost savings, with the average at 29% (Anair & Mahmassani, 2012). Another study by the Citizen Utility Board in Chicago estimated that dynamic pricing can reduce EV owner cost by 52% to 59%, assuming EV owners are only charging the minimum amount needed to cover daily driving and at the lowest cost (Zethmayr & Kolata, 2019). In Beijing, implementation of the TOU scheme could lower the operational cost of using EVs by 34% (Cao et al., 2012). In Indonesia, the electricity tariff is currently set at a flat rate by the state-owned electricity company (PLN) for residential consumers. However, an off-peak tariff is already in use for industry consumers (Husaini, 2019).

3.3. Regulations

Apart from financial incentives, governments could also employ several forms of regulations that favor EV uptake. These regulations are not exclusive to EVs, but some of them have already proven crucial for EV market penetration. Implementation of fuel economy standards have proven favorable to EVs. Additionally, CO_2 and pollutant emission standards have also been shown to increase EVs market diffusion (The ASEAN Secretariat, 2019). More details regarding these regulations are described below.

3.3.1. Fuel economy standards

Fuel economy standards are not purely a demand-side incentives, but have been shown to correlate strongly with EVs uptake. Compliance with fuel economy standards causes conventional vehicle prices to rise. As limits on CO_2 emission are tightened, the increase of ICEV price will be larger. This will affect the competitiveness of EVs. At some point, introducing alternative technologies such as EVs will be less costly than selling a more efficient conventional vehicle (Meszler et al., 2016).

One notable example is the CAFE standards in the United States, which determines a manufacturer's compliance based on the average fuel economy of the vehicles it produces annually. A recent study shows that by implementing only the CAFE standard, the BEV (battery electric vehicle) market share in the United States could reach up to 29% in 2030. The study also observes that the EV market share attained by imposing the CAFE standard alone is higher than when using only government incentives of up to USD 7,500 for consumers (Sen et al., 2017).

3.3.2. Exhaust gas standards

Stricter exhaust gas standards are not commonly used as an instrument to increase

EV penetration but rather as public health and environmental protection measures. Nevertheless, it contributes to the increasing cost of ICEVs, thus improving EV competitiveness. Conventional vehicles emit toxic air pollutants through fuel combustion and fuel evaporation. EVs, on the other hand, emit no exhaust and evaporative emissions, although still emit abrasive emissions (such as tyre wear).

A study by the International Council on Clean Transportation (ICCT) estimated that it will cost about USD 780 to USD1,130 for diesel cars and USD 10 to USD 30 for gasoline cars to move from Euro 4 to Euro 6 specifications (Sanchez et al., 2012). Meanwhile, for two- and three-wheel vehicles, it is estimated that the price will increase by USD 30 to USD 60 (Bansal et al., 2012). A stricter exhaust standard also requires a higher quality fuel, which costs more. The fuel mostly consumed in Indonesia (RON 88 and RON 90) cost IDR 6,450 and IDR 7,650 per liter (2017–2020 retail price) – equivalent to USD 0.46 and USD 0.54 per liter. Meanwhile, Euro 4-equivalent fuel costs IDR 10,300 per liter (2018–2020 retail price average) – equivalent to USD 0.73 per liter. Additionally, it was estimated that an improvement from Euro 4 to Euro 6 quality fuel in India would slightly increase the fuel price by about IDR 100 or less than USD 0.01 (Bansal et al., 2012).

3.4 Non-fiscal incentives

Non-fiscal or indirect incentives are those that do not have a direct monetary value to the consumer. Rather, these incentives save time and provide convenience, which are sometimes much valued by consumers. Indirect incentives include access to special lanes on roads, access to zero-emissions areas, exemptions from road tolls, free parking, and others. Public information campaigns could also be considered as an incentive to drive consumers' awareness of EVs.

3.4.1. Charging infrastructure development

One of the major barriers to EV adoption is the limited driving range they offer. Study by Tran et al. (2012) infers that range anxiety is best addressed by increasing charging opportunities rather than extending EV range. The study found that consumers tend to choose BEVs over PHEVs (which have a longer driving range), on the assumption that as charging stations become more widespread, this will lessen consumers' need for longer-range vehicles (Tran et al., 2012). Several other studies also support the claim that availability of charging infrastructure is crucial to increase EV adoption (Egbue & Long, 2012; Lopes et al., 2014; Sierzchula et al., 2014).

Sierzchula et al. (2014) analyzed data from 30 countries and found that charging stations have a significant and positive correlation with EV market share in a country. Moreover, the data also indicated that charging infrastructure is stronger at predicting EV market share than fiscal incentives. Adding one charging station per 100,000 people has a more significant impact (twice as much) on EV market share than giving USD 1,000 in consumer financial incentives.

As the leading country in EV market share, Norway built up its charging network way ahead of time. By 2013, Norway had built 4,029 normal public chargers and 127 fast-charging points, much more than needed to accommodate around 9,500 EVs running in that year. Furthermore, a close look suggests that EV sales have been increasing rapidly since 2009 when the Norwegian government started to accelerate the development of EV-charging infrastructure. Around 1,800 normal chargers and 70 fast chargers have been established since 2011, resulting in a 14-fold increase in EV sales from 730 units in 2010 to 10,400 units in 2013 (Mersky et al., 2016).

3.4.2. Special lanes access

Several countries like the United States, Norway and China use this policy as an additional incentive to push EV sales. In China, while fiscal incentive is still the dominant factor in most consumers' decision-making on EVs, for some, access to bus lanes is the over-riding factor. Traffic congestion is a major issue in China, so access to bus lanes could help to mitigate this (Wang et al., 2017). Consumers in Norway show similar tendencies; depending on where they are located and the road conditions, bus lane access could mean a great deal. For those who live near Oslo, freedom to use bus lanes would offer significant time savings (Fearnley et al., 2015).

3.4.3. Exemptions from road tolls

Although road toll exemptions have been used less frequently compared to other indirect incentives, it is seen as an effective tool to provide an additional push towards EV adoption. Several surveys and case studies concluded that toll-fee waivers are an important policy in driving EV sales in Norway (Aasness & Odeck, 2015; Figenbaum, 2017). Taking the city of Trondheim as an example, the number of EVs more than doubled on the previous year when 16 road toll stations exempted EVs from paying tolls in 2014.

3.4.4. Free parking

Free parking is another indirect incentive that has been employed in a number of countries (e.g. Germany, the Netherlands, the United States, China, and Norway). Free parking could help especially in cities with scarce, thus expensive, parking spaces. Several studies deduce that parking benefit has a correlation with EV sales, for example in the United States (Lutsey et al., 2016; Wee et al., 2018), in Europe and China (Ajanovic & Haas, 2016), and in Sweden (Egnér & Trosvik, 2018). Another study finds that for people in highly urbanized areas globally, free parking is an important factor (Lieven, 2015).

3.4.5. Access to low-emission zones

Low-emission zones have been established in many cities in Europe to tackle urban air pollution. Road transport has been recognized as the culprit for much of this urban pollution. Many studies have shown that the introduction of low-emission zones has managed to reduce air pollution at various magnitudes (Transport & Environment, 2018). This policy is originally aimed at restricting high-polluting vehicles (such as diesel cars or trucks) from accessing certain areas, especially city centres. However, several cities are already planning to go further and set up zero-emission zones, which allow only BEVs to enter the areas. Many reports mentioned the introduction of zero/low-emission zones as an important policy tool to increase EV penetration (Ajanovic & Haas, 2016; Hall et al., 2017; Trip et al., 2012). However, there are no studies available yet that quantify the impact of this policy on EV penetration.

3.5. Demand-side policy instruments for EVs across the globe

Various policy instruments have already been adopted by several countries to increase EV uptake. Not all of the instruments would be implemented at the same time in a country. Instead, the instruments chosen vary across regions due to exogenous reasons, like consumers' preference, targets set by governments, and general conditions within the countries themselves. Table 2 shows several demand-side instruments adopted by leading countries to boost EV market share.

Table 2. Demand-side policy instruments adopted by several countries for EV diffusion

Countries	Fiscal Incentive	Recurring Incentive	Non-Fiscal Incentive
Norway	Zero purchase tax 25% VAT (Value-Added Tax)	Exemption from vehicle license fee	Free parking Road toll exemptions Bus lane access Charging infrastructure
Netherlands	Registration tax based on CO_2 emission level of the vehicle	Road tax exemptions	Parking incentive HOV lane, bus lane access Charging infrastructure
Denmark	Registration fee based on vehicle price VAT deductions	Environment tax based on fuel consumption	Free parking in some cities
Germany	Purchase subsidies (cost is shared by government and car makers)	Annual tax based on CO_2 emission	HOV lane, bus lane access Parking incentive Public charging infrastructure
United States	Tax credit of up to USD 7,500	Annual registration fee is reduced/eliminated TOU electricity rate	Free parking HOV lane access Charging infrastructure
China	Purchase price subsidy of up to USD 9,500	Exemptions from annual vehicle tax	HOV lane, bus lane access Free parking Road toll exemptions Charging infrastructure
Sweden	Purchase price subsidy of up to USD 6,200	Exemption from annual circulation tax	Free parking Charging infrastructure
France	Purchase price subsidy of up to USD 9,570 VAT benefit	Registration fee benefit based on CO_2 emissions	Free parking in certain municipalities Charging infrastructure
Japan	Purchase price subsidy of up to USD 8,500	Annual vehicle tax reduction	Charging infrastructure

Note: HOV = High occupancy vehicles

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4. Passenger EV market penetration model

Despite several plans and targets stated by the government, Indonesia is still at a very early stage of EV diffusion judging by its low vehicle population, the limited availability of supporting infrastructure, and the lack of derivative regulations in the market. As outlined above, several demand-side policy instruments could promote EVs adoption in Indonesia. The key is to select the most appropriate policy instruments to induce optimal EV growth in Indonesia. Thus, it is firstly necessary to define the vehicle market mechanism of the country before integrating potential policy instruments.

IESR has created a model that simulates the vehicle market and projects the market shares of different types of vehicles, including EVs based on consumers' preference and also technology diffusion characteristics of a disruptive technology. Using this model, EV market share could be estimated in different policy scenarios. Eventually, the impacts of EV penetration could also be determined, mainly in emissions reduction.

In essence, this model considers several vehicle and fuel attributes that are deemed most influential for consumers in Indonesia and then projects them over time until 2050. Through a series of equations, the model generates market shares as the output; the market shares are then normalized with the S-curve pattern of disruptive technology. The purpose of this model is to estimate market shares for passenger EVs (cars and motorcycles) among the total passenger vehicles sales in each year, from 2020 until 2050 in Indonesia. Subsequently, the model yields emissions reduction, oil consumption savings, and power generation from the forecasted EV penetration. Additionally, it would also calculate the charging infrastructure needed to cater for the uplift in EV numbers.

Two main modes of transport are inspected in the model: motorcycles and cars. Motorcycles are grouped into one category, thus the choice is only between conventional and electric motorcycles. With passenger cars, the model divides them into four classes based on similarity in size and price: (1) small cars, (2) sedan, (3) multi-purpose vehicle (MPV), and (4) sport utility vehicle (SUV). Within each class, it is further broken down into three groups of vehicle technology: fossil-fueled, hybrid, and electric. Depending on the class of the vehicle, there could be a further breakdown into conventional and low-cost green car (LCGC) for fossil-fueled vehicle and also fully-hybrid (HEV) and plug-in hybrid vehicle (PHEV) for the hybrid category.

In order to estimate the market shares for each transport mode, the model employs nested multinomial logit (NMNL). Essentially, a multinomial logit model solves discrete choice problems. Discrete choice problems arise where there are a fixed number of possibilities as the outcome. In this case, there are a fixed number of choices regarding vehicle class and technology. Thus, the model would determine the probability of choosing one vehicle over others, which ranges from 0 to 1, based on the value of the vehicle. Before estimating the value of each choice, alternatives that are more alike are grouped together. This is the method that NMNL employs to make the model more accurate. To assess the value of each vehicle, a consumer utility function is used.

Consumer utility function is affected by several factors and out of these, a few vehicle and fuel attributes are selected. These include vehicle purchase price, fuel economy, driving/riding range, performance, maintenance cost, and refueling availability. Each factor has a different weight to the utility value, therefore different coefficients are needed to represent the sensitivity. Figure 5 below describes every stage in the model that eventually leads to final output.

