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# Electric Vehicle Adoption: A Comparative Analysis in Malaysia and ASEAN Countries

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### ABSTRACT

Electric vehicles (EVs) offer environmental and economic benefits, but face barriers to widespread adoption globally and in the ASEAN region. This paper analyses Malaysia's EV adoption approach and progress compared to neighbouring countries to understand its positioning and potential policy improvements. The analysis examines government EV incentives, infrastructure development, market growth, and remaining challenges across multiple ASEAN nations. While Malaysia introduced early EV incentives, progress remains slower than regional leaders like Thailand and Indonesia with under 31,000 EVs on Malaysian roads versus over 84,000 in Thailand. High vehicle costs, lack of public charging stations, and low consumer awareness require urgent policy action. By learning from the successes and missteps of advanced ASEAN EV markets, Malaysia can enhance strategic support through improved incentives, infrastructure investments, awareness campaigns, and intergovernmental collaboration to accelerate sustainable electric mobility.

## 1. Introduction

As a nation's development accelerates, there is typically a corresponding increase in transportation usage. However, this heightened demand for transportation often relies heavily on fossil fuels, leading to significant carbon emissions on a global scale. This reliance on fossil fuels within the transportation sector exacerbates the challenges posed by climate change, as the emissions released contribute to the worsening environmental impacts worldwide. Consequently, addressing this dependency on fossil fuels in transportation is crucial in mitigating the effects of climate change and reducing our environmental footprint. According to a recent study by the European Commission in 2022, findings showed that in 2021, the transportation sector was responsible for almost 20% of global carbon dioxide (CO<sub>2</sub>) emissions, reaching a substantial 7643.5 billion metric tons of CO<sub>2</sub> [1].

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Over the last ten years (2010–2019), Malaysia experienced a 10.74% uptick in CO<sub>2</sub> emissions per person. These data underscore the critical importance of ramping up efforts to combat current and future environmental risks [2].

If proactive measures are not implemented to tackle the escalating environmental issues, it is expected that this trend will persist. Green technology encompasses the utilization of techniques and materials that prioritize environmental sustainability while still catering to the needs and desires of society. The shift towards a green economy entails substituting environmentally detrimental industrial technologies with eco-friendly alternatives, fostering economic growth while minimizing environmental harm. This transition necessitates a move away from conventional energy sources towards sustainable and environmentally conscious alternatives, alongside the adoption of sustainable production methods for exported goods. Focusing on transitioning from fossil fuels to cleaner and more sustainable modes of transportation, particularly electric mobility, represents one approach to reducing greenhouse gas emissions [1].

Electric vehicles (EVs) are real vehicles involved with electric propulsion. With the rapid development of the economy and people's living standards, the total number of vehicles is continuously increasing day by day. Research and development focus on energy efficiency reduction of use and pollution control and the expansion of various EVs is increasing worldwide [3]. Currently, the most common vehicle type is still the conventional vehicles (CVs) powered only by an internal combustion engine (ICE) [4]. There will be a lot of societal issues in the future, like excessive pollution and the abuse of oil resources. The previously listed issues have drawn attention from around the world and presented serious difficulties for the car industry. As a result, car manufacturers everywhere are committed to creating new, energy-efficient automobiles. Considerable progress has been achieved in lowering costs, enhancing battery performance, and boosting energy efficiency since the introduction of lithium-ion batteries (LIBs). Almost all car manufacturers have started producing EVs because they can help reduce fuel dependence and eliminate automotive pollution. Many nations have established regulations to stop ICE vehicles in the next 10 to 30 years [5].

One of the most important aspects of the global efforts to slow down climate change and move towards sustainable transportation is the adoption of hybrid and EV [6]. Each nation in the Association of Southeast Asian Nations (ASEAN) region has its distinct circumstances when it comes to marketing and adopting hybrid and electric vehicles. These nations range widely in terms of their economic structures and phases of development. The following vehicles introduced types of new energy vehicles which are hybrid electric vehicles (HEVs), plug-in electric vehicles (PHEVs), electric batteries (BEVs), and fuel cell vehicles (FCVs). The paper starts by summarising the current situation of EV cars in Malaysia compared to other ASEAN countries like Brunei Darussalam, Myanmar, Cambodia, Indonesia, Laos, Philippines, Singapore, Thailand, and Vietnam, then focuses on EV development by country [7].

This report will focus on the approach and progress in terms of policy and market around ASEAN. In the context of hybrid vehicles, the term "policy" typically refers to government regulations, incentives, and initiatives aimed at promoting the adoption and use of hybrid and electric vehicles. These policies can include measures such as tax credits for hybrid vehicle purchases, subsidies for charging infrastructure, fuel economy standards, emissions regulations, and others [8]. Then the term "market" typically refers to the demand, supply, and overall economic environment for hybrid vehicles. This includes factors such as consumer preferences, government policies, and industry trends. The hybrid vehicle market has experienced significant growth in recent years due to factors, challenges, and status [9].

