energies

Review

Electric Vehicles in Malaysia and Indonesia: Opportunities and Challenges

Ibham Veza [1], Mohd Azman Abas [2,*], Djati Wibowo Djamari [3], Noreffendy Tamaldin [1,*], Fitri Endrasari [3], Bentang Arief Budiman [4], Muhammad Idris [5], Anthony C. Opia [6], Firman Bagja Juangsa [4] and Muhammad Aziz [7,*]

[1] Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Durian Tunggal 76100, Malaysia; ibhamveza@utem.edu.my
[2] Automotive Development Centre, Institute for Vehicle Systems and Engineering, Universiti Teknologi Malaysia, Johor Bahru 81310, Malaysia
[3] Mechanical Engineering Study Program, Sampoerna University, Jakarta 12780, Indonesia; djati.wibowo@sampoernauniversity.ac.id (D.W.D.); fitri.endrasari@my.sampoernauniversity.ac.id (F.E.)
[4] Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, Bandung 40116, Indonesia; bentang@ftmd.itb.ac.id (B.A.B.); firman.juangsa@ftmd.itb.ac.id (F.B.J.)
[5] Perusahaan Listrik Negara (PLN), Engineering and Technology Division, Jakarta 11420, Indonesia; muhammad.idris@pln.co.id
[6] Department of Marine Engineering, Niger Delta University, Wilberforce Island 560103, Nigeria; chukwunonso@graduate.utm.my
[7] Institute of Industrial Science, The University of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan
* Correspondence: azman.abas@utm.my (M.A.A.); noreffendy@utem.edu.my (N.T.); maziz@iis.u-tokyo.ac.jp (M.A.)

Citation: Veza, I.; Abas, M.A.; Djamari, D.W.; Tamaldin, N.; Endrasari, F.; Budiman, B.A.; Idris, M.; Opia, A.C.; Juangsa, F.B.; Aziz, M. Electric Vehicles in Malaysia and Indonesia: Opportunities and Challenges. *Energies* **2022**, *15*, 2564. https://doi.org/10.3390/en15072564

Academic Editors: Gianpiero Colangelo, Fabio Orecchini, Fabrizio Zuccari and Adriano Santiangeli

Received: 16 February 2022
Accepted: 24 March 2022
Published: 1 April 2022

Abstract: In the roadmaps of the automotive industry, the electric vehicle (EV) is regarded as a crucial technology for the future of automotive power systems. The EV has become a top priority of major global car manufacturers and is expected to disrupt the road transportation sector. In Malaysia and Indonesia, EVs just started as an important force. However, in Malaysia, the lack of EV infrastructure, along with its strong dependency on fossil fuels, poses an enormous challenge. The situation is very similar in Indonesia. Indonesia has huge potential as Southeast Asia's largest vehicle market and a major nickel producer, an important EV battery ingredient. Therefore, this article addresses several critical issues in implementing EVs in Malaysia and Indonesia. In preparing this review, we have thoroughly selected very important EV keywords that are frequently asked. We have also interviewed some prominent figures in the field of EV to address the most critical aspects worth including in the paper. In doing so, we plan to provide content that will be beneficial not only to the academic world but also to the automotive industry in general. Firstly, a summary of the EV adoption scenario in each country was presented. Afterwards, the types of EVs and battery capacities available in both countries were explained. The next section focused on the adoption rate of EVs, followed by the discussion of EVs charging infrastructure. In addition to that, issues pertaining to vehicle tax credit were also addressed. The opportunities and challenges of EV were then addressed in depth before concluding remarks were given.

Keywords: electric vehicles; battery electric vehicle; plug-in hybrid electric vehicle; hybrid electric vehicles; Malaysia; Indonesia

1. Introduction

In efforts to reduce greenhouse gases (GHGs) generated by air pollution, gases which can cause climate change, green technology was introduced [1,2]. The electric vehicle (EV) is a product in development that is expected to contribute to pollution reduction [3]. Together with sustainable power plants such as hydro, wind, nuclear, and solar power plants, EV deployment can effectively keep clean air on the road, directly increasing air quality.

In the global market, the technologies of EVs have been established, as indicated by the availability of commercial EVs. However, two major concerns must be handled. The first is the formation of a supply chain for EV components, especially drive train components such as batteries, inverters, and electric motors. The second is the safety issues that may arise due to EV implementation. In the supply chain, even though the number of EVs in the global market has increased drastically, the mass production of batteries and electric motors remains the biggest problem. The manufacturers supplying batteries are considerably small compared to the high demand for EV products. Thus, the battery is still the most expensive component in an EV. On average, the battery makes up about 40% of the total EV manufacturing cost [4]. It is problematic if the EV wants to compete with conventional vehicles running with internal combustion engines (ICEs). Another concern of EVs is the safety issues. The EV technology needs enormous data to collect, analyse, and improve the technology to ensure that the EVs are safe to be implemented. The more data obtained from simulation, testing, and actual incidents/accident, the better, assuring the safety of the EVs.

As one of the fastest developing nations in Southeast Asia, Malaysia has a population of 32.7 million in the first quarter of 2021 [5] and is expected to reach 41.5 million by 2040 [6]. Statistics from ASEAN Statistics Division for 2020 revealed that Malaysia had 29.96 million registered motor vehicles in 2019. In the same year, Malaysia recorded 925 registered motor vehicles per 1000 population which depicts that nine out of every ten Malaysians have a road vehicle [7]. With no restrictions on vehicle ownership, roads in Malaysia are being dominated by passenger vehicles (46.0%) and motorcycles (48.4%) [8,9], as can be seen in Figure 1. The Road Transport Department Malaysia revealed that there were 16.8 million licensed drivers in 2019, an increase of 10.5% from 2018 [10]. As for the total industry volume (TIV) for the automotive industry in Malaysia, both registered passenger and commercial vehicles in 2020 have dropped by 12.4% [11], believed to be caused by the COVID-19 pandemic. The sales distribution in the year showed 66.7% was from passenger vehicles and 17.6% was from 4 × 4/SUVs. However, Malaysia Automotive Association (MAA) has forecasted the TIV growth to increase by 6.0% in 2022, followed by an average growth of 3.1% from 2023 to 2025 [11].

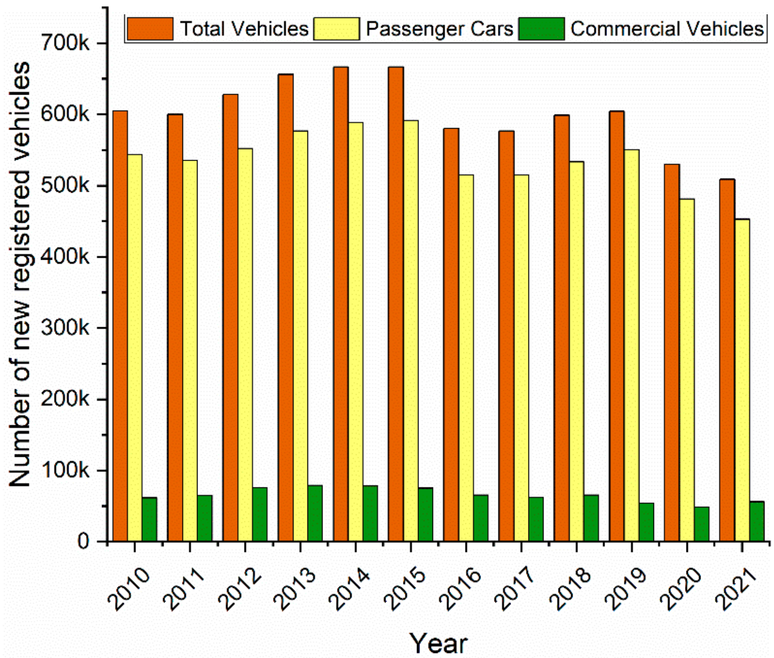

Figure 1. New passenger and commercial vehicles registered in Malaysia from 2010 to 2020.

Furthermore, as one of the biggest automotive markets in Asia, Indonesia plays an important role in determining the technological deployment of vehicles. Figure 2 shows that the market size of automotive in Indonesia is still increasing consistently. The huge number of motorcycles and the motorcycle growth rate for the last decade indicate that the current Indonesian public transport system cannot accommodate the mobilisation needs. This is the reason why private vehicle ownership is prevalent in the country. In the context of technological deployment, due to its sizable market share, the Indonesian preference may determine how fast vehicle electrification will be, at least in Southeast Asia.

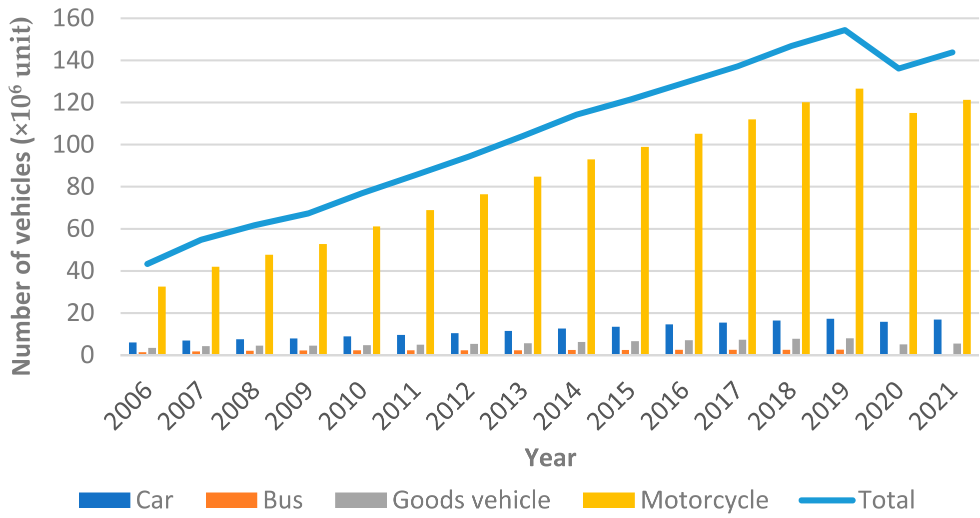

Figure 2. The market size of automotive in Indonesia.

Research and development (R & D) for EV-correlated technologies has been initiated by academia and industries in Indonesia [12,13]. The government has supported the R & D toward research grants over the last ten years. As a result, several achievements have been made, including technology transfer and mastery, prototyping, and critical component developments. However, the availability of components and their supply chain is still challenging and must be addressed. Furthermore, the development of EV industries must be supported by an initial captive market and government incentives to assure the business process can be done smoothly in Indonesia.

Despite the promising EV technology in Malaysia and Indonesia, it is difficult to find a scholarly article addressing both the opportunities and challenges of EV altogether in Malaysia and Indonesia. Most previous EV articles are published in the form of magazines, news stories, or government reports. Therefore, this study aims to provide a comprehensive academic review article related to EV development in Malaysia and Indonesia.

2. EV Adoption Scenario in Malaysia

The Malaysian automotive industry is being driven by several government agencies under different ministries. Government agencies and ministries are working together with the Ministry of Transport Malaysia to spearhead the Malaysian automotive industry. Malaysia Automotive Robotics and IoT Institute (MARii) is an agency established under the purview of the Ministry of International Trade and Industry Malaysia (MITI) that serves as the coordinating centre and think tank towards enhancing the automotive industry and overall mobility in Malaysia. In collaboration with MARii, MITI released the latest National Automotive Policy 2020 (NAP 2020) [14]. Among others, NAP 2020 highlights the development of the Next Generation Vehicle (NxGV) in the areas of charging, energy management, and safety. Meanwhile, Malaysian Green Technology and Climate Change Centre (MGTC), an agency of the Ministry of Environment and Water (KASA), drives the scope of green growth, climate change mitigation, and green lifestyle, which is also highly involved in the areas related to clean and efficient transport in Malaysia. In collaboration with MGTC, KASA is proposing the Low Carbon Mobility Blueprint 2021–2030 that involves vehicle fuel economy and emission improvement, EVs and low emission vehicle adoption, alternative fuel adoption, and GHG emission and energy reduction via mode shifts [15]. Both the NAP 2020 and the Low Carbon Mobility Blueprint 2021–2030 are expected to be a catalyst in further propelling the Malaysian automotive industry to be more competitive in the upcoming years.