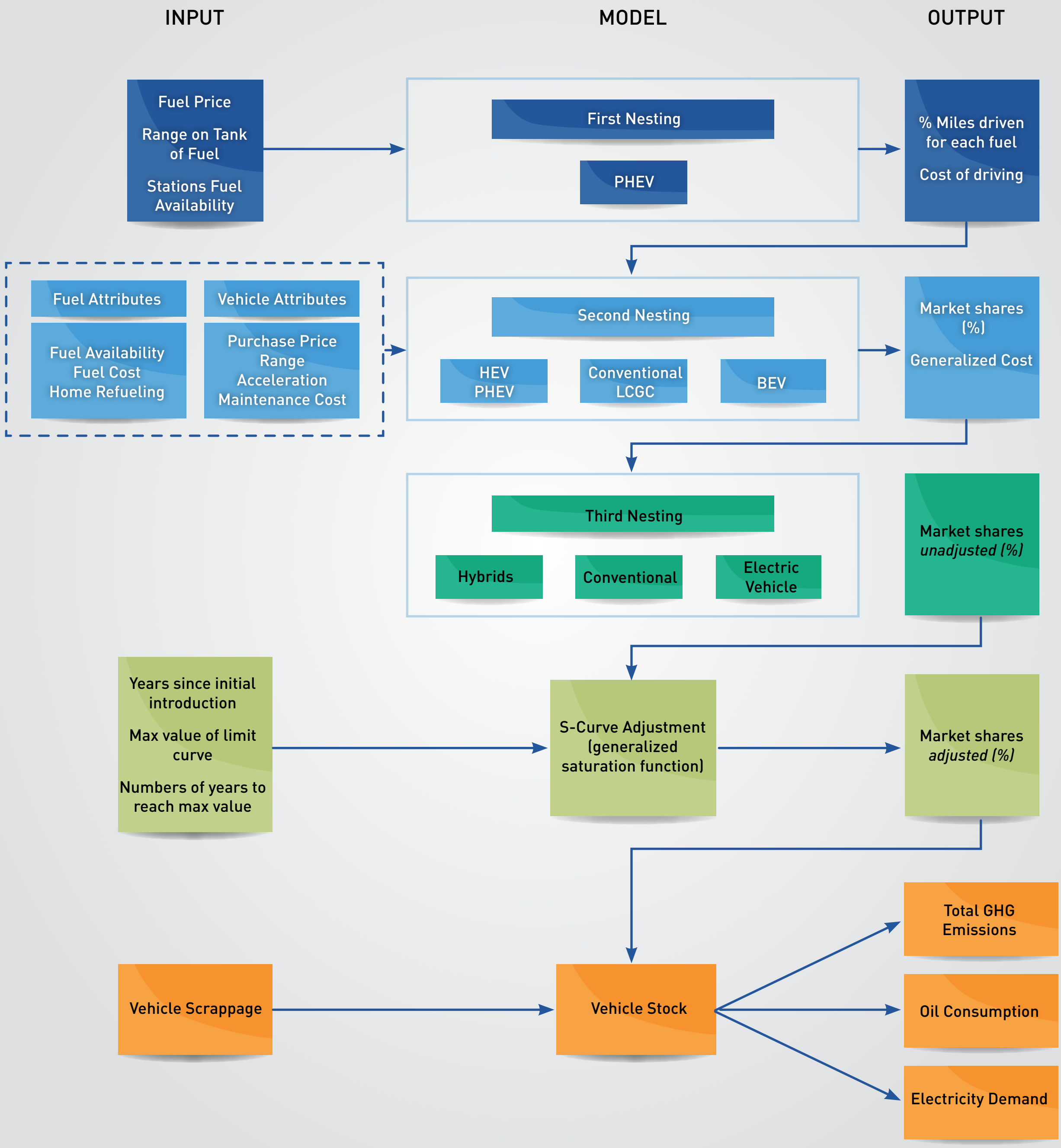
For the final output, the market shares are found for each mode (passenger cars and motorcycles) based on the class and also the technology of the vehicle. These market shares are then adjusted with a sigmoid curve that represents technology diffusion over time. It captures the various other factors that are not seized by the NMNL model. Once the market shares are determined, it is integrated into the vehicle stock until 2050. Finally, the total emissions, oil consumption and electricity demand of passenger vehicles in Indonesia could be calculated.

The model has a limitation in that it is not designed to capture the effect of supply-side policies such as fuel economy standards or non-financial (dis)incentives such as zero-emission areas, bus lane access, etc. Additionally, the model also does not capture the change in consumer characteristics that might influence their choice, such as a change in consumers' purchasing power.

This model is based on NMNL equations developed by the US Energy Information Administration (EIA) in 2010 (EIA, 2013) and also Oak Ridge National Laboratory (Greene, 2001).[5] The coefficients for the vehicle and fuel attributes initially are gathered from the EIA's *Annual Energy Outlook 2010*, hence they represent how US consumers chose their vehicles. However, they are then calibrated using historical data in Indonesia and Thailand for cars and motorcycles. The value of each attribute is benchmarked against other countries with similar conditions to Indonesia (e.g. Thailand and India) or in some cases, countries where the data is available.

5 Detailed description of the model is available in Appendix A.

Figure 5. EV penetration model input-output block diagram

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5. Policy scenarios for EV penetration in Indonesia

Using the EV market penetration model, various conditions could be set to attain the target of high EV penetration and significant GHG emissions reduction. However, the conditions are restricted to those that relate to vehicle and fuel attributes, taking the demand-side angle. Given this requirement, not all of the policies and incentives mentioned in the previous chapter could be implemented. Instead, incentives selected are those considered realistic to implement, effective, and compliant with the model.

5.1. Overview of policy scenarios

Using the model described in Chapter 4, three scenarios are established to envisage how future passenger transport in Indonesia will look based on different sets of policy instruments. The first scenario is business-as-usual, meaning the current policies and trends are expected to continue until 2050. The second is the moderate scenario, which introduces some policy interventions with a rather conservative value (mostly policies that are already in the government's pipeline). The last is the ambitious scenario, with all possible policy interventions being implemented aggressively, following best practices in other countries.

Under these scenarios, there are five policy instruments being evaluated: tax incentives, vehicle exhaust quality standards, carbon price, dynamic electricity pricing, and charging infrastructure development. The detailed breakdown is given in Table 3.

Table 3. Scenarios set up using different values of incentives

Policy instrument	BAU scenario	Moderate scenario	Ambitious scenario
Tax incentives	No tax exemption for EVs No increased taxation for ICEVs	Tax exemption until 2024: 12.5% registration tax Reintroduction of registration tax for EVs in 2025 No increased taxation for ICEVs *assumed domestic EV production, thus no import duty and import income tax applied	Exemption from all taxes for BEV and PHEV until 2025 Incremental taxation reintroduction for EVs (VAT, registration tax, luxury tax, and annual tax) Increased taxation for ICEVs up to 2.5 to 3 times current taxes *assumed domestic EV production after 2025, thus no import duty and import income tax applied
Exhaust quality standards	No improvement in fuel quality	Fuel quality improvement by 2025	Fuel quality improvement by 2025
Charging Infrastructure	No additional charging spot	Charging spot development follows PLN's projection (additional 167 in 2020 and 7,146 in 2030) extrapolated to 2050	16,000 additional charging spots in 2020, grows to 600,000 in 2050
Carbon pricing on fuel	No price on carbon emission	Carbon emission priced at USD 10/ tCO_2 by 2025, USD 25/tCO_2 by 2030, and USD 100/tCO_2 by 2050	Carbon emission priced at USD 10/ tCO_2 by 2021, USD 50/tCO_2 by 2030, and USD 245/tCO_2 by 2050
Time-varying electricity pricing	No off-peak tariff introduced	30% charging cost reduction	50% charging cost reduction

More details regarding the scenarios are discussed in the following sub-sections.

5.1.1. Business-as-usual (BAU) scenario

In general, the BAU scenario projects EV penetration if the current situation, i.e. official regulations and its subsequent government-approved plan, does not change. It does not incorporate newly planned activities or new initiatives that are yet to be adopted in nationwide regulatory frameworks such as the exemption of registration tax in Jakarta, night-time charging discount tariff, and PLN's projection for charging facilities development.

Recently, the government released Presidential Regulation 55/2019 on the Acceleration of Battery Electric Vehicles for Road Transportation Program. The regulation promised incentives for (B)EV-related industries and public transport companies as well as for individual (B)EV users. However, the implementation policies are yet to be released. The new regulation of tax on luxury goods (Government Regulation No. 73/2019) that will be enforced in 2021, exempts the luxury tax on BEVs and reduces luxury tax on PHEVs. This exemption, however, is ineffective for BEV penetration since BEVs were not taxed in previous regulations. Therefore, in the scenario, there is no tax reduction for EVs. Also, no additional taxation will be imposed on conventional vehicles.

As for conventional vehicles, fuel quality will stay as it is and a carbon price on fuel will not be implemented. Therefore, the fuel price will be kept at current levels, only adjusted according to global oil price projection by EIA. For charging infrastructure, these are the numbers used: there are only 7,000 public multi-purpose charging stations (5.5 to 22 kVA) and 10 EV chargers (22 to 150 kVA) available for electric motorcycles and cars. Lastly, the electricity price is set at a flat rate of IDR 1,650/kWh or USD 0.12 (as of December 2019).

5.1.2. Moderate policy intervention scenario

Most of the policy interventions applied in the moderate scenario are already planned or were recently being adopted by policy-makers. Exemption from registration tax for BEVs (motorcycles and cars) was recently adopted by the Jakarta provincial government in January 2020 (Pusdatin Bapenda DKI Jakarta, 2020). Exemption from tax on luxury goods was adopted by the national government in 2019, though this only significantly affected PHEVs since BEVs were not taxed under the previous regulation. In addition, it is assumed that either due to domestic demand or government intervention the PHEVs and BEVs will be manufactured domestically, therefore, import-related taxes (import duty and import income tax) are removed.

Fuel is expected to comply with Euro 4 specification (50 ppm sulphur content) and low-quality fuel is expected to be banned by 2025, assuming that Pertamina's refinery will only be able to produce low sulphur fuel by that time (Deka, 2018). This will increase the retail price of gasoline to about IDR 10,300 or USD 0.73 per liter (average retail price of Pertamina's Euro 4 fuel since 2018). A carbon price will also be imposed on gasoline consumption. The government is currently discussing implementation of a carbon price. However, it has not yet issued a statement regarding the nominal price. This scenario assumes a carbon price starting at USD 10/tCO_2 by 2025 that incrementally increases to USD 25/tCO_2 by 2030 and USD 100/tCO_2 by 2050; the numbers are significantly lower than the nominal suggested by the Intergovernmental Panel on Climate Change (IPCC).

On charging infrastructure development, this scenario assumes PLN's projection to have an additional 167 EV charging stations by 2020 and 7,146 by 2030 (Almer, 2019; Mulyana, 2020). This scenario also assumes a 30% discount for night-time charging, which is currently provided for home charging (Syaifullah, 2019).

5.1.3. Ambitious policy intervention scenario

Under the ambitious scenario, all taxes are exempted for both BEVs and PHEVs until 2025. After 2025, the taxes are reintroduced incrementally until 2035, including 10% VAT, 12.5% registration tax and an additional 10% luxury tax. The 2% annual tax will be reintroduced in 2025. To compensate for reintroducing taxes on EVs, additional taxes are imposed on ICEVs, both conventional cars and LCGCs. This assumes that the luxury tax and registration tax is changed to be based on carbon emissions, which results in lower tax for EVs and higher tax for ICEVs. The tax paid in initial years is assumed to increase 2.5 times for conventional cars and three-fold for LCGCs by 2035, which increases the vehicle purchase price by about 40%.

Fuel quality is assumed to comply with 50 ppm sulphur standard by 2025, as assumed in the moderate scenario. The carbon price is imposed more aggressively, starting at USD 10/tCO_2 by 2021, increasing to USD 50/tCO_2 by 2030 and USD 245/tCO_2 by 2050, in line with the suggestion by the High-level Commission on Carbon Prices and the IPCC (World Bank, 2019). The dynamic electricity pricing is expected to reduce the electricity bill by 50%, as the study on the US market suggested (Zethmayr & Kolata, 2019).

Annual charging infrastructure growth is taken as 3% of the ideal number of chargers per capita installed by Norway (1,950 chargers per million capita). Therefore, before 2025 Indonesia would have a vehicles-to-refueling stations ratio of less than 16 to one. This is an optimal scenario to be adopted since a ratio between 10 and 16 is considered to be ideal (Spöttle et al., 2018). If this scenario is to be pursued, then Indonesia would need to add 16,000 more normal and/or slow-charging stations in 2020 and cumulatively this would reach around 600,000 chargers by 2050.

5.2. Projection of EV penetration in different scenarios

The model projects the market share of each vehicle technology in each year from 2020 to 2050. The projection here is not meant to be an exact forecast of the EV future, especially considering the limitations of the model. Rather, the projection aims to indicate the impact of different policy interventions on EV market penetration and to analyze why the market penetration behaves differently with each intervention. Overall, the model shows that penetration of electric motorcycles behaves very differently than electric cars.

5.2.1. Market penetration of electric passenger cars

In the BAU scenario, the model estimates that EV penetration in the passenger car market will only reach less than 1% by 2050, mostly from HEVs and PHEVs. In the moderate scenario with currently planned policies and trends, EV share could increase to 14% by 2050, with only PHEVs penetrating prior to 2026 while BEVs will only dominate after 2040. In the ambitious scenario, EV penetration can reach 85% by 2050, dominated heavily by BEVs from 2027 onwards. The market share of EVs is presented in Figure 6 and Table 4.

Figure 6. Electric cars penetration in different scenarios

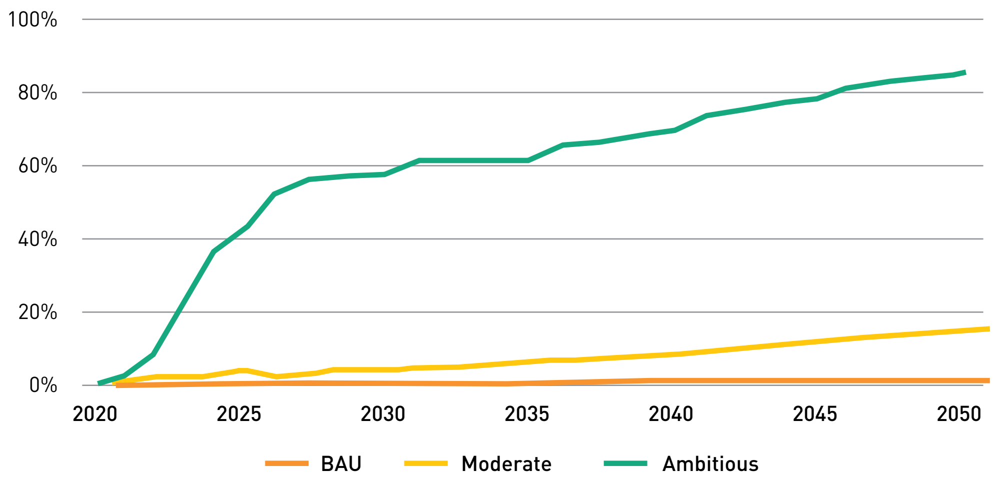


Table 4. Market penetration of electric passenger cars in different scenarios

		2020	2025	2030	2035	2040	2045	2050
BAU	HEV	0.0%	0.2%	0.3%	0.3%	0.4%	0.4%	0.5%
	PHEV	0.0%	0.1%	0.2%	0.2%	0.3%	0.4%	0.4%
	BEV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Moderate	HEV	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%
	PHEV	0.8%	2.1%	3.1%	3.6%	4.0%	4.5%	5.0%
	BEV	0.0%	0.0%	1.0%	2.4%	4.2%	6.3%	8.6%
Ambitious	HEV	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.3%
	PHEV	1.6%	23.9%	18.6%	13.9%	16.4%	19.0%	21.1%
	BEV	0.0%	17.2%	38.8%	46.7%	53.0%	58.9%	63.5%

The dismal projection of EV adoption in the BAU scenario is mainly attributed to the excessively high price of EVs. For example, in the MPV class, the HEV, PHEV and BEV purchase price will be still two times, 2.2 times, and 2.8 times higher respectively than for a conventional car. This causes HEVs to dominate the EV penetration, contributing more than half of the EV market in 2050.The purchase price of EVs is exceptionally high because currently these are not manufactured domestically and so must be imported. Imported EVs are subject to import duty and income tax, which can increase the purchase price by about 60%.

In the moderate scenario, tax exemptions provided until 2024 only benefit PHEVs, while BEV penetration remains at virtually zero until 2025. This indicates that the tax incentive provided is not sufficient to make BEVs competitive. However, the assumption that PHEVs and BEVs are produced domestically creates a major impact on EV price competitiveness. By 2030, the purchase price of BEVs would be competitive, at least in the Small Car segment. BEV adoption is then hampered by the lack of charging stations. Improved charging stations provision could triple the BEV market share, giving a total EV market share of more than 30%.

In the ambitious scenario, EV penetration will jump quickly in the first five years, reaching 40% market share by 2025, dominated by BEVs. With full tax exemptions, PHEVs and BEVs immediately become more competitive than conventional vehicles. Even in the MPV class, they are only 60% more expensive than conventional cars in 2020. HEVs, on the other hand, fail to penetrate the market since these do not receive similar incentives and remain uncompetitive.

In both the moderate and ambitious scenarios, PHEVs dominate the EV market in earlier years, but in the long run, BEVs come to dominate. This pattern occurs because in the earlier years, the battery cost is still high, thus PHEVs that use smaller batteries are more competitive. In contrast, cheaper batteries in the long-term affect BEVs significantly, creating a higher market share in later years. In addition, an increased fuel price after 2025 also helps BEVs to outcompete PHEVs.

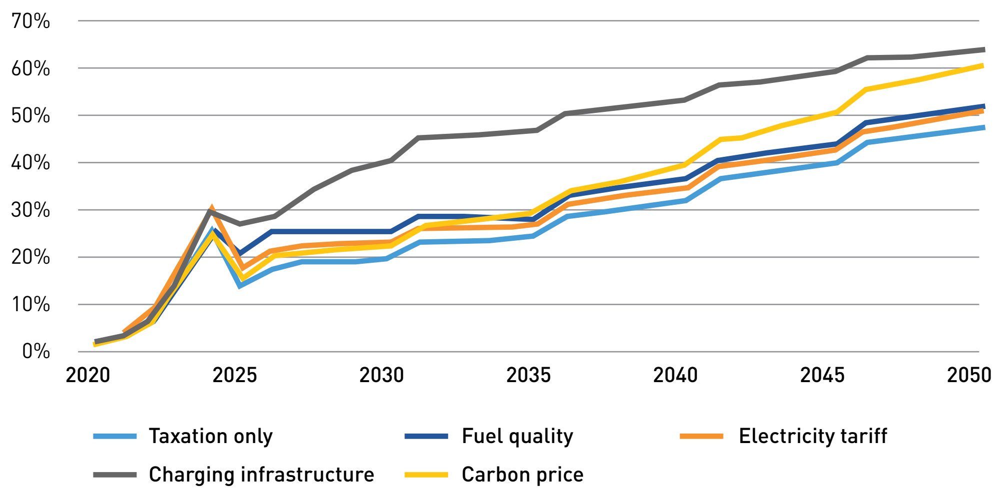
Among the vehicle classes, EVs struggle the most in the MPV class, due to the very low price of the conventional MPV market leader. Even in the ambitious scenario, PHEVs and BEVs only capture 68% of the MPV market in 2050. By 2050, the purchase price of BEVs in the ambitious scenario will already be cheaper than conventional cars in all class segments except MPVs. However, as battery costs fall, manufacturers might opt to produce BEVs for the low-class MPV segment, which is currently unavailable, to compete with the low-class conventional MPV. This might then improve the market share of BEVs in this segment.

Among all policy instruments analyzed, tax incentives prove to be the single most important policy instrument needed to create the electric passenger cars market. Applying all other policy interventions in the moderate scenario except tax incentives (fuel quality standards, carbon price on fuel, low electricity price, and additional charging stations), would only result in a 1.3% market share for EVs by 2050. In contrast, applying only the tax incentives of the moderate scenario would result in 4.4% EV penetration by 2050. Similarly, applying all other policy interventions in the ambitious scenario except tax incentives would only result in a 1.9% market share by 2050, while applying only the tax incentives results in a 48% EV penetration by 2050.

This dependency on tax incentives occurs because the taxation scheme, especially import-related taxes have a significant and direct impact on the vehicle purchase price, which is the main factor influencing consumer choice. However, after the purchase price of EVs goes down and is considered competitive, then the other factors start to take effect. Combining ambitious tax incentives with one of the following – lower charging tariffs, increased fuel quality, carbon price on fuel, or charging infrastructure improvement (with the ambitious scenario values) – would increase the penetration to 51%, 52%, 61%, and 64% in 2050 respectively. The EV penetration impacts of different policy combinations with tax incentives are presented in Figure 7.

This indicates that public charging station availability is the second most important instrument. Figure 6 provides the insight that

Figure 7. EV penetration in various policy interventions combined with tax incentives



the lack of charging infrastructure is hampering EV penetration, especially between 2025 and 2035, when the introduction of additional tax for conventional vehicles is expected to help increase EV adoption.

5.2.2. Market penetration of electric motorcycles

For two-wheelers, the model results are quite different. Even in the BAU scenario, the model projected that EV penetration will reach a quite high number, 67% by 2050. The moderate scenario will slightly increase the market share to 75% by 2050. The ambitious scenario sees the EV penetration increase to 92% by 2050. The increase in the ambitious scenario is even more significant in the earlier years, with the EV market share reaching 17% by 2025, just slightly below the Ministry of Industry's (MoI) target of 20%. Figure 8 and Table 5 display the market penetration of electric motorcycles in various scenarios.

This high EV penetration is mostly due to price competitiveness between electric and

Figure 8. Electric motorcycle technology market penetration in different scenarios

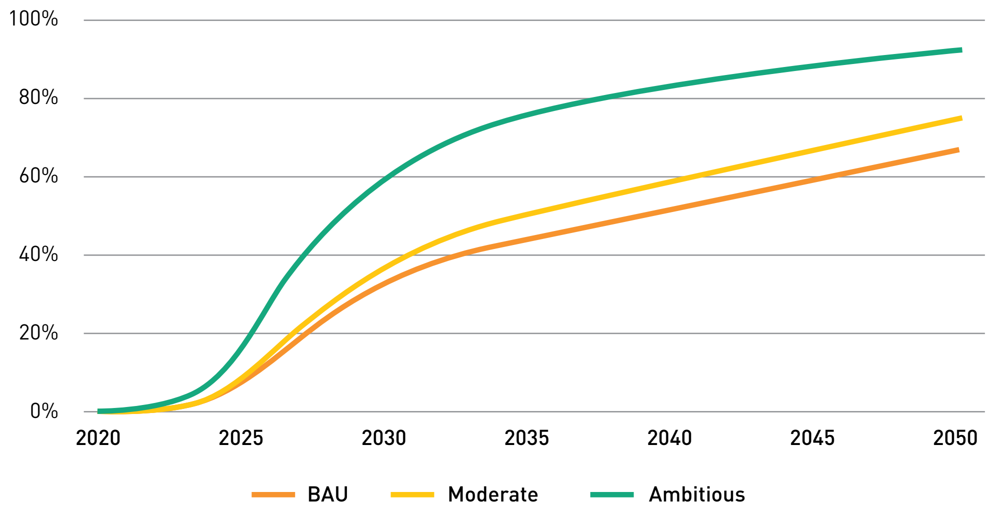


Table 5. Market penetration of electric motorcycles in different scenarios

		2020	2025	2030	2035	2040	2045	2050
BAU	EV	0.0%	7.3%	32.7%	44.4%	52.0%	59.4%	67.2%
Moderate	EV	0.0%	8.0%	37.6%	50.9%	59.3%	67.0%	74.5%
Ambitious	EV	0.0%	17.1%	60.2%	76.2%	82.9%	88.1%	92.3%

conventional motorcycles, which will already reach parity by 2023. The major factor is the increasing price of conventional motorcycles at 3% per annum (based on historical data). Moreover, the EV price is benchmarked to locally produced motorcycles, thus it is not burdened by import duty. The initial purchase price (year 2018) of electric motorcycles used in the model is only 34% higher than the price of comparable conventional motorcycles.

Despite the early price parity, EV penetration will grow quite slowly in the earlier years, with only a 3.5% share by 2024 before it starts accelerating to reach a 38% market share by 2030. This delay can be attributed mostly to the charging infrastructure development. Increasing only the public charging infrastructure on a par with the ambitious scenario will significantly accelerate EV penetration. Figure 9 shows the role of charging infrastructure improvement in accelerating EV penetration, compared to the other important policy instrument, tax incentives.

It can be seen that it is crucial to develop a lot of public charging stations initially. While most EV adopters would eventually use home chargers for daily use, they still need assurance that they could charge their EVs whenever they run out of power while commuting. Thus, pervasive public charging stations serve to ease the range anxiety among consumers. Breaking this barrier would significantly increase EV adoption as shown in Figure 9. However, focus is also needed to assist early adopters in getting access for home charging by increasing the residential electricity capacity limit. Electric motorcycle charging requires a power supply of about a few hundred VA to 1 kVA, depending on the brand and type. Therefore, the power supply needed at home will be at least 1,300 VA or 2,200 VA. Meanwhile, by 2019, there were 47 million households with a power supply of 450 VA or 900 VA, or about 70% of household electricity consumers (Wiratmini, 2019), which will need to upgrade if they want to charge their electric motorcycles.

Figure 9. Effect of ambitious tax incentives and charging infrastructure development on electric motorcycles market penetration

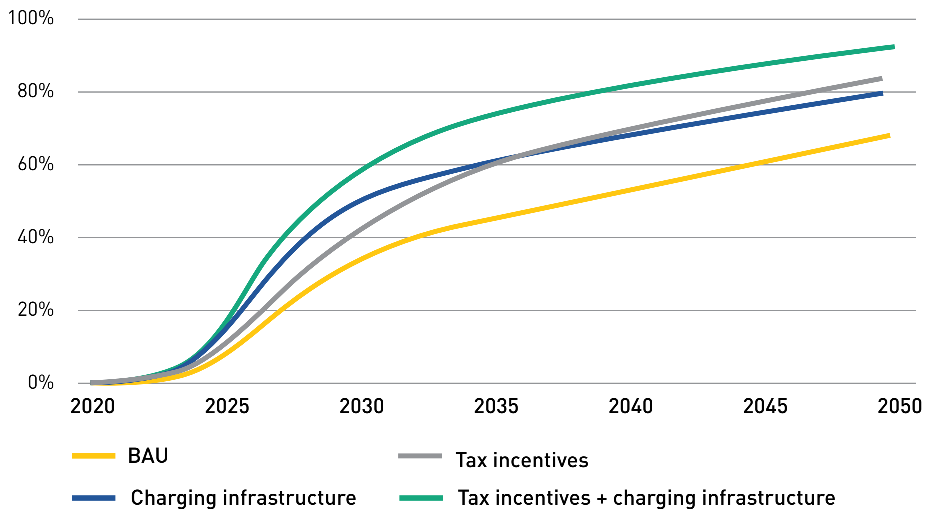
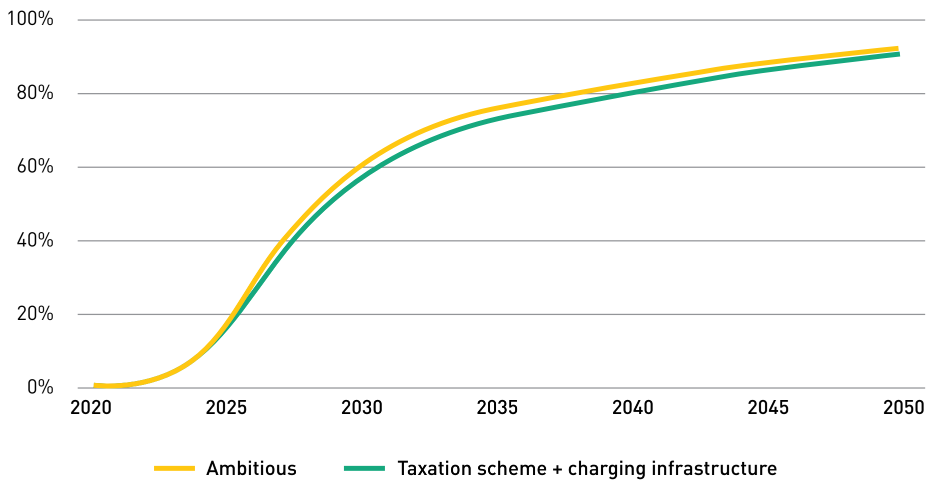


Figure 10. Comparison of electric motorcycle market penetration in the ambitious scenario, and in the scenario with only ambitious tax incentives and public charging development



The tax exemptions provided until 2025 fail to improve EV penetration significantly in the same period, if no improvement in public charging infrastructure is provided. Instead, the increased tax imposed on the conventional motorcycles makes a more significant impact, indicated by the widening gap between the BAU and tax incentive scenario after 2026 (yellow and grey lines in Figure 9). A similar trend is shown by the blue and green lines in Figure 9, with a widening gap post-2025.