In Malaysia, there are two national vehicle manufacturers: Perodua and Proton. In 2019, Perodua had the largest market share of 38%, while Honda had the second-largest market share of 17%, followed by Toyota and Proton [16]. From the consumer's perspective in Malaysia, a survey conducted by the Malaysian Electric Vehicle Owners Club (MyEVOC) [17] revealed that fuelling infrastructure is the biggest concern at the moment, followed by the cost. Regardless of the infrastructure concern, most of the MyEVOC members have been using their EVs for daily usage because the average driving range of 50 to 70 km is sufficient for home charging. Port specification is also not a concern for them as they are using a common UK/EU/SG, which are Type-2 for AC and CCS Combo Type-2 for DC rapid charging. The main concern lies in travelling out of the urban area where DC rapid chargers are only located in the North–South Expressway of West Malaysia.

2.1. Types of EV and Battery Capacities Available in the Malaysian Market

In September 2020, there were only four new battery EV (BEV) models available in the Malaysian market: Nissan LEAF, Mini Cooper Electric, BMW i3s, and Porsche Taycan; the rest of the EVs available in the market mostly consist of hybrid EV (HEV) and plug-in hybrid EV (PHEV). Table 1 lists some of the popular EV models available on Malaysian roads today [18]. The batteries from the available EV models in Malaysia are mostly the lithium-ion type, while a few models are the nickel-metal hydride type. The battery capacities of these models for HEV ranges from 0.86 kWh (Honda Jazz) to 1.6 kWh (Lexus IS), PHEV ranges from 11.6 kWh (BMW i8 Roadster) to 24.0 kWh (BMW X5), and BEV ranges from 28.9 kWh (Mini Electric) to 93.4 kWh (Porsche Taycan). The travelling distance for electric mode in the PHEV model may reach 77 km (BMW X5) before shifting into the gasoline-powered mode, while the BEV model may reach 385 km (Porsche Taycan). Alternatively, there are also other used EV models brought into the market.

Table 1. Among the EV models available in the Malaysian market as of August 2021.

EV Type	Vehicle Brand/Model	Engine Capacity (L)	Battery Type	Battery Capacity (kWh)	Travelling Range (km)
HEV	Honda Jazz Hybrid	1.5	Li-ion	0.86	-
	Honda City GN eHEV RS	1.5	Li-ion	1.3	-
	Hyundai Ioniq AE HEV Plus	1.6	Li-ion	1.56	-
	Merc-Benz CLS C257 CLS 350 AMG	2.0	Li-ion	1.0	-
	Merc-Benz GLE V167 GLE 450 AMG	3.0	Li-ion	0.9	-
	Lexus IS XE30 Facelift IS 300 h	2.5	Ni-MH	1.6	-
PHEV	BMW 3 Series G20 330e M Sport	2.0	Li-ion	12.0	60
	BMW 7 Series G12 LCI 740Le xDrive	3.0	Li-ion	12.0	45
	BMW5 Series G30 LCI 530e M Sport	2.0	Li-ion	12.0	67
	BMW X5 G05 xDrive45e M Sport	3.0	Li-ion	24.0	77
	BMW i8 Roadster i12 LCI eDrive	1.5	Li-ion	11.6	53
	Volvo S90 Mk2 Facelift Recharge T8	2.0	Li-ion	11.6	58
	Volvo S60 T8 Twin Engine R-Design	2.0	Li-ion	11.6	49
	Volvo XC60 Mk2 T8 Inscription Plus	2.0	Li-ion	11.6	45
BEV	Porsche Taycan	N/A	Li-ion	93.4	385
	Nissan Leaf ZE1 EV	N/A	Li-ion	40.0	270
	Mini Electric F56 LCI 2 Cooper SE	N/A	Li-ion	28.9	234

2.2. Adoption Rate of EVs in Malaysia

Toyota introduced HEV in the Malaysian market as early as 2009 [19], followed by Honda in 2010 [20], then in 2013, both Mitsubishi and Nissan introduced BEVs [21,22].

While the national vehicle manufacturers are still using ICEs in all their existing models, foreign manufacturers in Malaysia, such as Toyota, Honda, Nissan, Hyundai, BMW, Mercedes-Benz, and Volvo, have started to include a range of EV types as part of their product line-ups. As a result, the volume of EVs in Malaysia peaked in 2017 and 2018, with close to 9000 units on the annual registration [23]. More than 95% of the registered EVs are PHEV, but recently, in the year 2021, the share of the BEV segment has increased from 5% to 8% [23]. As of today, there are more than 31,000 units of registered EVs on Malaysian road, whereby 5% are BEV [23]. Even with such an increase, the existing adoption rate in Malaysia is considerably low.

2.3. Readiness of Malaysian EVs Charging Infrastructure

Apart from the price, the availability of public DC chargers is among the concern of Malaysian consumers. Sufficient DC charging infrastructure would relieve their anxiety on travelling using EV, and at the same time, increase the adoption and accessibility of electrification transport in Malaysia. While AC chargers are useful for overnight charging, DC chargers are the most important necessity for consumers when travelling with EV. This concern has been addressed to the government, related agencies, and related industries. In 2021, several efforts were put forward to address the concern. Among the recent efforts, MARii and the Malay Vehicle Importers and Traders Association of Malaysia (PEKEMA) have signed a collaboration to set up a network of 1000 DC rapid charging stations around the country by 2025 [24]. The collaboration will also look at the infrastructure ecosystem that, in turn, will create opportunities in other businesses and job opportunities in the country. In parallel, Tenaga Nasional Berhad (TNB), as the largest electricity utility company in Malaysia, has also focused on providing the necessary infrastructure by collaborating with various stakeholders in Malaysia [24]. To support Malaysia's transition into low carbon mobility, TNB is also willing to work with the private sectors that intend the transition; an example of this can be seen when TNB recently collaborated with DHL Express Malaysia to install charging stations along DHL's service routes as the initial step for the future transition [25].

2.4. Charging Stations Distribution in Malaysia

Where are the EV charging stations in Malaysia? As reported by [26], there are about 500 public AC chargers and 9 public DC chargers in Malaysia today. Currently, chargEV has the largest AC charger network in Malaysia [27]. The chargEV network was established by MGTC to provide public EV charging infrastructure in Malaysia for free. The chargEV network has 303 units of AC chargers in-operation across the states of Johor, Kedah, Kuala Lumpur, Melaka, Negeri Sembilan, Pahang, Perak, Penang, Putrajaya, Sarawak, and Selangor, as shown in Figure 3. The power output of the AC chargers ranges from 3.7 to 22.0 kW. To further support and facilitate EV users, chargEV also provides its own mobile apps to locate charging stations in Malaysia conveniently. Based on the chargeEV platform, MGTC also collaborated with BMW in mobility services, dedicated for BMW EV users in Malaysia to locate the charging stations. Besides chargEV, Shell, in collaboration with ParkEasy, also provides a free EV charging service called Shell Recharge [28]. AC charging stations were in smart parking bays at seven locations across Kuala Lumpur and Selangor.

Figure 3. Distribution of public AC charging stations by the charge network across Malaysia [29]. Courtesy of Malaysian Green Technology and Climate Change Centre.

As for DC chargers, an EV charging specialist company, EV Connection Sdn Bhd, has provided EV charging solutions in Malaysia since 2016 and aims to expand its installation in the next three to five years [30]. The company currently has the largest DC charger network in Malaysia, located along the North–South Expressway, as shown in Figure 4, passing through states of Perak, Kuala Lumpur, Melaka, and Johor. Meanwhile, Shell, in collaboration with Porsche, is planning to install 180 kW DC chargers in six Shell stations across Malaysia, including Singapore, by 2022 [31].

Figure 4. Current and upcoming locations of DC charger along the North–South Expressway by EV Connection Sdn Bhd [29]. Courtesy of Malaysian Green Technology and Climate Change Centre.

2.5. Are Malaysian EV Charging Stations Standardised?

Most of the available public EV charging stations in Malaysia use Level 2 type AC chargers that meet International Electrotechnical Commission (IEC) standards. Availability of Level 3 DC chargers is still at the minimum but increasing at a low pace. The power output of the available AC chargers ranges from 3.7 to 22.0 kW, depending on the location of the charging station. In comparison, available DC chargers are as high as 50.0 kW [32], with higher output chargers in development [31].

As for the ports, the public AC charging stations within the chargEV network in Malaysia are fitted with a Type 2 charging outlet as per IEC standards, which is compatible with all PHEV and BEV sold in Malaysia (Figure 5). In addition, the DC charging stations are fitted with Combined Charging System (CCS) Combo Type 2 port for rapid charging.

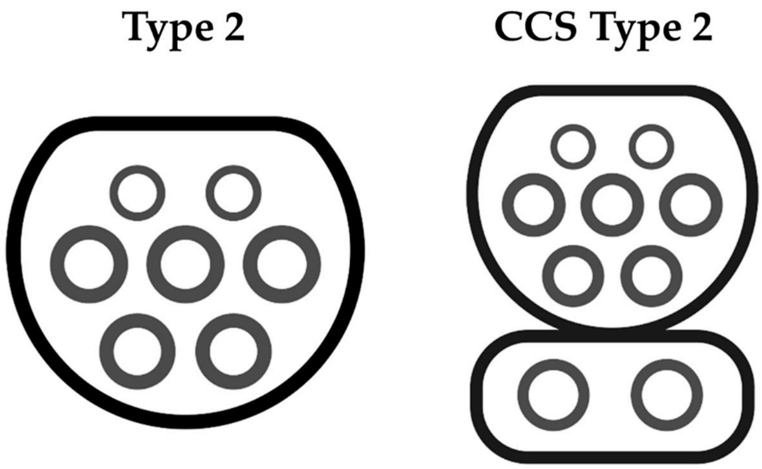

Figure 5. Type 2 and CCS Type 2 ports at EV charging stations in Malaysia.

Home charging is convenient due to the availability of local suppliers/distributors for purchase and installation. Furthermore, new housing developments in Malaysia have already started to include EV charging infrastructure as standard amenities in respective houses or residential areas [33].

2.6. EV Tax Credit in Malaysia and How It Works

On top of the sales tax, foreign vehicles in Malaysia are also charged with excise and import duties. The excise duty for locally assembled and imported vehicles may vary between 60% to 105%, depending on the vehicle model and engine capacity [34]. The import duty may reach up to 30%, based on which country the vehicle was manufactured [34]. With the combination of these tax charges, the price of foreign vehicles in Malaysia can be substantial for local consumers. In 2009, the Malaysian government introduced 100% import duty exemption and 50% excise duty exemption for HEVs with 2.0 L engines and below [35]. In the following year, the Malaysian government extended the exemption to the end of 2011 with a 100% exemption for both import and excise duties [35]. This exemption has brought down the local price of Toyota Prius from RM175,000 to RM139,900 [36]. The exemption has helped the sales of HEVs in Malaysia to rise to 614 units by 2010 [37]. When the exemption was supposed to end in December 2011, the Malaysian government then further extended the exemption to December 2013 [37]. After 2013, there were no such exemptions nor incentives introduced by the Malaysian government for HEVs and EVs until May 2021. MARii, under the purview of MITI, announced they would soon release an accelerated policy on EVs under the existing NAP 2020, which will comprise incentives regarding sales, excise, and import duties for EVs [38]. Such incentives provide affordability to Malaysian consumers and are expected to elevate the existing adoption rate.

2.7. Opportunities and Challenges of EV in Malaysia

Comparing the latest progress of EV adoption with the neighbouring countries, Malaysia is left behind, even though Malaysia started its initiatives in 2016. While Malaysia is currently revising its policy (at the time of writing) to boost EV adoption, the neighbouring countries are constantly taking drastic simultaneous actions in many areas involving manufacturing, policy, incentives, and public awareness. Despite being slow, this allows

Malaysia to learn and benchmark the adoption by the other countries, thus allowing adaptation and improvisation.

Among many initiatives, infrastructure accessibility and consumer's incentive are the biggest contributors to any EV adoption. The quantity of EV charging stations in Malaysia is still considerably low, and the rate of establishment of the stations since 2016 is sluggish. This can be associated with the sluggish conversion of consumers from combustion engines to electrification, which correlates to a survey conducted by a BFM radio station Twitter poll where 40% of respondents would not consider an EV, due to the insufficient charging infrastructure in Malaysia. Malaysia's biggest challenge, for now, is to increase the number of EV charging stations at strategic locations. With sufficient charging infrastructure, higher EV adoption is expected to cause an increase in electricity usage and load in Malaysia. It provides an opportunity for TNB to increase their revenue and further upgrade their infrastructure and resources while at the same time allowing them to introduce new services for the consumers and expand outside their conventional scope of just being a utility provider. Apart from TNB, local agencies and companies, such as MARii and PEKEMA, in their recent collaboration to provide EV infrastructure [24], should also take the opportunity to venture into the e-mobility ecosystem by providing EV-related solutions and services such as battery maintenance and battery swapping services. Establishing a management system capability over the infrastructure allows the providers to collect valuable energy consumption data from parties such as the government, agencies, city councils, housing developers, and vehicle manufacturers.