Figure 10 compares the market penetration of electric motorcycles in the ambitious scenario to the penetration when only ambitious tax incentives and public charging development are implemented. The combination of ambitious tax incentives and public charging infrastructure improvement closely resembles the ambitious scenario. This means that the other policy interventions – carbon pricing, fuel quality standards, and dynamic electricity tariff – do not affect the EV penetration in motorcycles as much as in the passenger cars.

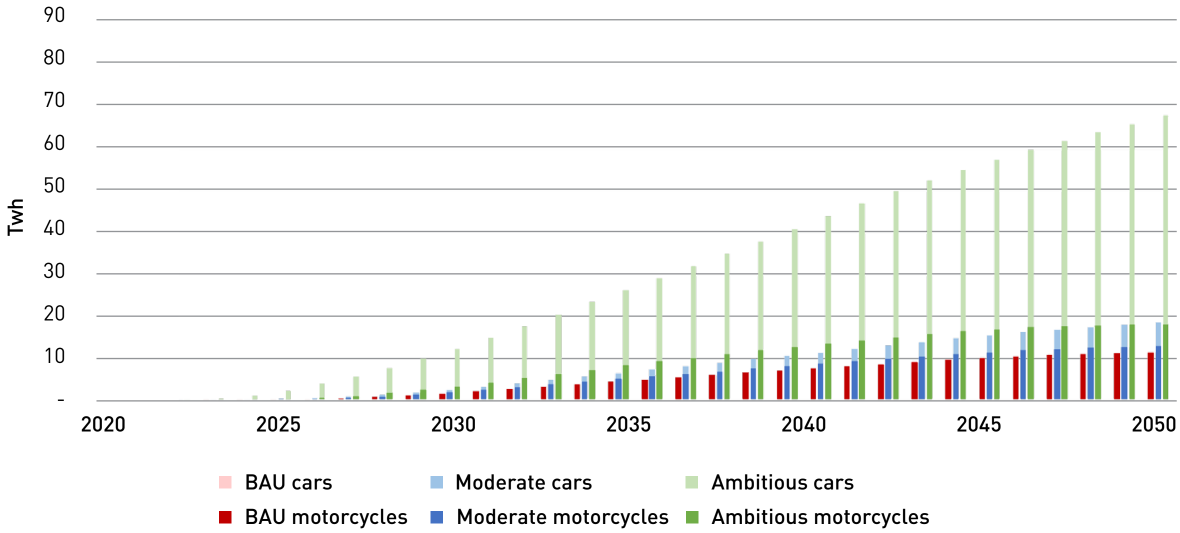
5.3. Implications of EV deployment

It has been shown that aggressive EV penetration could be attained with certain policy instruments in place. This in effect gives rise to the many benefits that EVs possess. As one of the important implications, the GHG emissions reduction potential of EV deployment is estimated in the following sub-section. From a macro-level perspective, the electrification of passenger vehicles would bring large implications to energy system design and planning in Indonesia. First, it will directly affect the power system, including electricity demand and the power grid infrastructure. Next, it will affect oil consumption and trade, and consequently planning for future refinery building. The change in oil and electricity consumption will in turn alter the GHG emissions rate, although other factors also contribute, especially the generation mix of electricity. Additionally, policies introduced in order to accelerate EV penetration will require investment and financial support by the government that might result in increased government spending or reduced government revenue. Lastly, EV development will inevitably affect the domestic automotive and components industry.

5.3.1. Impacts on the power system

Deeper EV penetration will increase demand for electricity. Under the BAU scenario, electric passenger vehicles will increase the total electricity demand by 0.2 TWh by 2025, by 2.1 TWh by 2030, and by 11.6 TWh by 2050, driven mainly by the penetration of electric motorcycles. In the moderate scenario,

Figure 11. The contribution of electric cars and motorcycles to additional electricity demand in different scenarios



electricity demand will increase by 0.6 TWh by 2025, by 3.3 TWh by 2030, and by 18.6 TWh by 2050, still mostly due to penetration of electric motorcycles. The ambitious scenario will drive up the electricity demand by 3.9 TWh by 2025, by 14.9 TWh by 2030, and by 68.2 TWh by 2050, with electric cars contributing more than half of this demand. This assumes an annual travel distance of 15,000 km for cars and 5,000 km for motorcycles.

In comparison, total electricity sales in 2018 was 232 TWh, and this is expected to increase to 360 TWh by 2025 according to the latest PLN business plan, RUPTL 2019-2028. RUEN projected that electricity demand will be close to 2,400 TWh in 2050, assuming a 7,000 kWh per capita consumption. However, the RUEN projection seems to be overestimated considering the actual electricity demand in the past three years has been much less than the projection.

The supply of electricity must be able to match the increase in demand cause by increasing EVs population. Therefore, the highest point of electricity demand (peak demand) needs to be assessed. This peak demand will take shape differently, depending on the charging behaviour of EV users. Two scenarios are constructed to understand different dynamics in on- and off-peak charging. The peak-charging scenario assumes that most of the EV users start charging during peak demand hours (between 17.00 and 22.00), while the rest of the users charge at different times throughout the day. In the off-peak charging scenario, it is assumed that all the EVs could be charged during off-peak hours, distributed evenly. To understand the extent of the impact, the ambitious scenario of EV penetration is applied. In building these scenarios, the daily electricity load profile of the Java-Bali grid is used. Correspondingly, the total power capacity used is also for Java-Bali interconnection from the projection in RUPTL. The time frame selected is in 2028 as it has the latest projection of power plant capacity available in RUPTL. The schematics of these on- and off-peak charging scenarios are given in Figure 12 and Figure 13.

As can be seen from Figure 12, if most EV users start charging during peak demand when people get home, the peak demand will increase by 6 GW, reaching to around 51 GW of total electricity demand. This figure is very close to the power capacity limit predicted at around 52 GW. Moreover, if all of the EVs are charging between 18.00 and 20.00, then there would be a shortage of electricity supply in that period. Therefore, additional power plants and power grid (transmission and distribution) capacity will be needed to cover the increased peak demand. The peak will also require very steep

Figure 12. EV electricity demand curve in on-peak charging (uncontrolled) scenario

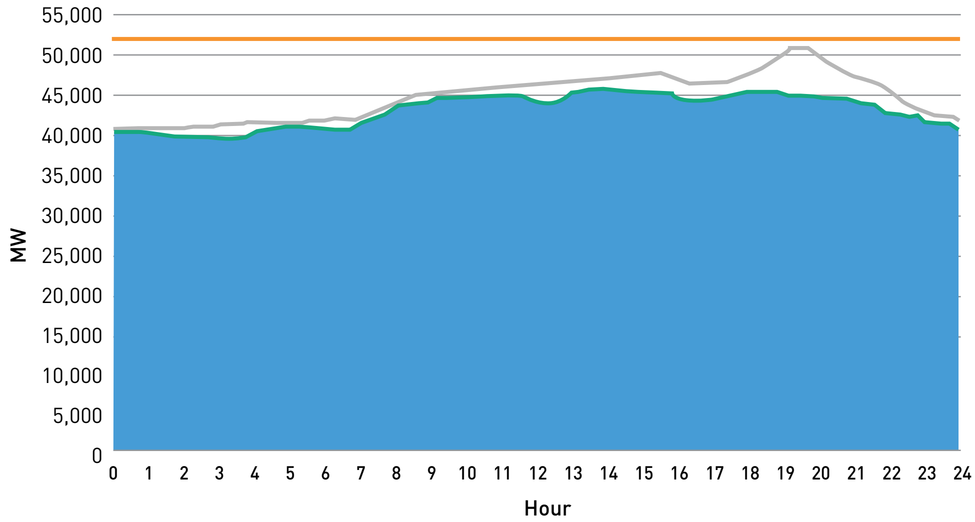
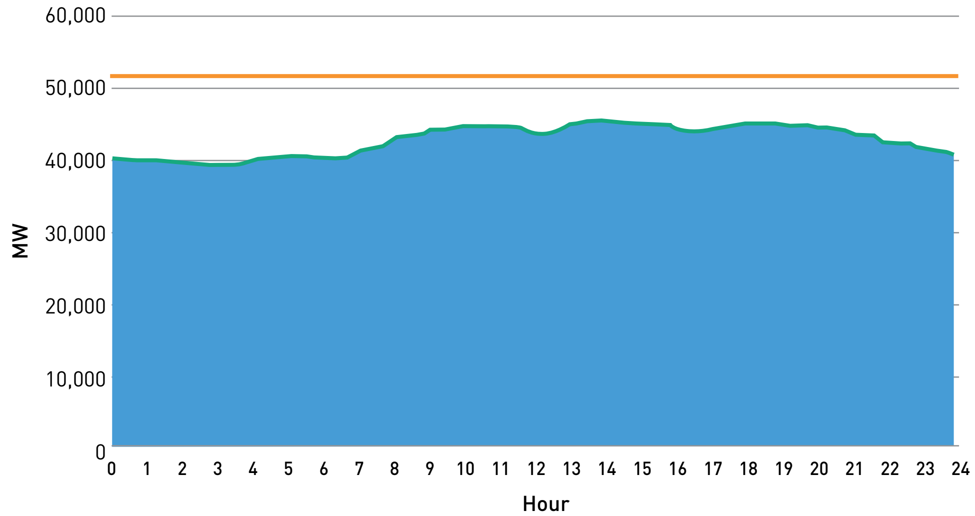


Figure 13. EV electricity demand curve in off-peak charging (controlled) scenario



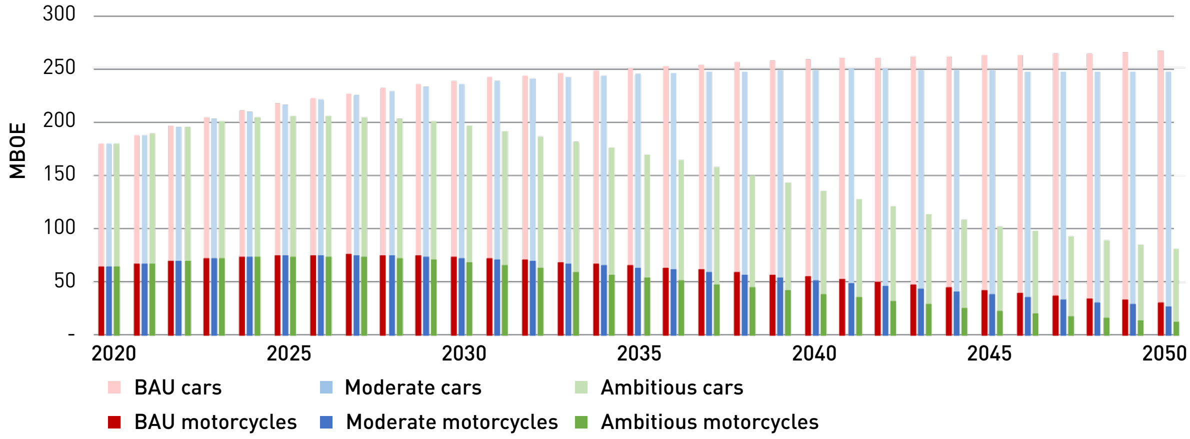
ramping up of around 3 GW/hour. The additional capacity will only serve roughly three hours per day. Hence, there is a need to utilize more off-peak charging.

Unlike peak charging, an off-peak charging scheme distributes off-peak hours of charging capacity throughout the day more evenly. Figure 13 shows that the additional power demand from EVs will not occur in peak hours, thus avoiding the need to add more power generation during those hours. This way, investment in new power plants and grids can be planned to fit the existing expansion plan. To achieve this scenario, policy instruments like TOU (time-of-use) charging tariff could be implemented as one example.

5.3.2. Impacts on oil fuel demand and imports

Shifting to EVs reduces oil fuel demand in transport compared to the BAU scenario. Figure 14 shows the fuel consumption in

Figure 14. Annual fuel consumption of passenger cars and motorcycles in various scenarios

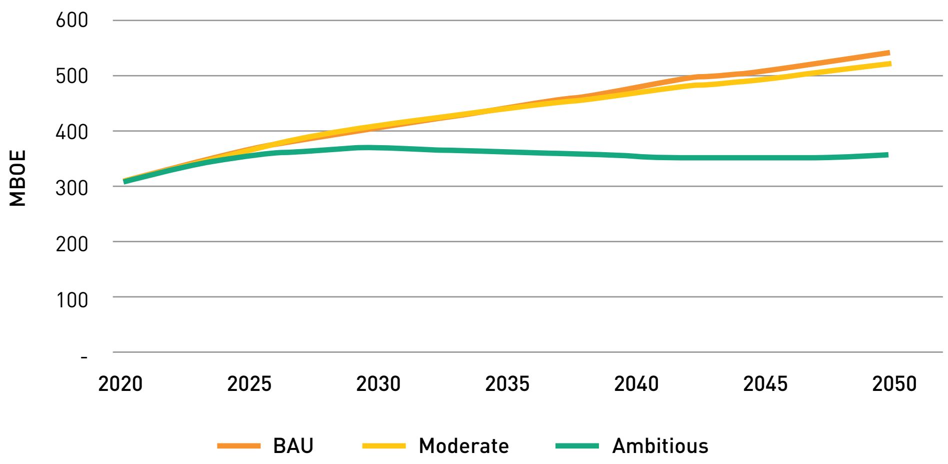


various scenarios. In the BAU scenario, oil consumption will slightly increase from 180 million barrels of oil equivalent (MBOE) in 2020 to about 233 MBOE in 2030 and 248 MBOE in 2050. The increase is stalled due to the relatively high penetration of electric motorcycles. Oil consumption by motorcycles will peak at 76 MBOE in 2027, then decline to 74 MBOE in 2030 and 32 MBOE in 2050. Meanwhile, consumption by passenger cars will keep increasing from 114 MBOE in 2020 to 159 MBOE in 2030 and to 216 MBOE in 2050. The proportion of motorcycles in fuel consumption declines from 36% in 2020 to only 13% in 2050.

The moderate scenario policies can only reduce the oil consumption by around 7% by 2050. In this scenario, the total oil consumption by personal passenger vehicles will peak already in 2038 at 237 MBOE, but only managed to decline to 229 MBOE by 2050. The contribution of motorcycle and passenger cars in fuel consumption is similar to the BAU scenario.

The ambitious scenario can reduce oil consumption more significantly by 16% (36 MBOE) in 2030 and by 67% (166 MBOE) in 2050 compared to the BAU scenario. For comparison, in 2018, the total oil import was 113 MBOE.

Figure 15. Annual fuel consumption of road vehicles (including cars, motorcycles, buses and freight vehicles) in various scenarios assuming no electrification of buses and freight vehicles



RUEN estimated that the oil import will be about 716 million barrels in 2030 and 1,469 million barrels in 2050. This means that the ambitious passenger EV penetration could reduce oil import by 5% in 2030 and 11% in 2050.

According to the RUEN projection, oil consumption by buses and trucks will increase from 40 MBOE and 91 MBOE in 2020 to 115 MBOE and 159 MBOE in 2050 respectively. If assumed that oil consumption by other road transport modes (trucks and buses) follows that projection, the total oil consumption will only increase to about 541 MBOE in the BAU scenario, 521 MBOE in the moderate scenario, and 356 MBOE in the ambitious scenario, as shown in Figure 15. This does not consider the electrification of both buses and trucks. This indicates that the high penetration of passenger EVs in the ambitious scenario can help to stabilize oil demand in the future, thus reducing the need for new refineries. With current development, domestic refineries will be able to process 630 MBOE by 2025 following the project planned in RUEN.

5.3.3. Impacts on carbon emission

Several reports have already pointed out that EVs do reduce the total GHG emissions in a country. In EU countries, the GHG emissions of EVs are 17% to 30% lower as compared to fossil-fueled vehicles over the entire lifecycle of the vehicles (EEA (European Environment Agency), 2018). In terms of total carbon emissions per km travelled, EU countries' average for EVs is equal to 88 gCO_2/km, which is remarkably lower than conventional cars with 142 gCO_2/km in 2010 (Buekers et al., 2014). On a global average, the carbon intensity of EVs are lower than ICEVs on a well-to-wheel basis (IEA, 2019b). Furthermore, a projection until 2030 made by IEA also estimates that EVs could offset emissions of about 220 MtCO_2 which would have been generated from conventional vehicles on a well-to-wheel basis (IEA, 2019b).

However, it has been long debated whether EVs can actually reduce CO_2 emissions when lifecycle emissions are considered. While the emissions of fuel burning and electricity generation are more straightforward, the emissions of car component manufacturing, including batteries, is less well understood. Studies reported a range of battery manufacturing emissions from 56 to 494 kgCO_2e/kWh battery capacity, due to different assessment methodologies, involving different locations of battery production (Hall & Lutsey, 2018).

IESR (2019) estimated that under the current electricity generation mix, the GHGs emitted by EVs are lower than conventional vehicles if the calculation is only based on vehicle use emission (from fuel cycle and tailpipe). However, if vehicle manufacturing emissions (including battery production) are considered, electrification will in fact increase GHG emissions. The operational data is based on MPV cars data projection for 2025, assuming an annual travel distance of 150,000 km, ICEV fuel consumption of 16 km/l gasoline, and EV electricity consumption of 5.6 km/kWh. Due to limited data, the emissions data of vehicle manufacturing is obtained from China (Qiao et al., 2017).

Using the same assumption, it is estimated that in order to achieve net emissions reduction, the grid emission factor must be at least 734 gCO_2/kWh generation. Table 6 shows the relationship of the grid emission factor to the emission reduction that can be achieved by shifting to EV. Furthermore, the emissions from battery production is expected to decrease in the future with more efficient production and reuse or recycling of batteries after its lifetime.

According to the RUEN, the grid emission factor could decrease from 800 gCO_2 per kWh

Table 6. Relationship of grid emission factor to emission reduction potential of EVs

Emission reduction	0%	10%	20%	30%	40%	50%	58%
Grid emission factor (gCO_2/kWh)	734	608	482	356	231	105	0

in 2015 to 400 gCO_2 per kWh in 2050. The current RUPTL 2019–2028, however, shows slower progress in decarbonizing the power sector. It projects that the emission factor in 2028 will stay at 0.7 tCO_2 per MWh, significantly higher than around 530 gCO_2 per kWh as estimated by RUEN. For this report, it is assumed that the emission factor will follow the RUEN projection, but is adjusted to be seven years slower to fit with the current RUPTL plan, getting to 420 gCO_2 per kWh by 2050. In comparison, the potential emission reduction with a more ambitious decarbonization effort in the power sector is also considered. The GHG emission of passenger vehicles in different EV penetration scenarios and different generation mixes is presented in Figure 16.

In the BAU scenario, with very low penetration of EVs, the GHG emissions of passenger vehicles resembles the fuel consumption. Emissions will increase from 71 $MtCO_2e$ in 2020 to 96 $MtCO_2e$ in 2030 and 110 $MtCO_2e$ in 2050. Emissions from motorcycles will peak by 2029 at 31 $MtCO_2e$ and drop to 17 $MtCO_2e$ in 2050, driven by the high penetration of electric motorcycles with much higher efficiency than conventional motorcycles. Emissions from cars will increase from 45 $MtCO_2e$ in 2020 to 93 $MtCO_2e$ in 2050 with no sign of reaching a peak.

In the moderate scenario, GHG emissions are only reduced to 4% lower than in the BAU scenario. This limited GHG emission reduction is due to relatively high emissions in electricity generation, diminishing the role of EV penetration to emission reduction. Similarly, in the ambitious scenario, the GHG emissions are reduced to 61 $MtCO_2e$ in 2050, or 45% lower than in the BAU scenario; this is less significant than the reduction in oil consumption that could reach 67% in the same year.

With more ambitious decarbonization in the power sector through a coal phase-out policy (Arinaldo et al., 2019), the potential emission reduction is remarkable, especially for the ambitious scenario. In the moderate scenario, emissions could be reduced by 10% instead of 4% and in the ambitious scenario, it could be reduced by 65% instead of only 45%.

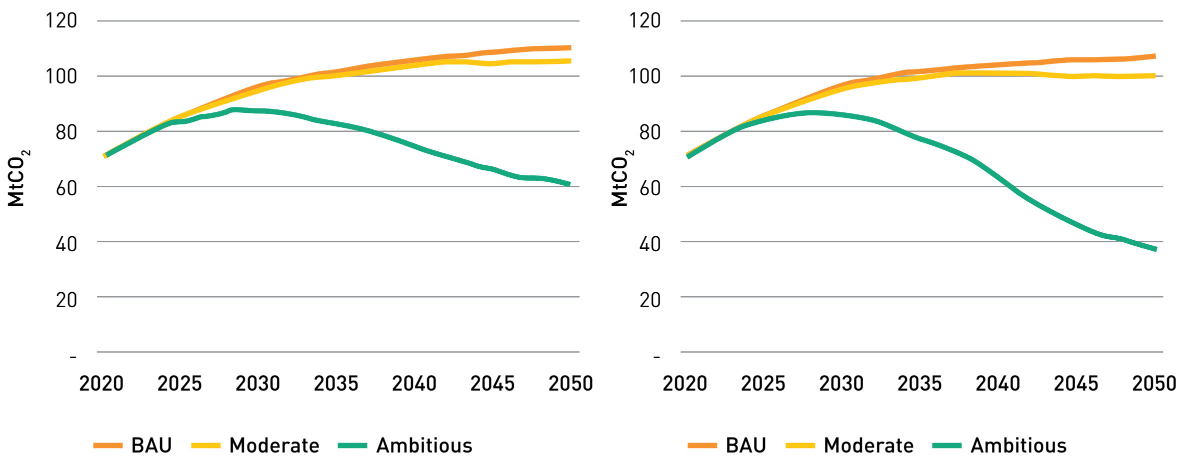
5.3.4. Impacts on state financial and investment

Each policy mentioned in the previous chapter requires financial support or investment by either the government or the private sector. From previous analysis, it is clear that there are two major policy instruments that require significant investment: tax incentives and charging infrastructure.

Impact of tax incentives

Tax incentives for EVs constitute the main

Figure 16. Annual GHG emissions of passenger vehicles in different scenarios assuming the RUEN generation mix (left) and coal phase-out generation mix (right)



policy tool that has the largest influence on EV penetration in the passenger car sector. Implementing this will result in revenue reduction for the state and local government. However, tax increases for ICEVs will generate revenue for the government. These tax increases will be just as important after the reintroduction of taxes on EVs in later years.

Figure 17 shows the tax revenue from vehicle sales in the different scenarios.[6] There is almost no difference in government revenue in the moderate and BAU scenarios, even though the import-related taxes are not taken into consideration in the moderate scenario. This means that, if import duty and import income tax are removed, without increasing taxes on conventional vehicles, the government can push for a 15-fold increase in EV penetration without losing revenue from taxation.

Meanwhile, there is quite a significant loss of government revenue under the ambitious scenario during 2023 to 2025, when all taxes are exempted for PHEVs and BEVs. After 2025, with incremental reintroduction of taxes for EVs and increasing taxes for ICEVs, the tax revenue starts to catch up with the BAU scenario. By 2030, increased taxes on ICEVs will already cover the revenue loss due to EV tax reduction.

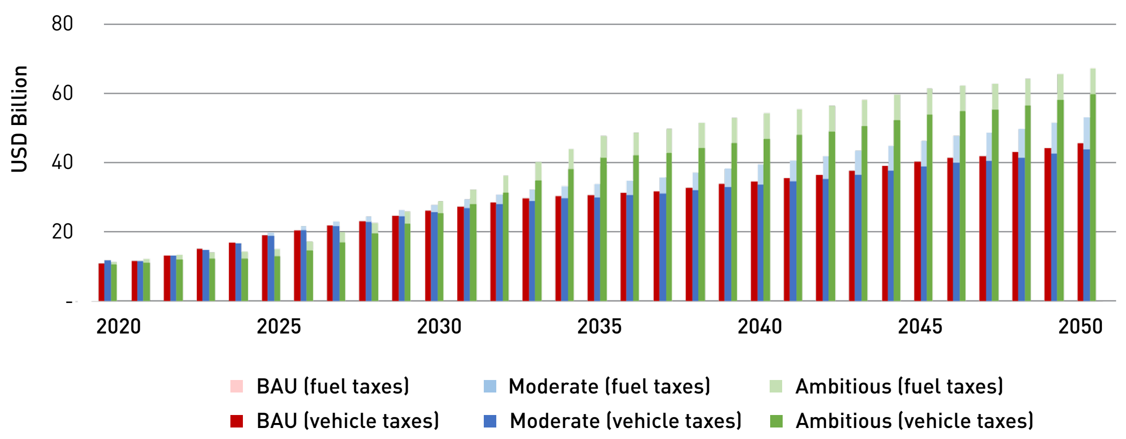
As well as vehicle taxation, carbon tax on fuel consumption, implemented in the moderate and ambitious scenarios, will also generate revenue for the government. However, the imposed carbon tax is not sufficient to compensate for the revenue loss in the early years of the ambitious scenario (2021 to 2027). Meanwhile, in the moderate scenario, the carbon tax on fuel generates USD 800 million, which can cover the small revenue loss.

It is important to note that despite the relatively low contribution of vehicle sales-related taxation to the state revenue, its contribution could be more significant for provincial governments. Government revenue from vehicle sales taxes in 2016 was estimated to be IDR 91 trillion (USD 6.8 billion), or 6% of the total government revenue (Tempo.co, 2017). However, in Jakarta province, for example, the revenue from vehicle registration tax, annual tax, and fuel tax comprised 20% of the total revenue in 2019 (Upthumas, 2020).