Another challenge for EV adoption in Malaysia is the consumers. The range anxiety, or the consumer's fear of the EV running out of electricity, is a common challenge that a country must address. Among the main contributor to range anxieties are insufficient charging infrastructure and lack of awareness. In reality, a BEV with a full charge battery can travel more than 200 km, which is sufficient for daily urban driving in Malaysia. Certainly, the number of EV charging stations in Malaysia is still low. With the existing efforts to increase the number of EV charging stations and provide sufficient awareness, Malaysia would be able to address the range anxiety to the consumers. Besides the range anxiety, increasing the consumers' willingness to convert from fully combustion engine vehicles to EVs is a challenge that the government, agencies and related industries must work together to tackle through incentives, awareness and education. This will provide opportunities for the OEM in Malaysia to increase their sales and revenue, and at the same time, bring new investors into Malaysia. Consistent awareness programmes will eventually shift the existing consumer's perspectives. In parallel, the education sector will be able to take the opportunity to revise and update their teaching content in emphasising low carbon mobility, which includes EV in their subjects or course to cultivate future consumers.

3. EV Adoption Scenario in Indonesia

Despite recent progress in ICEs and biofuel utilisation [39–42], massive R & D in EV technology is currently being conducted worldwide, including in Indonesia, thus potentially revolutionising vehicle powertrains from ICE to electric motors. As stated in its Nationally Determined Contribution (NDC) in 2016, Indonesia has pledged to reduce 29% of its GHGs emissions using the business-as-usual scenario and up to 41% using international assistance and financial support by 2030 [43]. The Indonesian government aims to achieve this target by implementing several actions, one of which is vehicle electrification. Despite recent progress in biofuel [44–47], the country plans to increase EV adoption to reduce harmful emissions. In Indonesia, GHG emitted from the transport sector in 2016 was 134.5 Mt, which is 318% larger than GHG emitted from the transport sector in 1990. The transport sector contributes to 24.71% of GHG emissions, making it the second biggest GHG emitter after the emission from the energy sector [48].

Figure 6 shows the total vehicle sales and passenger vehicle sales in Indonesia from 2013 to 2020 [49–51]. The yearly sales are almost constant, except in 2020, when the COVID-19 pandemic struck the automotive industry, leading to the decline in vehicle sales.

However, the automotive market recovers steadily in 2021. Roughly every year, around 1 million vehicles are being sold in Indonesia. Thus, reprojecting the market into EVs will contribute greatly to the fulfilment of Indonesia's NDC by 2030.

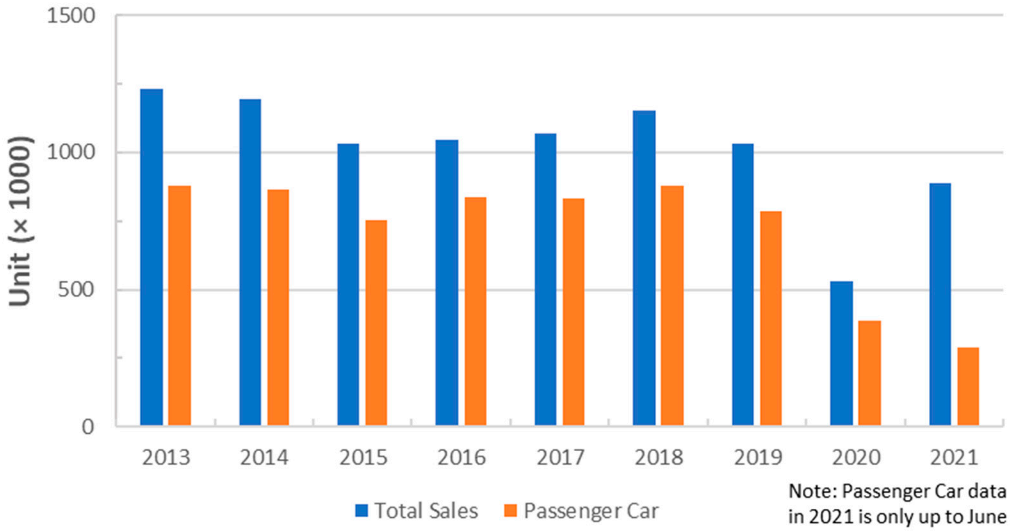

Figure 6. Vehicle total sales and passenger vehicle sales in Indonesia from 2013 to 2021.

In line with the commitment to reduce GHG emissions by 2030 and by noting that the transport sector has a significant contribution to GHG emissions, the Indonesian government created a program called *Program Kendaraan Bermotor Listrik Berbasis Baterai* (KBLBB), or BEV program, which will mark the implementation of EVs within its ministerial, local government, state-owned enterprises, and private enterprises. Based on this program, the Indonesian government will purchase 132,000 EVs and 2,450,000 electric motorcycles by 2030 [49]. However, judging from the EVs purchased from this program, this program is insufficient to fulfil the NDC. This is due to the insignificant numbers of EVs purchased from this program compared to the yearly total vehicle sales in Indonesia. Since most vehicles are privately owned passenger vehicles, ideally, the government program should help in the adoption of EVs for mass usage.

In 2019, the Presidential Regulation No. 55 of 2019 on Acceleration of Battery Electric Vehicles Program for Road Transportation was made. This regulation aims to allow commercial and non-commercial incentives for local manufacturers with minimum rates of local components and charging infrastructure expansion. As a result, not only on the EV market, but Indonesia also expands its focus on developing domestic EVs using localised manufacturing and supply chain. This was a big difference from 2013, when several attempts of developing national EVs failed due to the lack of appropriate regulation. Currently, several local companies are ready to produce electric buses with 35% local component [51].

As we will see in the discussion in the following subsections, the scenario adopted by the Indonesian government for mass vehicle electrification is to relax the regulation in the establishment of EV infrastructure and invite big players in EV to invest in Indonesia to expand their market. However, we have yet to see the regulation that will allow low-middle-class income people in Indonesia to own an EV.

3.1. Types of EV and Battery Capacities Available in the Indonesian Market

In 2020, more than 2000 EVs passed the feasibility test (see Figure 7) [50]. The feasibility test was done by the Directorate General of Land Transportation. The two-wheeled vehicle has the highest number among other vehicles. Figure 7 shows the potential of EVs that will penetrate the Indonesian market. However, not all of them are available on the market yet.

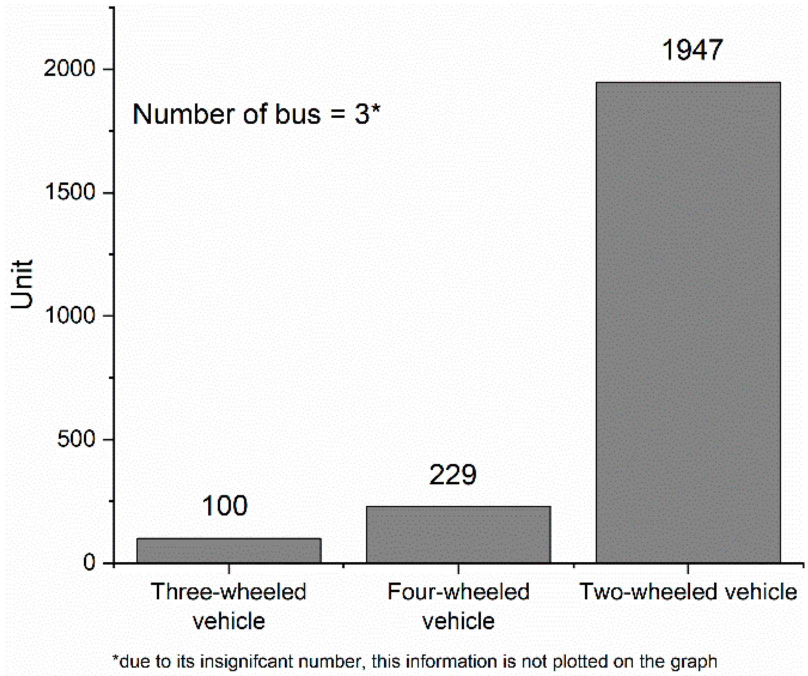

Figure 7. The number of EVs that passed the feasibility test in Indonesia (2020).

Table 2 shows the available EVs in the Indonesian market, where their size, function, and wheel power are comparable to commercial ICE vehicles. Table 2 also shows the battery type and battery capacity of the vehicle. Hyundai is probably the most advanced EV maker in Indonesia in terms of marketing their EVs; Hyundai has the greatest number of Level 3 charging stations in all locations, and they have 21 units in Jakarta alone.

Table 2. Available EVs in Indonesian Market.

EV Type	Vehicle Brand/Model	Engine Capacity (L)	Battery Type	Battery Capacity (kWh)	Travelling Range (km)
HEV	Toyota Camry Hybrid	2.5	Ni-MH	1.6	-
	Toyota C-HR Hybrid	1.8	Ni-MH	1.3	-
	Toyota Corolla Hybrid	1.8	Ni-MH	1.3	-
	Toyota Prius Gen-3	1.7	Ni-MH/Li-ion	0.75	-
	Honda CR-Z	1.5	Li-ion	0.6	-
	Nissan Kicks e-Power	1.2	Li-ion	1.57	-
PHEV	Mitsubishi Outlander	2.4	Li-ion	13.8	54
	Toyota Prius PHEV	1.8	Li-ion	8.8	68.2
	BMW i8 Coupé	1.5	Li-ion	11.6	55
BEV	DFSK Gelora Electric	N/A	Lithium Iron Phosphate	42	≥300
	Hyundai Ioniq Electric	N/A	Li-ion polymer	40.4	365
	Hyundai Kona Electric	N/A	Li-ion polymer	39.2	380
	BMW i3S	N/A	Li-ion	42.2	355
	Lexus UX 300e	N/A	Li-ion	54.35	260
	Tesla Model X Plaid	N/A	Li-ion	95.0	650
	Tesla Model X Long Range	N/A	Li-ion	95.0	685
	Tesla Model S Plaid	N/A	Li-ion	95.0	755
	Tesla Model S Long Range	N/A	Li-ion	95.0	790

Meanwhile, there are two prominent electric motorcycle makers in Indonesia: Gesits [52,53] and Smoot Tempur [54]. Gesits is an electric motorcycle produced by PT. WIKA Industri Manufaktur (WIMA), a joint venture between PT. Wijaya Karya Industri

& Konstruksi and PT. GESITS Technologies Indo, and it was established in 2018. Gesits can travel up to 50 km with a single battery, and it can be extended to 100 km with double batteries. The battery used is lithium-ion 72 V/2Q Ah. Gesits motorcycles need around 3 to 4 h for full charging. However, its future development will adopt battery swap for time efficiency, and they will collaborate with SWAP [55].

Smoot Tempur is an electric motorcycle with battery swapping technology from the first product released to the market, thanks to its collaboration with SWAP. By August 2021, there were 100 battery swap points for Smoot Tempur in Jakarta. The fact that the battery swap points are located at a renowned minimarket in Jakarta shows that electric motorcycle has penetrated the Indonesian market more than ever before. Even the swap points themselves are a form of marketing of electric motorcycles.

On the other hand, there are several attempts to develop national EVs for the Indonesian market [56]:

1. Tucuxi EV

This EV was ordered by the State Enterprises Minister, to initiate the development of the national EV. Tucuxi is equipped with a 268 hp electric motor and fast-charging feature, which needs 3 to 5 h for full charging, and it has a travel distance of 321 km. The accident during the vehicle test and the dispute after the accident are some reasons for the discontinuity of the Tucuxi project [57].

2 Gendhis and Evina

Gendhis and Evina are EVs developed by local company. Gendhis was displayed at KTT APEC in Nusa Dua Bali in 2013, and it is a hybrid MPV combining an electric motor and diesel engine. Meanwhile, Evina is a BEV equipped with a 50 hp electric motor, and it has 135 km of travel distance. However, the developed EVs were judged to be not fit for the Indonesian road [57].

3 Selo

Selo is an EV developed by small enterprise in 2013. It is equipped with an electric motor which has a power of 182 hp, and it needs only 4 h for full charging. It has 250 km of travel distance. After much work of developing the EV, Selo was deemed to be unfit to be produced in Indonesia [58].

4 Hevina

Hevina is a HEV developed by the Indonesian Institute of Sciences (*Lembaga Ilmu Pengetahuan Indonesia*, LIPI). It was introduced by LIPI in 2013. Hevina is powered by a 62 hp electric motor and an ICE, and was built for research purposes.

The EVs listed above, never went into production, and the problem is not technical, but rather administrative or bureaucratic in Indonesia [59]. In 2013, the regulation concerning EVs was not available yet in Indonesia.

More systematic program for EV development in Indonesia was funded by government via Indonesia Endowment Fund for Education (LPDP). University consortium led by ITB launched Mobil Listrik Nasional (MOLINA) and Research Innovative and Productive for Electric Vehicles (RISPRO Kenlis) programs in 2012 and is still running, with target to commercialize EVs having high local contents. Two EV prototypes were developed, including electric trike and electric bus, as starting point. The program has produced many scientific results in the field of EV technologies, including energy management system [60–62], platform design [63], charging [13], and other key drive train components [64]. The programs has showed significant progress and is expected to supply the future Indonesian automotive market.

3.2. Adoption Rate of EVs in Indonesia

Even though the sales trend shows an increasing demand for EVs, it has not met the projection made by the Indonesian Ministry of Energy and Mineral Resource (*Kementerian Energi dan Sumber Daya Mineral*, KESDM). For example, the projection shows that Indonesia would have 2,700,000 of two and three-wheeled EVs with 170,000 charging stations by 2021 (see Figure 8) [65]. In fact, Indonesia might have only 1,465,000 EVs, including vehicles, by 2021 [66]. Meanwhile, the charging stations available are only 148 units (per August 2021).

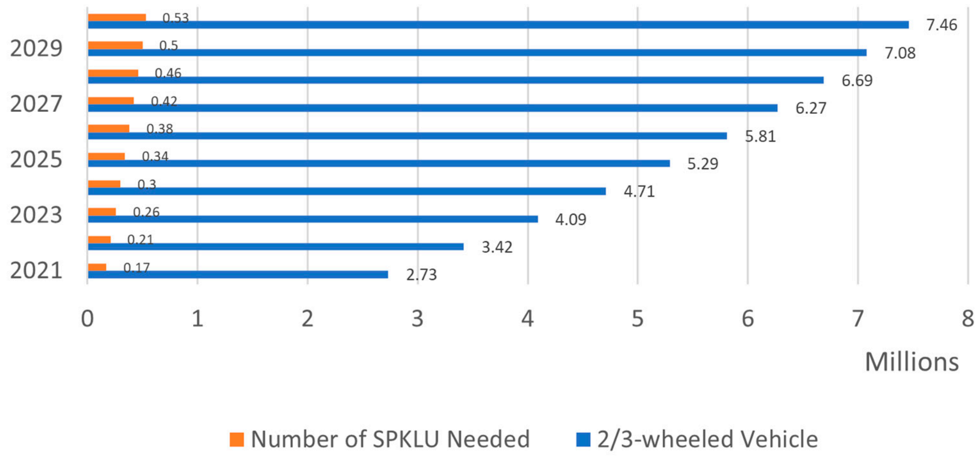

Figure 8. KESDM projection on the number of EVs in Indonesia from 2021 to 2030.

On the other hand, the KESDM of Indonesia also made a roadmap for the development of battery replacement stations and Level 3 charging stations (see Figure 9) [66]. Note that the figures for 2021 were unable to be realized. Then, based on this roadmap, the KESDM forecast the potential of EVs that can be supported by the battery replacement stations and Level 3 charging stations (see Figure 10) [66]. Assuming that the battery replacement stations are to be used by electric motorbikes and Level 3 charging stations are to be used by EVs, then for 2021, one Level 3 charging station must be able to support 218 EVs, while one battery replacement station must be able to support 448 electric motorbikes. Meanwhile, by 2030, one Level 3 charging station must be able to support 68 EVs, and one battery replacement station must be able to support 194 electric motorbikes. If these figures can be realized by 2030, then the infrastructure will be able to support the EVs environment in Indonesia.

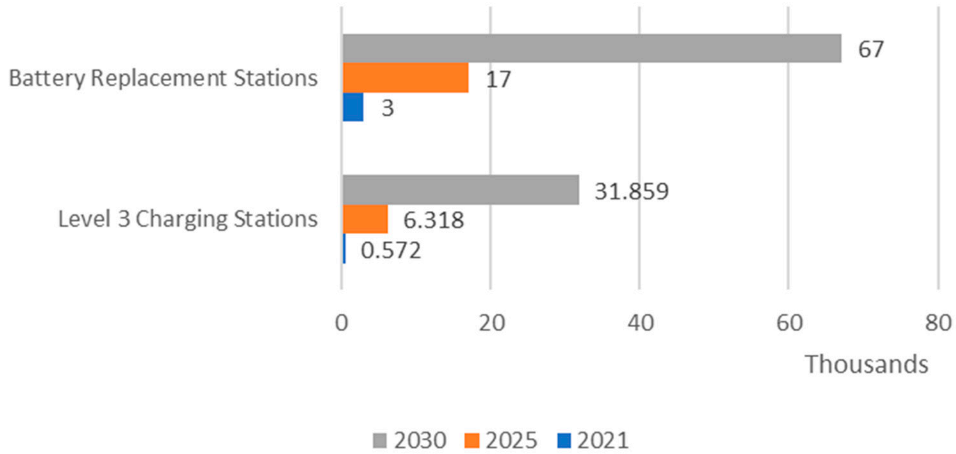

Figure 9. Roadmap of battery replacement and Level 3 charging stations made by KESDM.

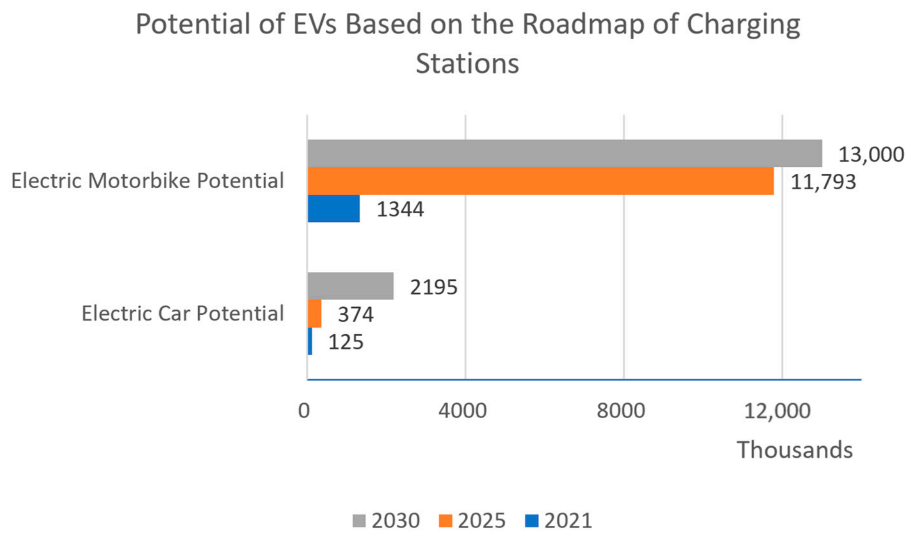

Figure 10. Potential of EVs based on the roadmap in Figure 9 made by KESDM.

The average Indonesian sales growth is about 6%, while production growth is around 7.5%. EVs contribute to about 0.02% of total vehicle sales [67]. These sales were dominated by HEVs. Even so, there is still an increasing trend in EV sales. As also stated in the current study by McKinsey, the demand for EVs in Indonesia might increase significantly. The analysis stated that Indonesia could boost its demand for EVs by developing more local talent, establishing R & D hubs, and transferring the capabilities from foreign experts and global leaders to local staff [68]. Gupta and Hansmann proposed three scenarios: reference, accelerated, and lagging scenarios [69].

The reference scenario found that the demand for EVs might grow into 250,000 units per year by 2030, representing 16% of vehicles sales. This number is way below the number that can be supported by the projected Level 3 charging stations in 2030 (see Figure 11), showing that the roadmap for Level 3 charging station development is satisfactory. The reference scenario was made under the Indonesian government target in the production of EVs. This scenario proposes the possibility that the demand for two-wheeled EVs will be around 1,900,000 units or 30% of the total two-wheelers sales. On the other hand, the accelerated scenario predicts that 40% of vehicles sold in 2030 are EVs. The accelerated scenario assumes that the EV take-up is supported by local production and other conditions (e.g., sufficient charging infrastructure). Lastly, the lagging scenario predicts that 12% of two-wheelers and 5% of vehicles sold in 2030 are electric. This scenario was made based on Indonesia's current trajectory—challenged to attract manufacturers to develop EVs locally, and the current 50% import tax applies.

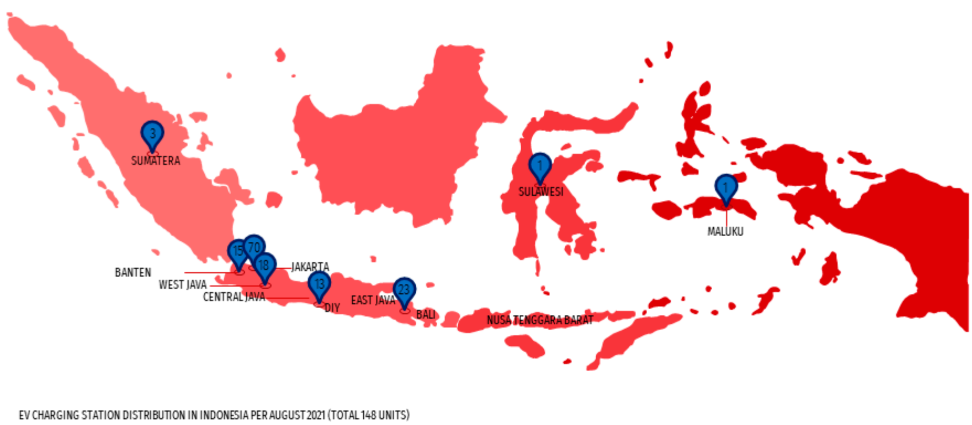

Figure 11. Level 3 charging stations distribution in Indonesia per August 2021.

3.3. Readiness of Indonesian EV's Charging Infrastructure

The readiness of EV's charging infrastructure in Indonesia can be seen from two aspects: the electricity supply capacity and charging station availability. For the former, it is confirmed that by 2020, the State Electricity Company (Perusahaan Listrik Negara, PLN) had a 2.5 GW electricity surplus [70]. This 2.5 GW surplus can accommodate EVs. Thus, Indonesia has sufficient capacity to supply electricity for EVs usage in terms of capacity. In the meantime, Indonesia will also reduce its dependency on fossil-fuel-based power plants by building more renewable-energy power plants. Therefore, EVs will have zero emissions and become green vehicles.

Regarding the charging infrastructure, public charging stations mainly have three types, as shown in Table 3 [71]. According to a study by the National Renewable Energy Laboratory from the United States Department of Energy, about 3.4 DCFC (DC Fast Charging) and 40 Level 2 charging stations are needed for 1000 EVs [72]. The Indonesian government predicts that 7,460,000 EVs will be sold by 2030. Therefore, Indonesia should provide at least 25,364 DCFC and 298,400 Level 2 charging ports. Meanwhile, the KESDM has predicted that by the end of 2021, Indonesia will have 1,465,000 EVs (120,000 units of vehicles and 1,340,000 units of motorcycles) and 572 public EV charging stations (*Stasiun Pengisian Kendaraan Listrik Umum*, SPKLU), which is equivalent to Level 3 charging stations [66]. Based on [72], Indonesia should have 4981 Level 3 charging stations by the end of 2021. These show that Indonesia needs to pay more attention to the development of EV's charging stations.

Table 3. Public charging stations type.