Impact of charging infrastructure development

Since the availability of charging stations is paramount to EV uptake and also to sustain EV operation over time, significant investment will be needed in this area. The BAU scenario

Figure 17. Government revenue from vehicle sales and fuel taxes in different scenarios



6 The annual tax is calculated based on 10 years vehicle operation. While in reality the vehicle price used for the annual tax is depreciated over time, in this calculation the vehicle price is assumed to be constant.

suggests that currently there are only around 7,000 slow chargers in Indonesia. While it is found that development of public slow-charging stations positively correlates with a high number of EVs, especially for countries that do not fully maximize home-charging capabilities, no correlation has been found between EV share and DC fast-charging points in general (Funke et al., 2019). Thus, one of the key takeaways is that first, home-charging capabilities have to be improved, and then slow-charging public charging points need to be built, mainly to eliminate range anxiety among consumers and to also support consumers who do not have access to home chargers. The development of public slow chargers is meant to reduce consumers' range anxiety. Thus, the emphasis should be put on how to grow the number of charging stations and distribute them across the country. In estimating the number of necessary public slow chargers, the overall number is taken as aggregate for both electric cars and motorcycles. As previously mentioned, the focus is on providing charging stations to ease the range anxiety and not to cater for all the power demand from EVs.

For public slow chargers with power rated between 7.2 kW and 22 kW, data from Europe, India and the United States show that they cost less than USD 2,000 (Suehiro & Purwanto, 2019). Since India has a similar situation to Indonesia, and both have not yet gained economies of scale for EV chargers, the pricing scheme is taken as a benchmark for Indonesia. Table 7 describes the price breakdown for a slow charger.

On the basis of the information above, the investment needed for charging infrastructure in each scenario could be estimated. The results are shown in Table 8.

As can be seen from Table 8, the total investment for the BAU and moderate scenarios are quite close. Yet when compared to the ambitious scenario, the gap is very wide. This is due to the fact that in the ambitious scenario, many more chargers are set to be developed. Given the high cost presented by charging stations, the government may not bear all the burden. Thus, private sector engagement

Table 7. Slow charger cost breakdown

Component	Cost (USD)
Slow charger (AC-2)	USD 1,058
For every six chargers	
Electricity connection, cabling, panels, etc	USD 2,810
Civil works	USD 1,058
Electric Vehicle Supply Equipment (EVSE) management system	USD 750

Source: author's estimation

Table 8. Total public charging investment for each scenario (USD)

Scenario	2025	2030	2050
BAU	1,350,000	2,450,000	6,300,000
Moderate	6,750,000	12,700,000	38,400,000
Ambitious	181,000,000	345,000,000	1,072,000,000

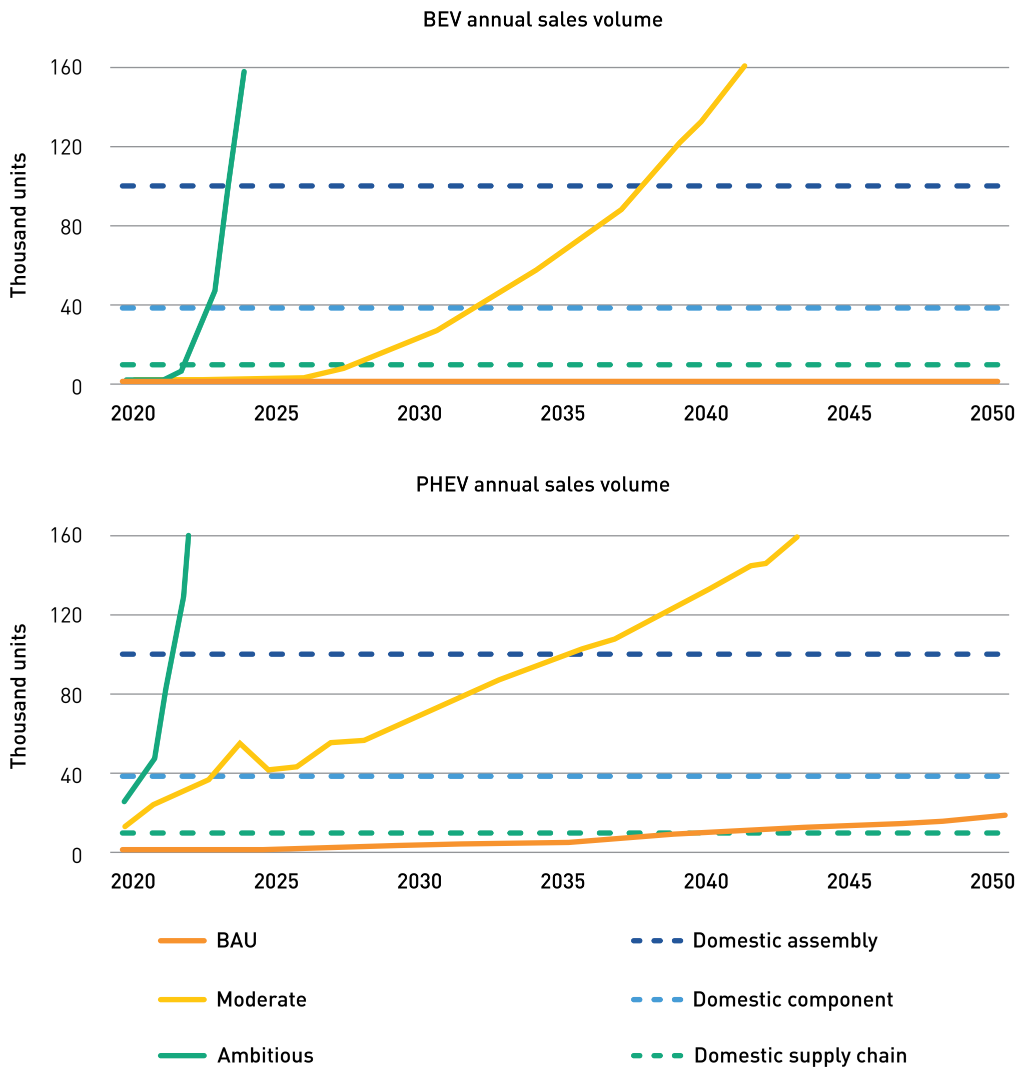
becomes crucial. The remaining challenge is to convince private investors that the investment would be profitable even though there are still very small numbers of EVs around.

5.3.5. Impacts on domestic automotive manufacturing capacity and the economic opportunities

With increasing EV penetration, it only makes sense to establish domestic manufacturing industries, both for end products and the necessary components, including electric motors, electric controllers and batteries. Without this, the ICEV industries will be driven out of business, bringing significant job losses and economic disruption. In 2017, the automotive industry and trading in Indonesia contributed 2% and 2.5% of national GDP respectively. The automotive manufacturing industry employed 35,000 workers, the components industry employed 480,000, and the service and spare parts outlets employed 2.5 million, in total contributing to about 2.5% of the national workforce.

To provide a context of how big the EV market will need to be to attract new investment, for example, DFSK, a Chinese car manufacturer has built its 50,000-unit annual capacity assembly line in Indonesia while only targeting 12,000 sales in its second year (Priyanto, 2018; Sudarwan, 2019c). With only less than 3,000 sales in 2019, it has already planned to build the engine manufacturing facility next to the assembly facility. Another example, Nissan

Figure 18. Sales volume of BEVs and PHEVs in various scenarios



(together with Datsun), had just about 40,000 in sales when it built its engine and transmission factory in 2016 (Gaikindo, n.d.; Khoirudin, 2016). Figure 18 shows the sales volume of electric cars in the different scenarios.

In the BAU scenario, the market share of electric cars is most probably not sufficient to attract the investment for domestic manufacturing in the next 10 years. The annual electric passenger car sales can only reach 10,000 sales by 2030 and 40,000 in 2049.

In the moderate scenario, PHEV sales will jump, exceeding 10,000 in the first year and reaching 40,000 by 2025; this will attract investment in domestic manufacturing, at least for the PHEV. Meanwhile, BEVs and HEVs will struggle to reach even 1,000 sales. BEV sales will only reach 10,000 by 2028 and 40,000 by 2032. With the relatively low domestic demand, car manufacturers might still build manufacturing facilities with export orientation. However, this requires more supply-side incentives to be competitive in the export market.

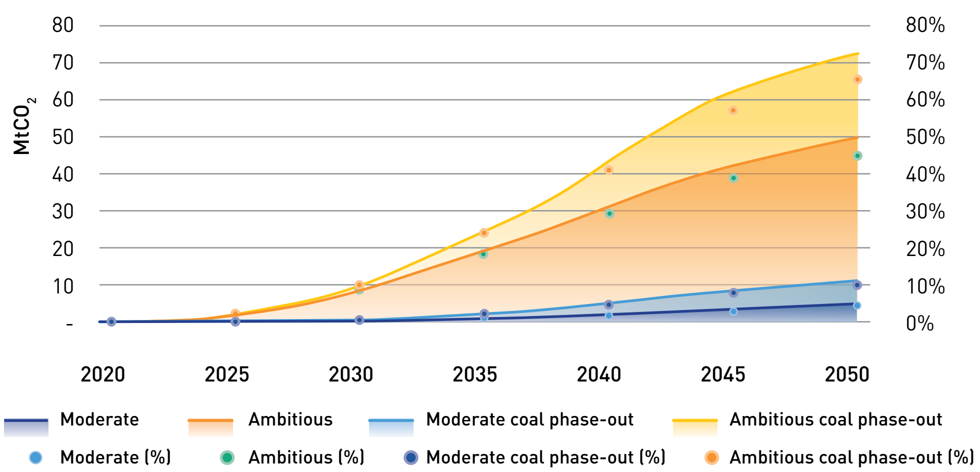
In the ambitious scenario, the EV market will undoubtedly be large enough to attract investments for local EV components production. PHEV sales will achieve 25,000 in the first year and exceed 100,000 by 2022. For BEVs, the trend takes off slightly more slowly and will reach 100,000 in sales by 2024. In comparison, only five major brands are currently selling more than 100,000 per year, with car models that have local content higher than 80% (Damara, 2020; Rafael, 2017; Sudarwan, 2019a, 2019b). With such high sales, manufacturers will be willing to establish a domestic supply chain, which results in higher local content.

In addition, a study showed that the raw materials for the automotive industry are mostly imported, including aluminium alloy, metal alloy, hot rolled steel, cold rolled steel, steel rod, plastic materials (such as acrylonitrile butadiene styrene and polypropylene), silicone, etc. They also showed that most components that require precise machining (bearing, gear, bolt, piston, etc.) and electronic parts (electronic control unit, sensor, camera, integrated circuit, semiconductor, etc.) are also mostly imported. These components will still be needed in future EV industries, especially the electronic parts (Japan International Cooperation Agency (JICA) & Nomura Research Institute Ltd, 2019).

6. Accelerating EV adoption to enhance Indonesia's NDC and GHG emissions reduction

Indonesia pledged to reduce the emissions from the energy sector by 314 $MtCO_2$ by 2030 or by 398 $MtCO_2$ by 2030 with international support. This pledge was reflected in the first Indonesian NDC (2016). In the moderate scenario, the emissions reduction in 2030 will be only 0.3 $MtCO_2$ if the power generation mix follows the RUEN projection. If the coal phase-out scenario is adopted, the emissions reduction in 2030 will be 0.6 $MtCO_2$, which is less than 1% of the cars and motorcycles emissions in the BAU scenario. The ambitious policy scenario can reduce emissions by 9% (8.4 $MtCO_2$) with the RUEN-projected generation mix or by 10% (9.6 $MtCO_2$) with coal phase-out compared to the BAU baseline in 2030. Meanwhile, in 2050, the emissions reduction achieved in the moderate scenario will be 4% (RUEN generation mix) or 10% (coal phase-out) from the BAU baseline. In the same year, the ambitious scenario will reduce emissions by 45% (RUEN generation mix) or by 65% (coal phase-out) against the BAU baseline.

Figure 19. CO_2 emission reduction through passenger EV penetration in different scenarios in $MtCO_2$ (line) and in percentage terms compared to the BAU baseline (points)



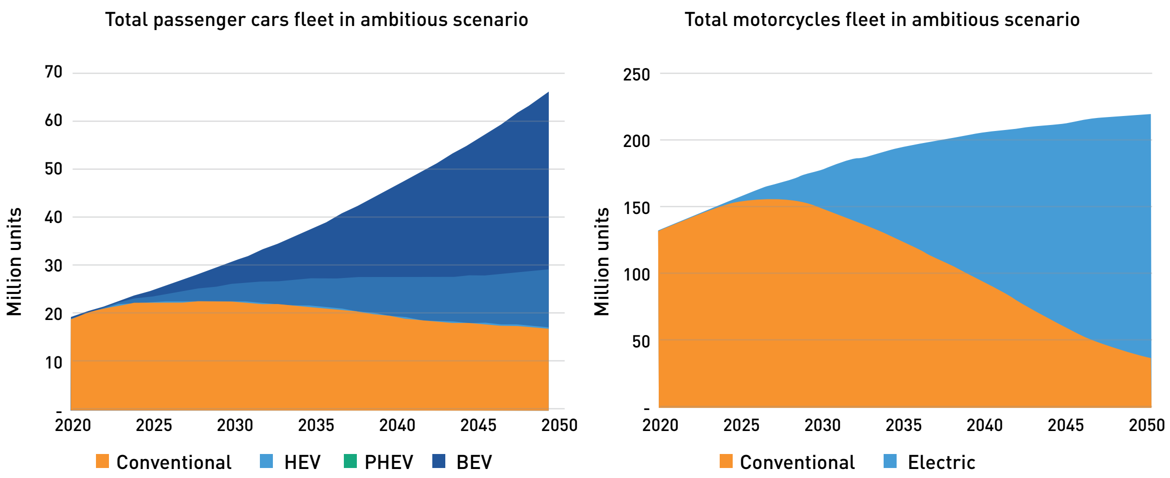
6.1. Impact of vehicle electrification on GHG emissions reduction

The projection shows that in the long term, the transition to EVs together with power sector decarbonization could reduce GHG emissions from the transport sector significantly. However, in the shorter term, until 2030, the impact on emissions reduction is much less remarkable. Even in the most ambitious scenario, the emission reduction from transition to EV will only contribute a cut of 10 $MtCO_2$, or about 3% of the emissions reduction from the energy sector targeted under Indonesia's NDC. The contribution is even less than 1% of the required emissions reduction to achieve Indonesia's fair share in keeping global warming below 1.5°C according to CAT. However, in 2050, the ambitious scenario with a cleaner generation mix can reduce emissions by 72 $MtCO_2$, or almost 6% of the emissions reduction needed (excluding LULUCF) to move from the 3°C trajectory to the 1.5°C trajectory.