Parameter	Level 1	Level 2	Level 3 (DCFC)
Capacity	1 kW	3–20 kW (typically 6 kW)	50 kW (occasionally 20 kW)
Charging time	20 h (to add 200 km of travel distance)	5 h (to add 200 km of travel distance)	30 min (to add 80% of 200 km of travel distance)

3.4. Charging Stations Distribution in Indonesia

The development of EV charging stations in Indonesia is assigned to PLN. PLN can execute it by working together with Indonesian state-owned or other business enterprises [73]. Currently, there are more than 7000 units of Level 2 charging stations, distributed in 3800 locations in Indonesia, where 1922 of them are distributed in Jakarta. The Level 2 charging station is called a public charging station (*Stasiun Pengisian Listrik Umum*, SPLU). The Level 2 charging station can be used to charge electric motorcycles. However, in practice, not all these Level 2 charging stations are used to charge electric motorcycles. Instead, most of these Level 2 charging stations are used by street vendors to provide electricity during nighttime. This is due to the development of the Level 2 charging station in 2016, and also because the electric motorcycle was not well known yet. Therefore, it is not easy to retrieve the developed Level 2 charging stations from the street vendors to be used for an electric motorcycle.

Since the Level 2 charging stations are not usable anymore, PLN is more focusing on developing the Level 3 charging stations for the EV. There are 148 units of Level 3 charging stations distributed in 120 locations in Indonesia by August 2021. However, this is inadequate to support the targeted 1,465,000 EVs by the end of 2021.

The Level 3 charging stations in Indonesia are equipped with both AC and DC charging. In 2020, PLN performed an experiment to examine the readiness of Level 3 charging stations in Indonesia. The experiment was done by travelling from Jakarta to Bali using an EV. In the end, it was proven that the electric vehicle was able to reach the destination without any disruption [74]. So far, in Indonesia, all Level 3 charging stations can be and are used by EV users. However, the general manager of PLN Main Distribution Unit PLN (*Unit*

Induk Distribusi, UID) stated that the charging frequency at the Level 3 charging stations tends to be stagnant [75].

The distribution of Level 3 charging stations in Indonesia can be seen in Figure 11, where most of the Level 3 charging stations are concentrated in Java Island, especially in Jakarta. There are 3 units in Sumatera (GOR Jakabaring 1 unit, Hyundai Palembang 1 unit, and the rest area Bakauheni—Terbanggi Kayu Agung 1 unit), 15 units in Banten (PLN UID Banten 6 units, BPPT 1 unit, Angkasa Pura II 1 unit, Mitsubishi 2 units, and Hyundai 5 units), 22 units in West Java (PLN UID West Java 1 unit, BPPT/LEN 1 unit, expressway between Jakarta—Surabaya 2 units, and Hyundai 18 units), 70 units in Jakarta (PLN headquarter 1 unit, PLN UID Jaya 6 units, BPPT 1 unit, Pertamina 5 units, Blue Bird 15 units, Shell Indonesia 2 units, Mitsubishi 13 units, Hyundai 21 units, Mercedes-Benz 1 unit, BMW 2 units, Medco 1 unit, and Starvo 2 units), 13 units in Central Java and Yogyakarta (PLN UID Central Java—Yogyakarta 1 unit, expressway between Jakarta—Surabaya 4 units, and Hyundai 8 units), 23 units in East Java, Bali and NTB (PLN UID East Java 1 unit, PJB 2 units, PLN UID Bali 3 units, PLN—Jasa Marga Bali 3 units, PLN UIW NTB 1 unit, Mitsubishi Bali 2 units, Hyundai East Java 10 units, and Hyundai Bali 1 unit), 1 unit in Sulawesi (PLN Mattoangin), and 1 unit in Maluku (PLN Ambon).

Meanwhile, there are 9 units of Battery Replacement Stations (*Stasiun Penukaran Baterai Kendaraan Listrik Umum*, SPBKLU) which are managed by PLN and Pertamina. This SPBKLUs are distributed mainly in Jakarta (6 units), Tangerang (1 unit), and Tangerang Selatan (2 units).

3.5. Are Indonesian EV Charging Stations Standardised?

The EV charging stations in Indonesia is standardised by the following regulations:

1. The charging station must comply with the provisions of Electricity Safety by the KESDM [48]:
    a. The obligation to install a power quality meter with the same meter class as that of the System Operations Manager;
    b. Operational capability to pass low and high voltage;
    c. Provision of black-start capability;
    d. Periodic testing for generator work by the System Operations Manager;
    e. Provision of information for planning and executing operations;
    f. Processing of meter data for electricity transactions is carried out by comparing the main meter data with comparison meter data;
    g. The arrangement of metering equipment includes the must-have facilities, installation technicians, and test period.
2. It must obtain the Certificate of Operation Worthiness by the Technical Inspection Institution of KESDM;
3. It must obtain the standard product conformance of the charging station by the Product Certification Institution (BSN and KESDM);
4. The Level 3 charging station should be in a place that is easily accessible, has sufficient land area and does not interfere with the traffic;
5. By the regulation from the KESDM, Permen ESDM No. 5 of 2021, the Level 3 charging station can be built anywhere, as long as there is a document that proves the land ownership or the cooperation with the landowner [76]. Previously, the Level 3 charging station could only be built in places approved by the government.

3.6. EV Tax Credit in Indonesia and How It Works

The basis for EV tax in Indonesia is the Government Regulation No. 74 of 2021 concerning Amendments to Government Regulation No. 73 of 2019 concerning Taxable Goods Classified as Luxury in the Form of Motorized Vehicles [77], which states that the BEVs and fuel cell EVs (FCEVs) have 0% retail tax.

On the other hand, a PHEV with fuel consumption of at least 28 km/L or CO_2 emission of 100 g/km is taxed based on luxurious goods tax at 15% with a tax base of 33 1/3% from the retail price. This provision is regulated on Article 36A.

Starting from October 2021, tax on luxurious goods will no longer be based on the shape of the vehicle's body but based on the exhaust emissions produced or fuel consumption. The details are [78]:

1. All ICE vehicles with an engine's displacement of less than 3.0 L will be subject to luxurious goods tax at 15% when the fuel consumption reaches 15.5 km/L or produce CO_2 emissions less than 150 g/km, and at 20% if the fuel consumption is less than 11.5 km/L or produces more than 250 g/km CO_2 emissions. Furthermore, if the fuel consumption is less than 9.3 km/L, the luxurious goods tax will be 40% to 70%;
2. For vehicles with an engine displacement of 3.0 to 4.0 L, the luxurious goods tax is from 40% to 70% (Article 8 to 11);
3. For low-cost green cars (LCGCs), the luxurious goods tax is 15%, with a tax base of 20% from the retail price. The fuel consumption for LCGC should at least be 20 km/L or produce at most 120 g/km of CO_2 emissions;
4. For a fully EV with a carrying capacity of fewer than 10 people or 10 to 15 people, including the driver, the luxurious goods tax is 15%, with a tax base of 0% from the selling price. In other words, the fully EV has no tax at all;
5. For an EV with hybrid and mild hybrid technology, the luxurious goods tax varies (15%, 25%, and 30%) depending on the engine's displacement;
6. It can be concluded that producing electric LCGC will not only produce an EV at a competitive price, but it will free the vehicle from tax if it is a fully EV with zero CO_2 emissions.

3.7. Opportunities and Challenges of EV in Indonesia

As the 4th most populated country in the world, Indonesia offers high demand for EVs. Based on the report by YCP Solidiance, three opportunities can be utilised by the Indonesian government and future EV players [79]. First, there is the favourability of personal transportation ownership. In Indonesia, owning personal transportation is more convenient, flexible, and symbolises economic status. Second, there is the population growth and the rise of the affluent middle class. The growing trend to live environmentally conscious in Indonesia's affluent middle-class could result in EV uptake. The third opportunity that can boost the EV market in Indonesia is the low price of electricity. The price of electricity in Indonesia is one of the second cheapest in the world, which is only 0.1 USD/kWh. As a comparison, the price of petroleum in Indonesia is 0.9 USD/L. With travel distance of 4.8 km/kWh for EV [80] compared to 20 km/L for fuel-based vehicle, EV will cost 0.02 USD/km, while fuel-based vehicles will cost 0.045 USD/km. Thus, in Indonesia, EVs are cheaper to run than fuel-based vehicles.

The opportunities in the EV market in Indonesia can be shown by the recent announcement of the Indonesia Battery Corporation (IBC) issued on 26 March 2021. IBC is a combination of Indonesia Asahan Aluminium (Inalum), Pertamina, and PLN. This corporation will focus on battery development and EVs. Not limited to IBC, several companies have started their investment in the battery and EV industry in Indonesia. Some of those players are [81]:

1. Tesla

Indonesia's Deputy Minister of the Coordinating Ministry of Maritime and Investment Affairs, Luhut Binsar Pandjaitan, stated that Indonesia had signed the non-disclosure agreement (NDA) with Tesla [82].

2. Hyundai Motor Group and LG Energy Solution

Hyundai Motor Group and LG Energy Solution, as a partner, have signed a Memorandum of Understanding (MoU) with the Indonesian government regarding their plan to establish an electric battery cell plant in Indonesia [83]. The factory will be in Karawang, and the production will begin in 2024. It is estimated that the factory can produce an annual power capacity of 10 GWh. It means the factory can provide more than 150,000 BEVs. This supply can help Hyundai and Kia secure upcoming BEVs at a competitive price. Hyundai plans to produce its EVs starting from March 2022.

3. Contemporary Amperex Technology (CATL)

Indonesia is targeting CATL to invest 5 billion USD in developing a lithium battery plant in Indonesia [84]. So far, CATL has signed an agreement with Aneka Tambang, which ensures that 60% of the nickel from Indonesia will be processed into batteries in Indonesia.

4. Toyota

In 2021, Toyota increased its investment in Indonesia by USD 2 billion until 2024. It is also preparing 10 EV types that will be produced for the Indonesian market within 5 years.

5. Honda

Similarly to Toyota, Honda has committed to invest IDR 5.2 trillion until 2024. Additionally, there will be factory relocation from India to Indonesia.

Even though many opportunities support the growth of EVs in Indonesia, several challenges still need to be evaluated. First, there is no clear policy from the government on EVs. Even though there is Presidential Regulation No. 55 of 2019 on Acceleration of Battery Electric Vehicles Program for Road Transportation, the fluctuating change in Taxable Goods Classified as Luxury in the Form of Motorized Vehicles regulation has created negative impressions among the stakeholders. The second challenge is the price of EVs. An EV is known to be expensive. For example, the cheapest electric vehicle in the current Indonesian market is DFSK Gelora-E, which is about 469 to 499 million IDR [85]. As a comparison, Indonesia's income per capita by 2020 was 56.07 million IDR per year or 4.74 million IDR per month [86]. Furthermore, the Association of Indonesia Automotive Industry (GAIKINDO) stated that the Indonesian government should consider the development of electric LCGC to meet Indonesians purchasing power, which lies around 200 million IDR [87]. Lastly, the wait-and-see strategy from the Original Equipment Manufacturers (OEMs) and infrastructure players also become a blockade of EV development in Indonesia.

4. Concluding Remarks

4.1. EV Adoption Worldwide

Numerous countries worldwide have been developing the EV technology for environmental benefits (decreased emissions) as well as economic values (new jobs). Note that the use of EVs varies by country due to a number of factors such as government policies, end-user demand, market prices, and charging infrastructure availability.

As the largest EV market in the world, the Chinese government offers incentives not only for the demand but also for the supply side. Therefore, consumers who want to purchase EVs and manufacturers who produce them are both given incentives. This policy has successfully increased the sales of EVs in China. The European Union (EU), the second-largest EV market, has different policies depending on the country. However, in general, most EU countries offer an exemption for purchase tax, value-added tax (VAT), and a reduction in registration tax. EV charging infrastructure is also provided to increase the EVs market penetration. In North America, subsidies for EV purchase are provided, but policies vary in the province or state. In Canada, for example, only three provinces in 2017 allowed EVs to have unrestricted access in the High Occupancy Vehicle (HOV) lane, including Ontario, British Columbia, and Québec. This policy is now spreading to several other provinces. In the USA, the situation is very similar, where financial incentives, exemptions of emissions tests, and parking incentives are given in several states.

In Asian countries, such as Japan, incentives for research and development are massively provided by the government. This includes funding and sponsorship for EVs battery, fuel cells, and other research areas in EVs. In South Korea, tax rebates and subsidies for the installation of charging infrastructure are given. In Singapore, the government imposed a carbon tax increment to increase the EVs market share in the country. In the Middle East, a number of incentives are also provided to increase the adoption of EVs in this region. Figure 12 shows the summary of policies and incentives to increase the adoption of EVs in several countries.