This emissions reduction from EV adoption is less immediate than fuel-switching policies, such as the biodiesel blending (B30) policy. For example, implementation of B30 in 2020 is expected to reduce emissions by 14 $MtCO_2$ (Ministry of Energy and Mineral Resources, n.d.). EV adoption contributes less to short-term emissions reduction since it takes a considerable amount of time to replace the existing ICEV fleets with the electric ones, as indicated in Figure 20.

In an impossible scenario with 100% EV sales from 2020, it will take until 2040 to replace all the existing ICEVs. In this case, with a cleaner generation mix, EVs will reduce 90% of GHG emissions from cars and motorcycles by 2045. If the 100% EV sales occur later, the significant impact of emissions reduction will also be delayed. With the 2050 emission target in mind, putting a ban on conventional vehicles will be necessary by 2035. In implementing the ban, conventional vehicles would almost disappear by 2050, accounting for less than 5% of the total fleet. This is in line with the suggestion by CAT to stop ICEV sales by 2035 to 2040 (Climate Action Tracker, 2019b). This is also in accordance with many other countries that already announced bans on fossil-fueled vehicles in the near future, including Norway, Sweden, Ireland, Nepal, Scotland, and others (Partnership on

Figure 20. Share of conventional and electric vehicles in the total passenger cars and motorcycles fleet in the ambitious scenario



Sustainable Low Carbon Transport, 2019).

This does not negate the need to start EV adoption as soon as possible to achieve long-term results. Early EV adoption is also important to develop the industrial capacity required to meet needs in later years. Meanwhile, the implementation of quick-win measures, such as biofuel, as a transition, is necessary to reduce emissions in the short term with consideration of full lifecycle emission of the feedstock.

6.2. Decarbonizing the power sector is important to improve EV emissions reduction potential

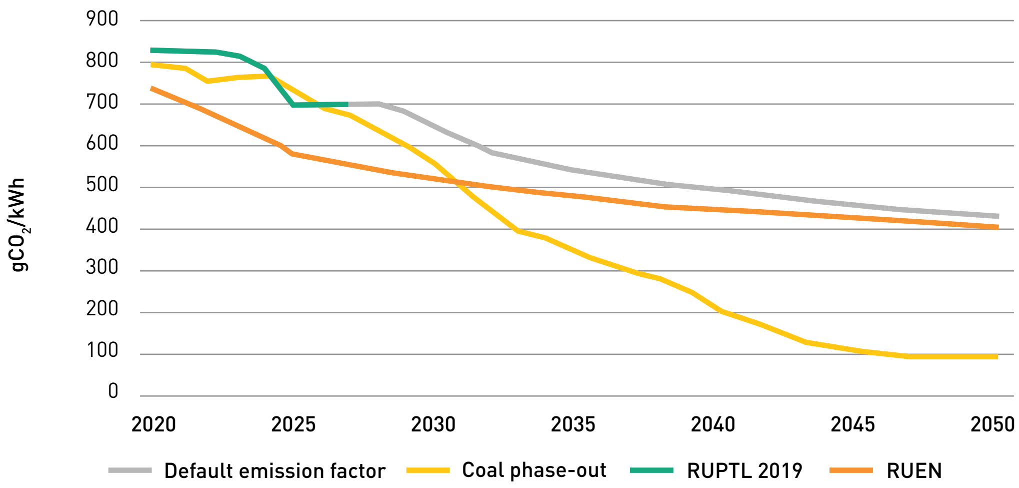
The projection shows that decarbonization of the power sector can further reduce GHG emissions from the transport system. Even in the moderate scenario with limited market penetration of EVs, the coal phase-out policy could reduce another 6% of GHG emissions from private passenger vehicles by 2050. In the ambitious scenario, the coal phase-out policy could reduce emissions even further, cutting another 20% of GHG emissions.

Figure 21 shows the different projections of electricity generation emissions factors. RUPTL 2019 (blue line) planned to lower the emission factor to 0.7 by 2025 by increasing the renewable portion to 23% of electricity generation. This emission factor is still considerably higher than planned in RUEN (red line). The default emission factor used in this study is set as RUPTL until 2028, then followed by the RUEN projection with a seven-year delay (grey line). The coal phase-out policy (Arinaldo et al., 2019) can reduce the emission factor further than under RUEN, assuming the growth of other fossil-fueled power plants stays at the current rate (yellow line). In the coal phase-out scenario, the electricity generation will comprise 78% renewables and 22% natural gas in 2050.

However, the recent trend in the power generation mix has not shown as much progress as planned in RUEN, and even RUPTL. According to the last three editions of Climate Transparency's *Brown to Green Reports*, the emissions factor of Indonesia's power sector is increasing rather than declining, from 0.734 tCO_2/MWh in 2014 to 0.761 tCO_2/MWh in 2018 (Climate Transparency, 2017, 2018, 2019). On a similar note, the share of renewables in the generation mix has stagnated since 2011, and has even been declining since 2016 (IESR, 2019). Actual growth of renewables installed capacity has always been lower than planned in RUPTL (IESR, 2018). On the other hand, the coal proportion in the generation mix has been increasing and exceeded 60% in 2019 (Ministry of Energy and Mineral Resources, 2020).

To maximize the GHG emissions reduction benefit of EVs in the long term, the government needs to decarbonize the power sector.

Figure 21. Indonesian electricity emissions factor projection under different generation mix scenarios



Source: authors' own, based on data from RUEN, RUPTL 2019-2028, and Arinaldo et al. (2019)

Considering the amount of investment required, the need for technical planning and adaptation, and the socio-economic impact, decarbonization is not going to happen overnight. Instead, to avoid disruptive transition, it must be planned thoroughly and started sooner rather than later. Supportive regulations are necessary to move from the current renewables stagnation trend (IESR, 2019).

6.3. Policies for EV adoption

This study finds that a taxation scheme based on (tailpipe) CO_2 emissions is an important instrument to help create EV competitiveness, especially for electric cars which currently are more costly than the conventional cars. Additionally, tax exemption, especially the import-related taxes, is necessary in the earlier period to allow electric cars to penetrate the market and later attract manufacturers to build domestic factories.

Once the upfront cost of EVs becomes more competitive, the availability of public-charging infrastructure becomes more influential. This is more apparent in the motorcycle market, which sees only a slight price difference between electric and conventional motorcycles. PLN will not be able to provide all the public chargers required, and therefore suitable business models that can attract investors need to be developed.

According to the model, even the implementation of all measures in the ambitious scenario will not manage to achieve 100% EV sales by 2040 as required to comply with CAT's 1.5°C pathway. This indicates that demand-side financial incentives alone are not sufficient to fully transition to EVs. Other types of policy instruments are needed as non-financial incentives for consumers, such as banning conventional vehicles from urban centres (low-emission zones). On the supply side, fuel economy standards are championed as an important tool to force manufacturers to shift to EVs, along with other supply-side financial incentives such as tax holidays for importing components and income-tax breaks.

According to IEA, in addition to those instruments, for an early EV market, it is essential to establish vehicle and charger standards before accelerating EV adoption. Public procurement schemes can be helpful as promotion tools and can drive initial market demand. Public procurement can be implemented through public transport (bus) operators or official vehicles of government officials, both central and local government (IEA, 2019a).

Photo by Noah Negishi on Unsplash

7. Conclusion and policy recommendation

Electric vehicles have significant GHG emissions reduction potential in the long term. However, given Indonesia's current market, existing regulations and industrial situation, EVs face challenges in penetrating the vehicles market. Without any improvement, as stated in the BAU scenario, electric cars penetration is expected to stay below 1% of market share until 2050. However, electric motorcycles are expected to cover 67% of market share by 2050. With the government's existing planned policies (i.e., the moderate scenario), the EV penetration is predicted to reach 14% for cars and 75% for motorcycles by 2050. With more ambitious policy interventions, the EV market share is expected to reach 85% for cars and 92% for motorcycles by 2050.

To achieve a high EV market share and significant emissions reduction, supportive policy instruments are necessary. The policies are aimed at providing incentives for EVs and disincentives for ICEVs. The instruments include fiscal incentives (both upfront and recurring), non-financial incentives, and regulatory incentives. These instruments are widely adopted in other countries with high EV penetration. Based on this study, there are several policy instruments that are necessary to drive EV penetration in Indonesia.

1. Policy instruments to incentivize purchase of EVs:
   - Increasing public charging infrastructure investment, both by public and private funds. Up to 2030, this will need USD 345 million in investment for public charging infrastructure to achieve the high EV penetration (for a greater than 50% car and motorcycle share by 2030). In order to attract private investment, policies need to facilitate viable business models with attractive payback periods, for example by providing lower electricity tariffs compared to the household tariff. This intervention is especially important in accelerating EV adoption in motorcycles, which is the main transport mode.

- Transforming the existing taxation scheme into one based on tailpipe CO_2 emissions. The initiative by the Ministry of Finance to base the luxury tax on tailpipe CO_2 emissions is a good start. Additionally, CO_2 emissions can also be a factor in calculating registration tax and annual tax. The new taxation scheme can also consider tailpipe air pollution.
- Providing purchase incentives that can create EV competitiveness – for example, tax exemptions. Until 2025, exemption from import-related taxes alone would increase electric car penetration seven-fold approximately, but exemption from all taxes would increase penetration more than 100-fold. This can be done without significant revenue loss in most of the years.
- Providing non-financial incentives for EV users as commonly adopted in other countries – such as road toll exemption, free parking, and low-emission zones. For certain cities, such as Jakarta, additional incentives could be imple-mented, namely freedom to use bus lanes and exemptions from the odd-even policy.
- Creating an initial market through public procurement of EVs. Electrifica-tion of public buses and official vehicles for government officials should be initiated. This could signal to the market the government's willingness to develop EVs.

2. Policy instruments to disincentivize purchase of ICEVs:
   - Discouraging people from buying and using conventional vehicles by increasing the fuel price, through fuel quality standard improvement and a carbon price. Fuel quality standards are necessary to reduce local air pollution, while a carbon price can increase state revenue to cover the revenue loss from EV tax exemption.
   - Establishing a mandatory fuel economy standard to reduce transport emissions while EVs are not yet competitive. As a benchmark, the Global Fuel Economy Initiative targets the global fuel economy in order to reach 4.4 liter gasoline equivalent per 100 km by 2030. In addition, mandatory fuel economy standards are also helpful to push manufacturers into developing and producing EVs domestically. This will need to be accompanied with other incentives for manufacturers such as tax exemptions from certain component imports and tax holidays.
   - Banning sales of conventional vehicles for both passenger cars and motorcycles by 2035 to accelerate the phase-out of conventional vehicles from the road. Banning conventional vehicle sales by 2035 will practically eliminate conven-tional vehicles by 2050, leaving fewer than 5% in operation.

3. Policy instruments to address the implications of EV penetration to power sector:
   - Decarbonizing the power sector through increasing renewable energy and reducing coal consumption in electricity generation. There should be no more new coal-fired power plants planned other than those planned in RUPTL 2019–2028. Coal power plants' operational lifetimes should be limited to 20 years, meaning no emissions from coal combustion after 2047. This will increase renewables' contribution to 78% of the generation mix while the rest is supplied by gas.
   - Introducing different electricity tariffs for peak and off-peak periods (dynamic pricing). This will be necessary to manipulate EV charging times and avoid an increase in peak demand that could reach 6 GW in 2028, and even higher in the long run. Additionally, this policy could boost EV penetration through lower electricity costs for EV users.

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Appendix A

Electric Vehicle Market Penetration Model

I. Introduction

The model aims to estimate market shares for electric passenger vehicles (cars and motorcycles) of the total passenger vehicles sales in each year, from 2019 until 2050 in Indonesia. Subsequently, the model yields emissions reduction and oil consumption savings from the forecasted electric vehicles (EV) penetration. Additionally, it would also generate the charging infrastructure needed to cater for the uplift in electric vehicles.

With regard to passenger cars, the model divides these into four classes based on the similarity in size and price:

1. Small cars
2. Sedan
3. Multi-purpose vehicle (MPV)
4. Sport utility vehicle (SUV)

Each class is further broken down into three groups of vehicle technology: fossil-fueled, hybrid, and electric. Depending on the class of the vehicle, there could be a further breakdown into conventional and low-cost green car (LCGC) for the fossil-fueled vehicle category; and also fully-hybrid and plug-in hybrid vehicle for the hybrid category.

In contrast to passenger cars, motorcycles are only categorized based on two different vehicle technologies, namely conventional and electric motorcycles.

Therefore, the market shares are found for each mode (passenger cars and motorcycles) based on the class and the technology of the vehicle. These market shares are then adjusted with a sigmoid curve that represents technology diffusion over time. It captures the various other factors that are not seized by the nested multinomial logit model.

II. Methodology

In order to estimate the market shares for each transport mode, the model employs nested multinomial logit (NMNL). This is chosen due to the nature of the NMNL model that solves discrete choice problems. Essentially, the discrete choice problem arises where there are a fixed number of possibilities as the outcome. In this case, there are a fixed number of choices regarding vehicle class and technology. The model would determine the probability of choosing one vehicle over others, which ranges from 0 to 1, based on the value of the vehicle. To assess the value of each vehicle, consumer utility function is used. The consumer utility function is affected by several factors and out of all possible factors, a few vehicle and fuel attributes that are considered most influential are selected:

- vehicle purchase price
- vehicle fuel economy
- vehicle range
- vehicle acceleration
- vehicle maintenance cost
- fuel availability (including home charging).

Each factor has a different weight to the utility value, therefore different coefficients are needed to represent the sensitivity. The coefficients for passenger cars choice are gathered from AEO Outlook 2010 which calibrates the numbers based on historical patterns of consumers in the United States. For motorcycles, the coefficients are calibrated based on consumers' behavior in Vietnam.

The utility function is given as:

$$U = \sum \beta i.Xi$$

Where X stands for the value of each attribute of a vehicle for a consumer and β represents the coefficient that weighs the attribute to the overall utility value. Then, the probability of choosing a vehicle is found by using the equation below:

$$P = e^{Ui}/\sum e^{Ui}$$

Essentially, the probability is the ratio of the exponent of utility function for a vehicle over the sum of the exponents of utility function for other vehicles.

Furthermore, as mentioned above, a set of technologies are chosen for this model and they are bound in various size classes of vehicles. Since there could be interaction between similar technologies, the model eliminates the confusion caused by that interaction by grouping technologies with similar characteristics and then comparing each group.

The size classes and the technologies groupings are listed as below:

- Small cars
  - Fossil-fueled:
    - Conventional
    - LCGC
  - Hybrid:
    - PHEV
    - HEV
  - Electric:
    - BEV
- Sedan
  - Fossil-fueled:
    - Conventional
  - Hybrid:
    - PHEV
    - HEV
  - Electric:
    - BEV
- MPV
  - Fossil-fueled:
    - Conventional
    - LCGC
  - Hybrid:
    - PHEV
    - HEV
  - Electric:
    - BEV
- SUV
  - Fossil-fueled:
    - Conventional
  - Hybrid:
    - PHEV

    - HEV
- Electric:
    - BEV

To generate the probability of choosing one vehicle based on the structure above, two stages of nesting are used. The first level of nesting calculates the consumers' choice probabilities within the same group of technologies (conventional, hybrid, and electric); and then the model calculates the probability of choosing between one group and the others. Hence, the final market share for a specific technology in a vehicle class would be the product of probability in the first nest multiplied by the probability of the second nest that contains the technology.

Before the first nest, calculations are made only for vehicle technologies capable of operating on more than one fuel: flexy engine and PHEV. The purpose of this calculation is to determine the proportion of miles the consumer will drive on each fuel. This in turn determines the cost to drive a mile, which is required in the subsequent nest.

III. List of assumptions

1. **Vehicle price:** determined by estimating the price from representative vehicles within each class using their market share, and then scaled using the EV price from Thailand.

Vehicle purchase price (2018 USD)

Technology	Small Car	Sedan	MPV	SUV	Motorcycles
Conventional	17,047	38,459	20,126	31,874	1,341
HEV	24,448	39,924	42,187	52,460	-
PHEV	56,000	54,000	71,024	85,796	-
BEV	40,590	63,272	70,284	85,581	1,800
LCGC	8,239	-	10,869	-	-

2. **Maintenance cost:** gathered from OEMs websites in Indonesia (e.g. Toyota, Mitsubishi, etc).

Maintenance cost in 2018 USD/year

Technology	Small Car	Sedan	MPV	SUV	Motorcycles
Conventional	198	284	212	284	42
HEV	190	280	208	280	-
PHEV	198	284	212	284	-
BEV	145	233	162	233	26
LCGC	127	-	172	-	-

3. **Range:** gathered from desktop research of each vehicle characteristic, with annual growth of 3%.

Vehicle range in 2018 (miles)

Technology	Small Car	Sedan	MPV	SUV	Motorcycle
Conventional	475	500	375	446	150
HEV	525	593	636	750	-
PHEV	518	600	556	510	-
BEV	100	125	150	187	50
LCGC	431	-	359	-	-

4. **MPG:** gathered from desktop research of each vehicle characteristic, with annual growth of 2.5%.

Fuel economy in 2018 (MPG)

Technology	Small Car	Sedan	MPV	SUV	Motorcycles
Conventional	45	38	32	31	145
HEV	50	45	49	47	-
PHEV	166	120	75	75	-
BEV	310	135	100	125	625
LCGC	49	-	38	-	-

5. **Acceleration:** gathered from desktop research of each vehicle characteristic, with annual decline of 0.7%.

Vehicle acceleration in 2018 from 0 - 60 mph (sec)

Technology	Small Car	Sedan	MPV	SUV	Motorcycles
Conventional	13.0	12.0	14.0	14.5	19.0
HEV	9.0	10.0	12.0	8.5	-
PHEV	8.0	10.0	10.0	9.2	-
BEV	8.0	9.5	10.0	8.0	9.0
LCGC	12.0	-	14.0	-	-

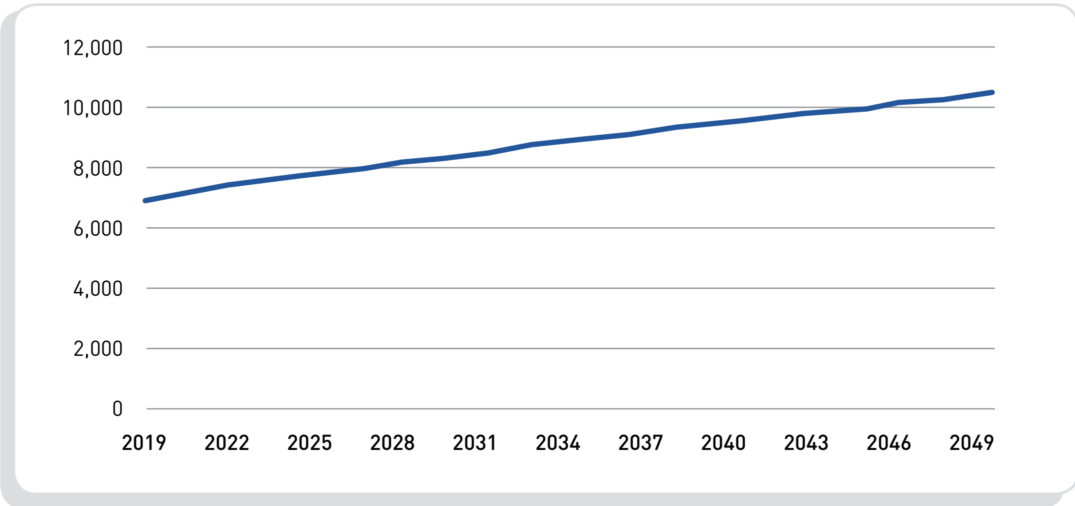
6. **Electricity price:** using the medium electricity tariff in Indonesia, and then forecasted using the national average electricity production cost. In 2018, the electricity price is taken as 195 USD/boe, with annual growth of 0.55%.

7. **Gasoline price:** using the RON 88 retail price in Indonesia, adjusted based on global oil price projection by EIA.

	2020	2025	2030	2035	2040	2045	2050
Electricity price (USD/boe)	197.15	202.63	208.27	214.06	220.01	226.13	232.41
Gasoline price (USD/boe)	83.87	84.06	84.24	84.42	84.60	84.78	84.97

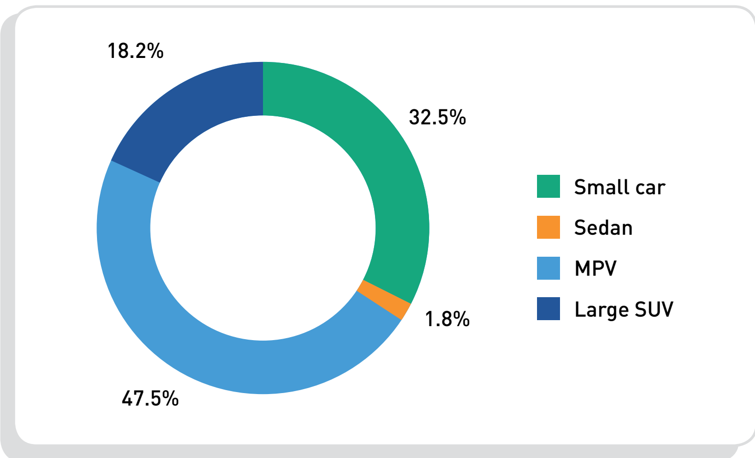
8. **Charging infrastructure:** modeled as the percentage of the best practice number of chargers per capita that is done by Norway, which is 1,950 chargers/million capita.

Number of charging stations in BAU scenario



9. **Market share for each vehicle class:** estimated from IPSOS Consulting data which forecast the market share for different vehicle size class in Indonesia.

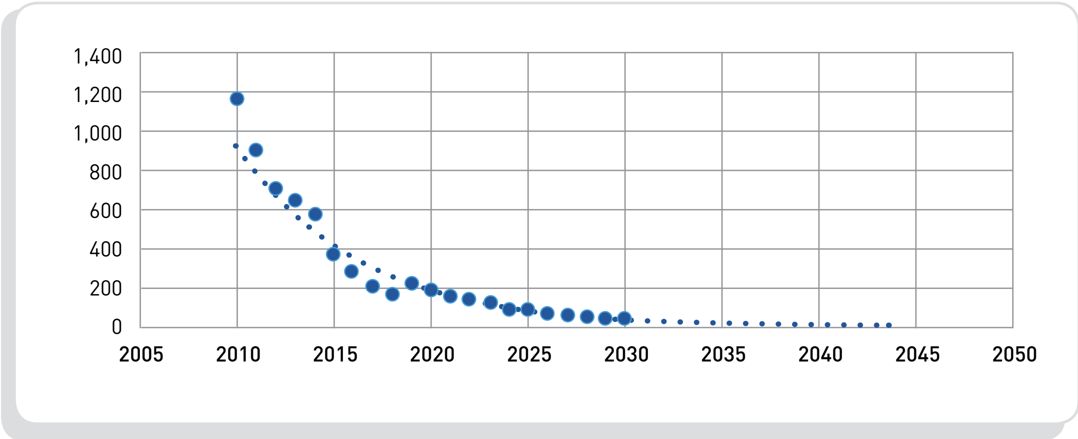
Vehicle sales share



10. **Home refueling availability:** an input of either 0 or 1 which represents the availability of home charging for a consumer.

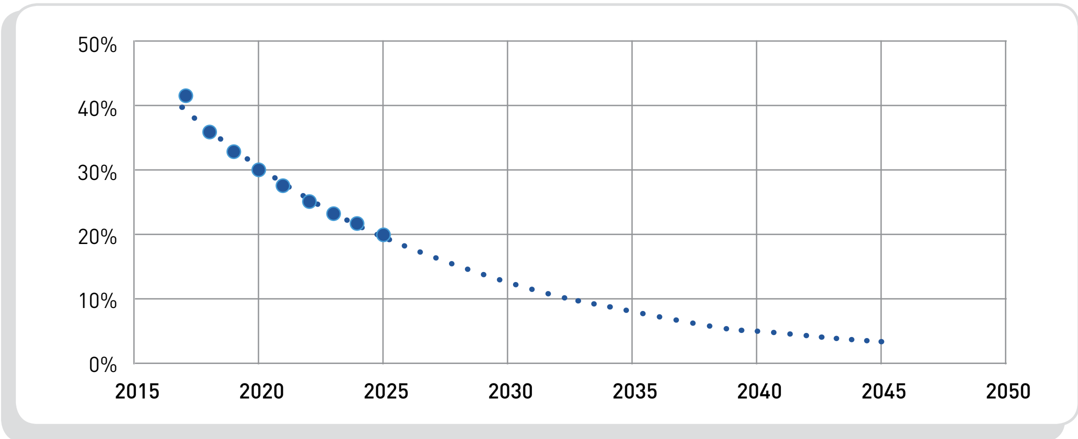
11. **Battery price decline:** determined from Bloomberg New Energy Finance (BNEF) forecasts.

Battery price forecast (USD/kWh)



12. **Battery cost share:** determined from global average data and then multiplied by the rough estimation of taxes costs of the entire EV from Indonesia Energy Conservation and Efficiency Society (MASKEEI).

Battery costshare



Appendix B

Table B.1 Difference between electric vehicle types

Electric vehicle type	Overview	Energy source	Charging infrastructure
BEV	Full-electric vehicle, completely battery powered	Electricity	Charging station
PHEV	Optimizes battery as main power, but uses a fuel generator (range extender)	Gasoline/diesel Electricity	Gas station + charging station (alternative)
HEV	Mostly fuel-powered, but uses small battery packs to improve fuel efficiency	Gasoline/diesel	Gas station
FCEV	Full-electric vehicle, completely fuel-cell powered	Hydrogen	Hydrogen station

Source: Ministry of Industry (2019)

Climate Transparency

Climate Transparency is a global partnership with a shared mission to stimulate a 'race to the top' in G20 climate action and to shift investments towards zero carbon technologies through enhanced transparency. Climate Transparency is made possible through support from the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU), through the International Climate Initiative, ClimateWorks Foundation and the World Bank Group.

https://www.climate-transparency.org/

IESR

The Institute for Essential Services Reform is a research and advocacy institution on energy and environment policy. It is a unique think tank because it combines in-depth studies and analyses of policies, regulations and the techno-economic aspects of the energy and environment sector, with strong public interest advocacy activities to influence policy change at the national, sub-national and global levels. We produce science-based analyses and studies, and provide technical assistance and capacity-building for policy-makers, businesses, civil societies and other stakeholders in need, and work in partnership with other state and non-state actors on specific projects and campaigns. IESR is independent from any government or business interests.

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