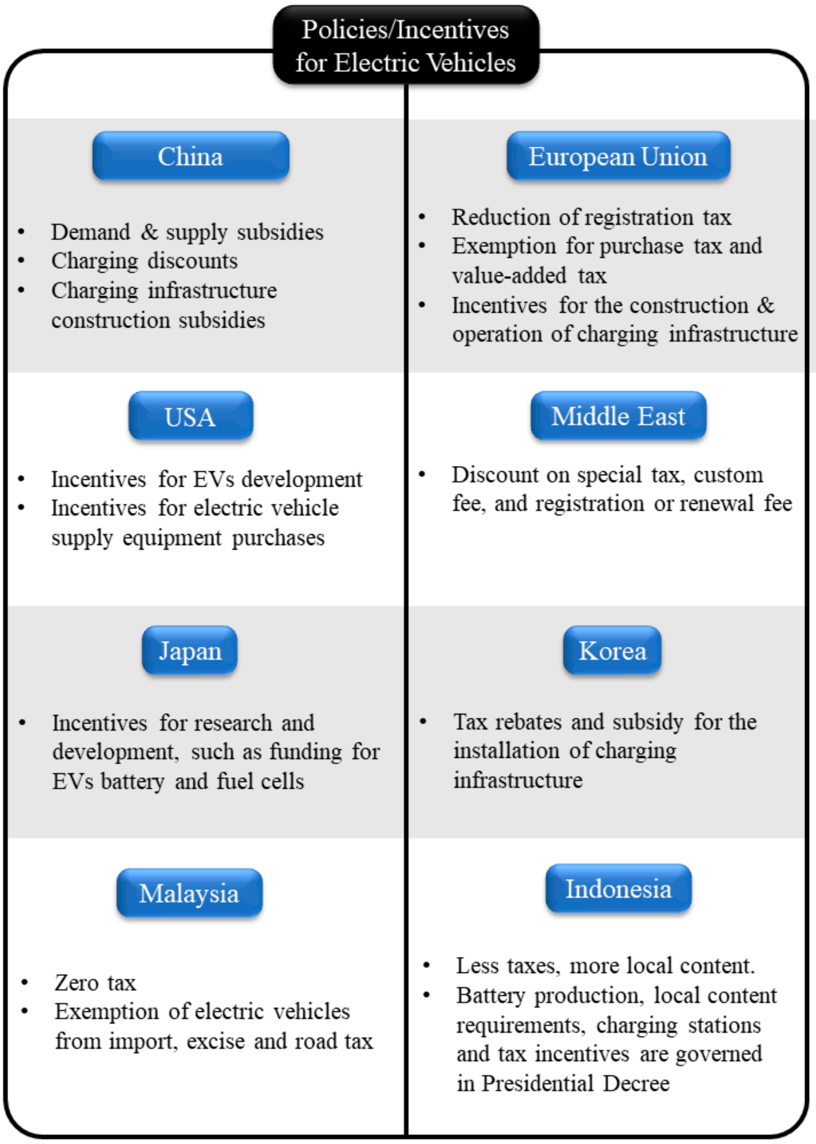

Figure 12. Policies and incentives for EVs in several parts of the world.

4.2. EV in Malaysia

Malaysia started the EV adoption in 2016, but the rate did not progress as was expected. Like the EU [88], Malaysia should set a target to have EV charging stations with a ratio of one charging station for every 10 EVs (BEVs and PHEVs) on the road. The number of public DC chargers in Malaysia should also be prioritised as this attracts more interest and provides convenience to the consumers. This target will be best be achieved by collaboration between the government, agencies, vehicle manufacturers, utility companies, and related industries. While doing so, TNB should temporarily offer a special electricity tariff for charging operators and residential/domestic customers to reduce their EV charging expenses as an incentive. Special incentives for land developers should also be given in new commercial and residential buildings, including a ratio of charging stations per resident/tenant. It is equally important to increase the number of EV charging stations in Malaysia, and thus the stations must also be strategically located. This is to ensure the locations of

EV charging stations are most convenient for the consumers' usage. As most of the EV charging stations are located within the West Coast states, Malaysia should also distribute EV charging stations within the East Coast (states of Kelantan and Terengganu) and East Malaysia (states of Sabah and Sarawak). A study should be made to strategically identify the optimum location of EV charging stations across Malaysia.

Besides the charging stations, Malaysia should immediately provide incentives for the consumers and OEMs. Due to the high import and excise duties for vehicles in Malaysia, reinstating the exemption on the duties for all types of EVs allows OEM to reoffer a distinct lower price of EVs for the consumers to afford. Furthermore, the discounted road tax for EVs should be immediately implemented, based on the CO_2 emission released, i.e., lower vehicle tax for lower emission vehicles. Such incentives will attract more consumers to convert to EV and assist the EV adoption rate in Malaysia.

Motorcycles are the second most popular mode of transport in Malaysia. Therefore, OEMs should also start to introduce the latest electric motorcycles into the local market. With the availability of electric motorcycles and the existing growth of the motorcycle market in Malaysia, Malaysia can encourage more consumers to opt for electric-powered motorcycles.

The education sector in Malaysia should also start cultivating future consumers by providing education and awareness for the younger generations. In addition, the education sector should play an equal role to emphasise further low carbon-related content, which includes energy-efficient vehicles in schools and higher learning institutions through their courses and activities. Higher education should also allocate enough research grants directly related to EV to generate further local capabilities, facilities, and intellectual properties that can attract more investors.

Finally, Malaysia should look ahead to the upcoming technologies such as higher voltage charging, wireless charging, and hydrogen fuelling station (FCEV). Understanding and being prepared for the upcoming technologies will allow Malaysia to be more prepared for the adoption and at the same time copes with other countries' progress. Instead of concentrating only on the main EV components such as batteries, Malaysia should expand into other areas within the ecosystem such as infrastructure manufacturing, vehicle/component testing and consumer services.

4.3. EV in Indonesia

In terms of EV adoption in Indonesia, there are several recommendations for both (1) the Indonesian Government and (2) investors, OEMs, and EV producers.

For the Indonesian government to fulfil the Indonesian's NDC by 2030, where vehicle electrification is one of the options, the government must push for the adoption rate of EVs (especially BEV) for mass usage and push, so that the fuel-based vehicles' owners change their vehicles into EVs. However, the main problem for achieving mass usage in EVs is the high price of EVs and the lack of supporting infrastructure (proper charging stations).

Although the tax for BEV is zero, the base price is still very high, and most Indonesian people cannot afford it. From Table 2, we see that the BEV has sufficient EV range for home–office–home trips. Most EV makers supply their customers with appropriate home-charging apparatus, so that BEV users can charge their vehicle at night, and they can use it for a round trip without having to charge it at the public charging station. However, the lowest-priced BEV, DFSK Gelora Electric, still retails at 469 to 499 million IDR, more than twice the price most Indonesian people can afford.

The lack of BEVs with lower prices (with lower EV mileage) is due to the lack of a proper charging station. With lower EV mileage, people need to use the public charging station for their round trip from home to the office. However, as we can see, the number of public charging stations is not sufficient, which makes it difficult for the EV players to invest in this BEV specification. Therefore, we believe that the electric LCGC priced under 200 million IDR, as suggested by GAIKINDO, will not work without sufficient public charging stations. To this end, we suggest that the Indonesian government gives more relaxation to the regulation in the public charging station installation.

For investors, OEMs, and EV producers, with many initiatives in fabricating the supporting components of EV in Indonesia, low and no taxes for EVs, we believe that this is the right time for the investors to invest their capital in the EV market in Indonesia. Slowly but surely, EVs, especially BEV, are gaining attention in Indonesia. The Indonesian market needs more investment in the public charging stations, which will create a larger market in low-priced BEV. The EV Makers and OEMs must also start their initiatives in developing the low-priced BEV. With sufficient support and affordable price, BEV will be more attractive to the market.

With the plan for low and zero taxes for EVs, starting from October 2021, we believe that the Indonesian government has shown that they are serious about supporting the adoption of EVs in Indonesia. More initiatives from the EV makers, OEMs, and investors should respond to this movement to produce more affordable EVs.

5. Future Research

There are several critical challenges in large-scale development of EVs, including hard and soft domains [89]. Power management system plays an important role, particularly in HEVs. With intelligent power management techniques, optimal power handling, efficient energy flow to the propulsion unit, reduced system inaccuracies, maximised components life-time and reliable real-time applications can be obtained at various operating conditions. As a result, multiple objectives such as smoother gear shifting, minimised driveline vibration, lower fuel consumption and emission levels, as well as higher mileage extension and improved operation robustness can be achieved simultaneously. Note that EV power management techniques are typically categorised into two groups: (1) rule-based and (2) optimisation-based techniques. In the first technique, which is rule based, the control is governed either by deterministic on-off or by fuzzy-logic rules. In the optimisation-based techniques, on the other hand, the control approaches can be either finding a globally optimal solution or a real-time optimisation.

It is important to note that power system can be significantly affected by implementing the EV scenario. The electricity demand will inevitably increase with the surge in EV demand. This is because the introduction of EVs will considerably affect the demand peaks, decrease reserve margins, and increase electricity prices. However, it is worth noting that this will depend on the state (Malaysia) or province (Indonesia) and the recharge timing. Thus, the impacts of EVs in Malaysian and Indonesian power generation are worth investigating further. It is not part of the present article, but there is abundant room for further progress in this area. Therefore, a future study with more focus on EVs' impact on power generation in Malaysia and Indonesia is suggested.

As the stress to the electrical grid becomes a major issue due to high EVs penetration due to increased charging demand, it is important to look for a strategy to overcome such a problem. In countries where grid capability to balance supply and demand is exceptionally limited, massive EV penetration will severely impact the overall power distributions. For that reason, supplementary services of EVs such as vehicle-to-grid (V2G) in the electrical grid has been considered a promising approach [90]. V2G is a smart charging technology that enables vehicle batteries to absorb and return the electricity from and to the power grid, respectively [91]. Essentially, V2G treats EV batteries as not only devices to run the vehicles but also as backup storage units for the electrical grid. Therefore, if properly controlled, EV charging and discharging through V2G can sustain the electrical grid effectively. It is worth noting that although the concept of V2G seems straightforward, applying V2G needs a sophisticated set of smart technology [92]. Charging stations should be fitted out with computer software that can connect with the main grid to evaluate the overall demand at any time.

Author Contributions: Conceptualisation, I.V. and M.A.A.; methodology, M.A.A., D.W.D. and F.E.; formal analysis, I.V., N.T. and M.I.; investigation, M.A.A., D.W.D., N.T., B.A.B. and F.B.J.; resources, F.E., B.A.B., F.B.J. and M.I.; data curation, F.E., B.A.B., M.I. and A.C.O.; writing—original draft preparation, I.V., M.A.A., D.W.D. and B.A.B.; writing—review and editing, I.V., D.W.D., N.T., M.I., A.C.O., F.B.J. and M.A.; visualisation, A.C.O.; supervision, N.T. and M.A.; project administration, F.E. and F.B.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Indonesia Endowment Fund for Education (LPDP) under Research and Innovation Program (RISPRO) with contract no. PRJ-85/LPDP/2020.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors would like to acknowledge the Universiti Teknikal Malaysia Melaka (UTeM) for the postdoctoral fellowship. Information and insights from Malaysian Green Technology Corporation (MGTC) and the Malaysian Electric Vehicle Owners Club (MyEVOC) are greatly appreciated. Thanks also to the Indonesia Endowment Fund for Education (LPDP) under Research and Innovation Program (RISPRO) with contract no. PRJ-85/LPDP/2020.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Nikzad, R.; Sedigh, G. Greenhouse gas emissions and green technologies in Canada. *Environ. Dev.* **2017**, *24*, 99–108. [CrossRef]
2. Veza, I.; Roslan, M.F.; Said, M.F.M.; Latiff, Z.A.; Abas, M.A. Physico-chemical properties of Acetone-Butanol-Ethanol (ABE)-diesel blends: Blending strategies and mathematical correlations. *Fuel* **2021**, *286*, 119467. [CrossRef]
3. Casals, L.C.; Martinez-Laserna, E.; García, B.A.; Nieto, N. Sustainability analysis of the electric vehicle use in Europe for CO_2 emissions reduction. *J. Clean. Prod.* **2016**, *127*, 425–437. [CrossRef]
4. König, A.; Nicoletti, L.; Schröder, D.; Wolff, S.; Waclaw, A.; Lienkamp, M. An overview of parameter and cost for battery electric vehicles. *World Electr. Veh. J.* **2021**, *12*, 21. [CrossRef]
5. Department of Statistics Malaysia. Population & Demography. Department of Statistics Malaysia Official Portal. 2021. Available online: https://www.dosm.gov.my/v1/index.php?r=column%2FctwoByCat&parent_id=115&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09 (accessed on 8 September 2021).
6. Department of Statistics Malaysia. Population Projection (Revised), Malaysia, 2010–2040. Department of Statistics Malaysia Official Portal. 2016. Available online: https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=118&bul_id=Y3kwU2tSNVFDOWp1YmtZYnhUeVBEdz09&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09 (accessed on 8 September 2021).
7. ASEAN. ASEAN Key Figures 2020. Available online: https://www.aseanstats.org/wp-content/uploads/2020/11/ASEAN_Key_Figures_2020.pdf (accessed on 8 September 2021).
8. Kondo, H. *Sustainable Development of the Transport Sector: Malaysia*; Economic Research Institute for ASEAN and East Asia: Jakarta, Indonesia, 2018.
9. Malaysian Automotive Association. Sales & Production Statistics. Available online: http://www.maa.org.my/statistics.html (accessed on 8 September 2021).
10. Lim, A. Vehicles Registrations in Malaysia Reach 31.2 Million Units as of 2019. 2020. Available online: https://paultan.org/2020/04/02/vehicles-registrations-in-malaysia-31-2-mil-as-of-2019/ (accessed on 8 September 2021).
11. Malaysian Automotive Association. Press Statement: Results of 2020 Performance Better than Expected 2021. Available online: http://www.maa.org.my/pdf/2020/Market_Review_2020.pdf (accessed on 8 September 2021).
12. Asfani, D.A.; Negara, I.M.Y.; Nugraha, Y.U.; Yuniarto, M.N.; Wikarta, A.; Sidharta, I.; Mukhlisin, A. Electric Vehicle Research in Indonesia: A Road map, Road tests, and Research Challenges. *IEEE Electrif. Mag.* **2020**, *8*, 44–51. [CrossRef]
13. Sutopo, W.; Nizam, M.; Rahmawatie, B.; Fahma, F. A review of electric vehicles charging standard development: Study case in Indonesia. In Proceedings of the 2018 5th International Conference on Electric Vehicular Technology (ICEVT), Surakarta, Indonesia, 30–31 October 2018; pp. 152–157.
14. Malaysian Automotive Association. Ministry of International Trade and Industry. National Automotive Policy 2020. 2020. Available online: https://www.miti.gov.my/miti/resources/NAP2020/NAP2020_Booklet.pdf (accessed on 8 September 2021).
15. Yusof, A. Low Carbon Mobility Blueprint to Drive Larger Participation of EV Players: New Straits Times. NST Online. 2021. Available online: https://www.nst.com.my/business/2021/04/683754/low-carbon-mobility-blueprint-drive-larger-participation-ev-players (accessed on 8 September 2021).
16. Malaysian Automotive Association. Market Review for 2018 and Outlook for 2019. Kuala Lumpur. 2019. Available online: http://www.maa.org.my/pdf/Market_Review_2018.pdf (accessed on 8 September 2021).
17. Halmi, S.; (Malaysian Electric Vehicle Owners Club, Kuala Lumpur, Malaysia). Personal communication, 2021.

18. CarBase. Hybrid and EV. Available online: https://www.carbase.my/body-type/hybrid-and-ev (accessed on 8 September 2021).
19. Tan, P. RM175k Toyota Prius Now Available in Malaysia. 2009. Available online: https://paultan.org/2009/08/04/rm175k-toyota-prius-now-available-in-malaysia/ (accessed on 8 September 2021).
20. The Star. Insight Into RM98,000 Hybrid Car. 2010. Available online: https://web.archive.org/web/20101203205403/http://thestar.com.my/news/story.asp?file=%2F2010%2F12%2F3%2Fnation%2F7550972&sec=nation (accessed on 8 September 2021).
21. Chew, T. Mitsubishi i-MiEV: The Tech Features of the First Electric Car in Malaysia. 2013. Available online: https://www.expatgo.com/my/2013/09/10/mitsubishi-i-miev-malaysia/ (accessed on 8 September 2021).
22. ExpatGo. Nissan Leaf All-Electric Car Launched in Malaysia. 2020. Available online: https://www.expatgo.com/my/2013/11/17/nissan-leaf-launched-malaysia/ (accessed on 8 September 2021).
23. Omar, H.N.; (Malaysian Green Technology and Climate Change Centre, Bandar Baru Bangi, Malaysia). Personal communication, 2021.
24. Lim, A. MARii and Pekema to Accelerate Development of EV Infrastructure in Malaysia—1000 DC Chargers by 2025. 2021. Available online: https://paultan.org/2021/08/13/marii-and-pekema-to-accelerate-development-of-ev-infrastructure-in-malaysia-1000-dc-chargers-by-2025/ (accessed on 8 September 2021).
25. Zainuddin, F.R. TNB Ready to Facilitate Malaysia's Transition into Low-Carbon Mobility. 2021. Available online: https://www.tnb.com.my/assets/press_releases/202107101bi.pdf (accessed on 8 September 2021).
26. Kaur, D. Malaysia to Have 1000 EV Charging Stations by 2025. 2021. Available online: https://techwireasia.com/2021/08/malaysia-to-have-1000-ev-charging-stations-by-2025/ (accessed on 8 September 2021).
27. ChargEV Malaysia. List of chargEV Chargers. Available online: https://chargev.chargev.my/faqs/list-of-chargev-charger_updated-june-2021-2/ (accessed on 8 September 2021).
28. Shell Malaysia. Shell Recharge with Parkeasy. Available online: https://www.shell.com.my/motorists/shell-recharge/shell-recharge-with-parkeasy.html (accessed on 8 September 2021).
29. Malaysian Green Technology and Climate Change Centre. chargEV is Driving Malaysia's Electric Vehicle Infrastructure. 2021. Available online: https://www.mgtc.gov.my/2019/09/chargev-is-driving-malaysias-electric-vehicle-infrastructure/ (accessed on 8 September 2021).
30. Yun, T.Z. Sustainable Tech: Building Chargers for an EV Future. 2021. Available online: https://www.theedgemarkets.com/article/sustainable-tech-building-chargers-ev-future (accessed on 8 September 2021).
31. NST Business. Shell to Set Up EV Charging Stations in Malaysia, Singapore. 2021. Available online: https://www.nst.com.my/business/2021/03/678458/porsche-shell-set-ev-charging-stations-malaysia-singapore (accessed on 8 September 2021).
32. EV Connection. EV Info. Available online: http://www.ev-connection.com/ev-info/ (accessed on 8 September 2021).
33. MahSing. Three Things About EV Charging You Should Know before Purchasing an Electric Car in Malaysia. 2021. Available online: https://www.mahsing.com.my/blog/3-things-about-ev-charging-you-should-know-before-purchasing-an-electric-car-in-malaysia/ (accessed on 8 September 2021).
34. Shah, H. New Malaysia Excise Duty Regulations Introduced for 2020 Could See CKD Car Prices Rise by Up To 15%. 2020. Available online: https://paultan.org/2020/01/17/new-malaysia-excise-duty-regulations-introduced-for-2020-could-see-ckd-car-prices-rise-by-up-to-15/ (accessed on 8 September 2021).
35. Tan, P. NAP Review's Hybrid Car Incentives. 2009. Available online: https://paultan.org/2009/10/29/the-nap-reviews-half-baked-hybrid-car-incentives/ (accessed on 8 September 2021).
36. Tan, P. New Toyota Prius Lowered Price—Rm 139,900. 2010. Available online: https://paultan.org/2010/10/28/new-toyota-prius-price-rm139900/ (accessed on 8 September 2021).
37. Tan, P. Budget 2012: Hybrid Car Incentives Extended Until 2013. 2011. Available online: https://paultan.org/2011/10/07/budget-2012-hybrid-car-incentives-extended-till-2013/ (accessed on 8 September 2021).
38. Ker, N. MARii: Malaysia's EV Policy to Offer "Handsome" Tax Incentive to Accelerate Development. 2021. Available online: https://soyacincau.com/2021/05/21/marii-malaysia-ev-policy-handsome-tax-incentives-to-accelerate-development/ (accessed on 8 September 2021).
39. Kaniapan, S.; Hassan, S.; Ya, H.; Patma Nesan, K.; Azeem, M. The utilisation of palm oil and oil palm residues and the related challenges as a sustainable alternative in biofuel, bioenergy, and transportation sector: A review. *Sustainability* **2021**, *13*, 3110. [CrossRef]
40. Katijan, A.; Latif, M.F.A.; Zahmani, Q.F.; Zaman, S.; Kadir, K.A.; Veza, I. An Experimental Study for Emission of Four Stroke Carbureted and Fuel Injection Motorcycle Engine. *J. Adv. Res. Fluid Mech. Therm. Sci.* **2019**, *62*, 256–264.
41. Veza, I.; Roslan, M.F.; Said, M.F.M.; Latiff, Z.A.; Abas, M.A. Cetane index prediction of ABE-diesel blends using empirical and artificial neural network models. *Energy Sources, Part A Recover. Util. Environ. Eff.* **2020**, *42*, 1–18. [CrossRef]
42. Veza, I.; Said, M.F.M.; Latiff, Z.A.; Abas, M.A. Application of Elman and Cascade neural network (ENN and CNN) in comparison with adaptive neuro fuzzy inference system (ANFIS) to predict key fuel properties of ABE-diesel blends. *Int. J. Green Energy* **2021**, *18*, 1510–1522. [CrossRef]
43. Ritchie, H.; Roser, M. Indonesia: CO_2 Country Profile. Our World in Data. 2020. Available online: https://ourworldindata.org/co2/country/indonesia (accessed on 5 October 2021).

44. Mohammed, A.T.; Jaafar, M.N.M.; Othman, N.; Veza, I.; Mohammed, B.; Oshadumi, F.A.; Sanda, H.Y. Soil fertility enrichment potential of Jatropha curcas for sustainable agricultural production: A case study of Birnin Kebbi, Nigeria. *Ann. Rom. Soc. Cell Biol.* **2021**, *25*, 21061–21073.
45. Veza, I.; Said, M.F.M.; Latiff, Z.A. Progress of acetone-butanol-ethanol (ABE) as biofuel in gasoline and diesel engine: A review. *Fuel Process. Technol.* **2019**, *196*, 106179. [CrossRef]
46. Ambaye, T.G.; Vaccari, M.; Bonilla-Petriciolet, A.; Prasad, S.; van Hullebusch, E.D.; Rtimi, S. Emerging technologies for biofuel production: A critical review on recent progress, challenges and perspectives. *J. Environ. Manag.* **2021**, *290*, 112627. [CrossRef] [PubMed]
47. Veza, I.; Karaoglan, A.D.; Ileri, E.; Kaulani, S.A.; Tamaldin, N.; Latiff, Z.A.; Said, M.F.M.; Hoang, A.T.; Yatih, K.V.; Idris, M. Grasshopper optimisation algorithm for diesel engine fuelled with ethanol-biodiesel-diesel blends. *Case Stud. Therm. Eng.* **2022**, *31*, 101817. [CrossRef]
48. Sunarti; Supriadi, A.; Kencono, A.W.; Prasetyo, B.E.; Kurniasih, T.N.; Sunaryo, F.K.; Kurniadi, C.B.; Alwendra, Y.; Bhaskoro, T.P.; Setiadi, I.; et al. Kajian Penggunaan Faktor Emisi Lokal (Tier 2) dalam Inventarisasi GRK Sektor Energi. 2017. Available online: https://www.esdm.go.id/assets/media/content/content-kajian-emisi-gas-rumah-kaca-2017.pdf (accessed on 5 October 2021).
49. CNN Indonesia. Target RI 2030, 25 Ribu SPKLU Dan 3 Juta Kendaraan Listrik. 2021. Available online: https://www.cnnindonesia.com/teknologi/20210805183618-384-676999/target-ri-2030-25-ribu-spklu-dan-3-juta-kendaraan-listrik (accessed on 5 October 2021).
50. Nurhayati, F. Lebih Dari 2000 Unit Kendaraan Listrik Lolos Uji Kelayakan. 2021. Available online: https://databoks.katadata.co.id/datapublish/2021/05/06/lebih-dari-2000-unit-kendaraan-listrik-lolos-uji-kelayakan (accessed on 5 October 2021).
51. Priyanto, W. Bus Listrik Milik Moeldoko Siap Diproduksi. 2021. Available online: https://otomotif.tempo.co/read/1429059/bus-listrik-milik-moeldoko-siap-diproduksi (accessed on 5 October 2021).
52. Gesitsmotors. Gesits Spesifikasi. 2021. Available online: https://gesitsmotors.com/spesifikasi/ (accessed on 5 October 2021).
53. Raka. Telisik Spesifikasi Motor Listrik Gesits, Karya Anak Bangsa Yang Mulai Mendunia. 2021. Available online: https://www.autofun.co.id/berita-motor/telisik-spesifikasi-motor-listrik-gesits-karya-anak-bangsa-yang-mulai-mendunia-29729 (accessed on 5 October 2021).
54. Brian. Motor Listrik Smoot Punya 100 Titik Penukaran Baterai di Jakarta. 2021. Available online: https://otorider.com/motor-listrik/2021/motor-listrik-smoot-punya-100-titik-penukaran-baterai-di-jakarta-motcbgedrta (accessed on 5 October 2021).
55. Swap Staff. SWAP. Available online: https://swap.id/tentang-swap (accessed on 5 October 2021).
56. Rubiah, H. Daftar Mobil Listrik Buatan Indonesia Karya Anak Bangsa, Keren Tak Kalah Menarik Dari Tesla dan BMW. 2020. Available online: https://jabar.tribunnews.com/2020/06/05/daftar-mobil-listrik-buatan-indonesia-karya-anak-bangsa-keren-tak-kalah-menarik-dari-tesla-dan-bmw (accessed on 5 October 2021).
57. Lo, J. With Indonesia's Answer to Elon Musk in Jail, Electric Vehicles are Going Nowhere. 2021. Available online: https://www.climatechangenews.com/2021/05/21/indonesias-answer-elon-musk-jail-electric-vehicles-going-nowhere/ (accessed on 5 October 2021).
58. Praditya, I.I. Bakal Dibeli Malaysia, Ini Curhatan Pencipta Mobil Listrik RI. 2015. Available online: https://www.liputan6.com/bisnis/read/2306742/bakal-dibeli-malaysia-ini-curhatan-pencipta-mobil-listrik-ri (accessed on 5 October 2021).
59. Agustinus, M. Kok Bisa Proyek Mobil Listrik Dahlan Iskan Gagal. 2017. Available online: https://finance.detik.com/energi/d-3564927/kok-bisa-proyek-mobil-listrik-dahlan-iskan-gagal (accessed on 5 October 2021).
60. Karmawijaya, M.I.; Haq, I.N.; Leksono, E.; Widyotriatmo, A. Development of big data analytics platform for electric vehicle battery management system. In Proceedings of the 2019 6th International Conference on Electric Vehicular Technology (ICEVT), Bali, Indonesia, 18–21 November 2019; pp. 151–155.
61. Kusuma, C.F.; Budiman, B.A.; Nurprasetio, I.P.; Islameka, M.; Masyhur, A.H.; Aziz, M.; Reksowardojo, I.K. Energy Management System of Electric Bus Equipped with Regenerative Braking and Range Extender. *Int. J. Automot. Technol.* **2021**, *22*, 1651–1664. [CrossRef]
62. Reksowardojo, I.K.; Arya, R.R.; Budiman, B.A.; Islameka, M.; Santosa, S.P.; Sambegoro, P.L.; Aziz, A.R.; Abidin, E.Z. Energy management system design for good delivery electric trike equipped with different powertrain configurations. *World Electr. Veh. J.* **2020**, *11*, 76. [CrossRef]
63. Endrasari, F.; Djamari, D.W.; Budiman, B.A.; Triawan, F. Rollover Stability Analysis and Layout Optimization of a Delta E-trike. *Automot. Exp.* **2022**, *5*, 137–149.
64. Sholahuddin, U.; Purwadi, A.; Haroen, Y. Structural Optimizations of a 12/8 Switched Reluctance Motor using a Genetic Algorithm. *Int. J. Sustain. Transp. Technol.* **2018**, *1*, 30–34. [CrossRef]
65. Pusparisa, Y. Proyeksi Jumlah Kendaraan Listrik di Indonesia Hingga 2030. 2020. Available online: https://databoks.katadata.co.id/datapublish/2020/07/30/proyeksi-jumlah-kendaraan-listrik-di-indonesia-hingga-2030 (accessed on 5 October 2021).
66. Umah, A. Penggunaan Mobil Listrik RI Bisa Sampai 125 Ribu Unit. 2021. Available online: https://www.cnbcindonesia.com/news/20210119121258-4-217097/2021-penggunaan-mobil-listrik-ri-bisa-sampai-125-ribu-unit (accessed on 5 October 2021).
67. BKPM. Electric Vehicle. 2020. Available online: https://www.bkpm.go.id/images/uploads/printing/Electric_Vehicle_Brochure_2020.pdf (accessed on 5 October 2021).

68. Agarwal, R.; Agarwal, V.; Hansmann, T.; Lath, V.; Tan, K.T.; Yi, Z. Ten Ways to Boost Indonesia's Energy Sector in a Postpandemic World. 2020. Available online: https://www.mckinsey.com/industries/oil-and-gas/our-insights/ten-ways-to-boost-indonesias-energy-sector-in-a-postpandemic-world (accessed on 5 October 2021).
69. Gupta, R.; Hansmann, T. Growing Demand for Electric Vehicles a Boost for Indonesia's Economy. 2021. Available online: https://www.thejakartapost.com/academia/2021/05/27/growing-demand-for-electric-vehicles-a-boost-for-indonesias-economy.html (accessed on 5 October 2021).
70. Yuana, L. Listrik Surplus 2500 MW, PLN Gandeng PT Opintech Wujudkan Proyek SPKLU. 2020. Available online: https://www.timesindonesia.co.id/read/news/253887/listrik-surplus-2500-mw-pln-gandeng-pt-opintech-wujudkan-proyek-spklu (accessed on 5 October 2021).
71. Chargehub, S. 2020 Guide On How To Charge Your Electric Car With Charging Stations. Available online: https://chargehub.com/en/electric-car-charging-guide.html (accessed on 5 October 2021).
72. Dolsak, N.; Prakash, A. The Lack of EV Charging Stations Could Limit EV Growth. 2021. Available online: https://www.forbes.com/sites/prakashdolsak/2021/05/05/the-lack-of-ev-charging-stations-could-limit-ev-growth/?sh=58a2cb256a13 (accessed on 5 October 2021).
73. Sakti, A.Y.N. Standar dan Regulasi Dalam Industri Kendaraan Listrik dan SPKLU (Stasiun Pengisian Kendaraan Listrik Umum). 2020. Available online: https://psat.bppt.go.id/berita/standar-dan-regulasi-dalam-industri-kendaraan-listrik-dan-spklu-stasiun-pengisian-kendaraan-listrik-umum (accessed on 5 October 2021).
74. Maskur, F. Mobil Listrik Berhasil Uji Perjalanan Rute Jakarta-Bali, Ini Daftar SPKLU. 2020. Available online: https://otomotif.bisnis.com/read/20201231/275/1337380/mobil-listrik-berhasil-uji-perjalanan-rute-jakarta-bali-ini-daftar-spklu (accessed on 5 October 2021).
75. Meilanova, D.R. Permen SPKLU Dukung Mobil Listrik Segera Terbit, Ini Isinya. 2020. Available online: https://ekonomi.bisnis.com/read/20200813/44/1278945/permen-spklu-dukung-mobil-listrik-segera-terbit-ini-isinya (accessed on 5 October 2021).
76. Pratiwi, I. Percepat Pembangunan SPKLU, Pemerintah Siapkan Insentif. 2021. Available online: https://www.republika.co.id/berita/qyy7z8370/percepat-pembangunan-spklu-pemerintah-siapkan-insentif (accessed on 5 October 2021).
77. Archyw. Valid 16 October, These Are the Cars That Are Exempt from Paying Taxes. 2021. Available online: https://www.archyworldys.com/valid-october-16-these-are-the-cars-that-are-exempt-from-paying-taxes/ (accessed on 5 October 2021).
78. Kosasih, D.T. Pajak Mobil Listrik Resmi Terbit, Ini Rinciannya. 2019. Available online: https://www.liputan6.com/otomotif/read/4093905/pajak-mobil-listrik-resmi-terbit-ini-rinciannya (accessed on 5 October 2021).
79. YCP Solidiance. Key Drivers and Challenges of EV Implementation in Indonesia. 2018. Available online: https://ycpsolidiance.com/article/key-drivers-and-challenges-of-ev-implementation-in-indonesia (accessed on 5 October 2021).
80. McIntosh, J. How It Works: Making Sense of EV Specifications. 2021. Available online: https://driving.ca/column/how-it-works/how-it-works-making-sense-of-ev-specifications (accessed on 5 October 2021).
81. KNIC. Bright Future for Electric Vehicle Industry in Indonesia. 2021. Available online: https://www.knic.co.id/bright-future-for-electric-vehicle-industry-in-indonesia (accessed on 5 October 2021).
82. Pangastuti, T. Proposal Kerjasama Segerea Diterima Indonesia dan Tesla telah Teken Perjanjian NDA. 2021. Available online: https://investor.id/business/236068/indonesia-dan-tesla-telah-teken-perjanjian-nda (accessed on 5 October 2021).
83. Jones, C.B. Hyundai Motor Group and LG Energy Solution Sign MoU with Indonesian Government to Establish EV Battery Cell Plant. 2021. Available online: https://www.enginetechnologyinternational.com/news/facility-development/hyundai-and-lg-energy-solution-start-construction-of-ev-battery-cell-plant.htm (accessed on 5 October 2021).
84. Reuters Staff. Indonesia Says China's CATL Plans to Invest $5 Billion in Lithium Battery Plant. 2020. Available online: https://www.reuters.com/article/us-indonesia-nickel-china-idUSKBN28P0MK (accessed on 5 October 2021).
85. Purnomo, D. Boleh Dicek, Ini 5 Mobil Listrik Murni Termurah di Indonesia. 2021. Available online: https://id.motor1.com/features/521112/5-mobil-listrik-termurah-indonessia/ (accessed on 5 October 2021).
86. Hikam, H.A.A. Pendapatan Orang RI Jadi Rp 27 Juta/Bulan di 2045 Berkat UU Cipta Kerja. 2021. Available online: https://finance.detik.com/berita-ekonomi-bisnis/d-5609969/pendapatan-orang-ri-jadi-rp-27-jutabulan-di-2045-berkat-uu-cipta-kerja (accessed on 5 October 2021).
87. Dananjaya, D. Agar Lebih Murah, Gaikindo Usul Mobil Listrik Versi LCGC. 2021. Available online: https://otomotif.kompas.com/read/2021/07/26/151200815/agar-lebih-murah-gaikindo-usul-mobil-listrik-versi-lcgc (accessed on 5 October 2021).
88. Erickson, L.E.; Robinson, J.; Brase, G.; Cutsor, J. *Solar Powered Charging Infrastructure for Electric Vehicles*; CRC Press: Boca Raton, FL, USA, 2017.
89. Lebrouhi, B.E.; Khattari, Y.; Lamrani, B.; Maaroufi, M.; Zeraouli, Y.; Kousksou, T. Key challenges for a large-scale development of battery electric vehicles: A comprehensive review. *J. Energy Storage* **2021**, *44*, 103273. [CrossRef]
90. Huda, M.; Tokimatsu, K.; Aziz, M. Techno economic analysis of vehicle to grid (V2G) integration as distributed energy resources in Indonesia power system. *Energies* **2020**, *13*, 1162. [CrossRef]
91. Heilmann, C.; Friedl, G. Factors influencing the economic success of grid-to-vehicle and vehicle-to-grid applications—A review and meta-analysis. *Renew. Sustain. Energy Rev.* **2021**, *145*, 111115. [CrossRef]
92. Zheng, Y.; Niu, S.; Shang, Y.; Shao, Z.; Jian, L. Integrating plug-in electric vehicles into power grids: A comprehensive review on power interaction mode, scheduling methodology and mathematical foundation. *Renew. Sustain. Energy Rev.* **2019**, *112*, 424–439. [CrossRef]