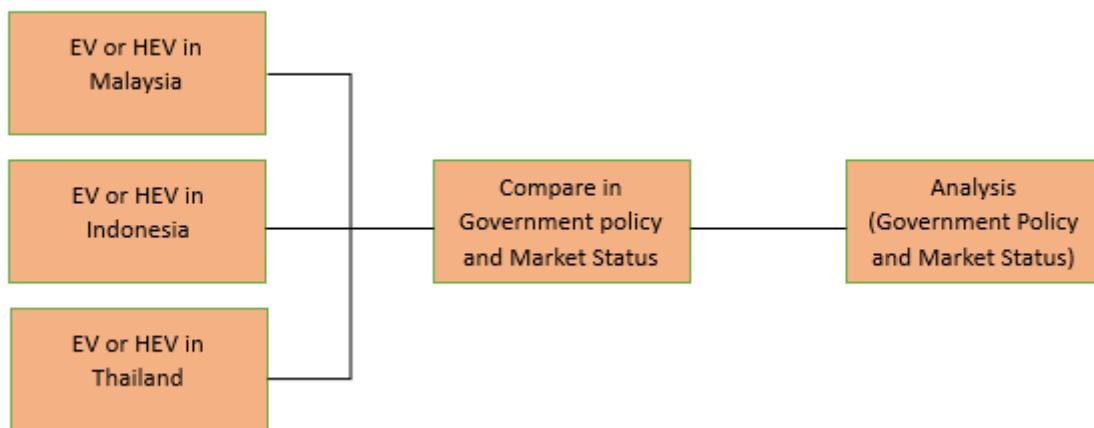
The rest of the paper is designed as follows: Section 1 introduces EV technology. Section 2 indicates the methods used in this review work. Section 3 provides the government policy and market

status of EVs in ASEAN countries, which are Malaysia, Indonesia, and Thailand. Finally, in Section 4, the paper is concluded.

## 2. Methodology

### 2.1 Scope of Study and Framework

Comparison of EV or HEV with various countries, especially ASEAN countries with Malaysia can improve Malaysia's quality and technology. This can help Malaysia encourage the use of EV or HEV. Through this study, two countries have been selected namely Indonesia and Thailand that will be compared with Malaysia regarding EV or HEV. Therefore, a literature review of the three countries was conducted to facilitate comparison according to various aspects. Nevertheless, this study will compare the government policy and market status. A summary of this study and framework is shown in Figure 1.



**Fig. 1.** Summary of the study framework

### 2.2 Literature Review Process

This study examines a systematic approach and compares government policy and market status in ASEAN countries by involving an examination of existing scholarly works. The discovery of the literature review was done by searching for the keywords "EV", "HEV", "Malaysia", "Indonesia", "Thailand", "government policy" and "market status". This study makes a screening and revision between 2015 and 2023. This literature review forms an important basis for further research that can provide insight and knowledge on government policies and market conditions in ASEAN countries. This literature review process is shown in Figure 2.



Fig. 2. Literature review process

### 3. Analysis in Malaysia and ASEAN Countries

The rapid growth of well-established EV markets is bolstered by robust policy measures across four key areas: official EV targets, constraints on ICE production and sales, consumer incentives, and bolstering EV charging infrastructure (EVCI). In the Asian region, governments demonstrate varying degrees of commitment to electrification (Figure 3). China, Japan, and South Korea have implemented comprehensive policy frameworks to facilitate adoption. In emerging Asian markets, Thailand has introduced its 3030 EV Production Policy, aiming to achieve 30 percent of domestic vehicle production by 2030 [10]. Indonesia, in alignment with international agreements like the Kyoto Protocol, has a national mission to develop a strategy to reduce greenhouse gas emissions in the energy sector, particularly focusing on electric vehicles to minimize carbon emissions in transportation [11].

In Malaysia, the adoption of EVs has been slower compared to other developing Asian countries. This may be attributed to the lack of a clear policy framework, including the absence of an official ban on ICE vehicles. However, Malaysia is reassessing its EV policy and has recently announced new measures, such as tax exemptions for locally manufactured and imported EVs, as well as significant expansion plans for the country's EV charging infrastructure by 2025 [12]. In markets like Malaysia, it will be essential to focus on both EV distribution and charging infrastructure simultaneously to achieve adoption levels comparable to those projected for other ASEAN markets. This dual approach is crucial for creating an environment conducive to EV uptake and fostering consumer confidence in EVs.

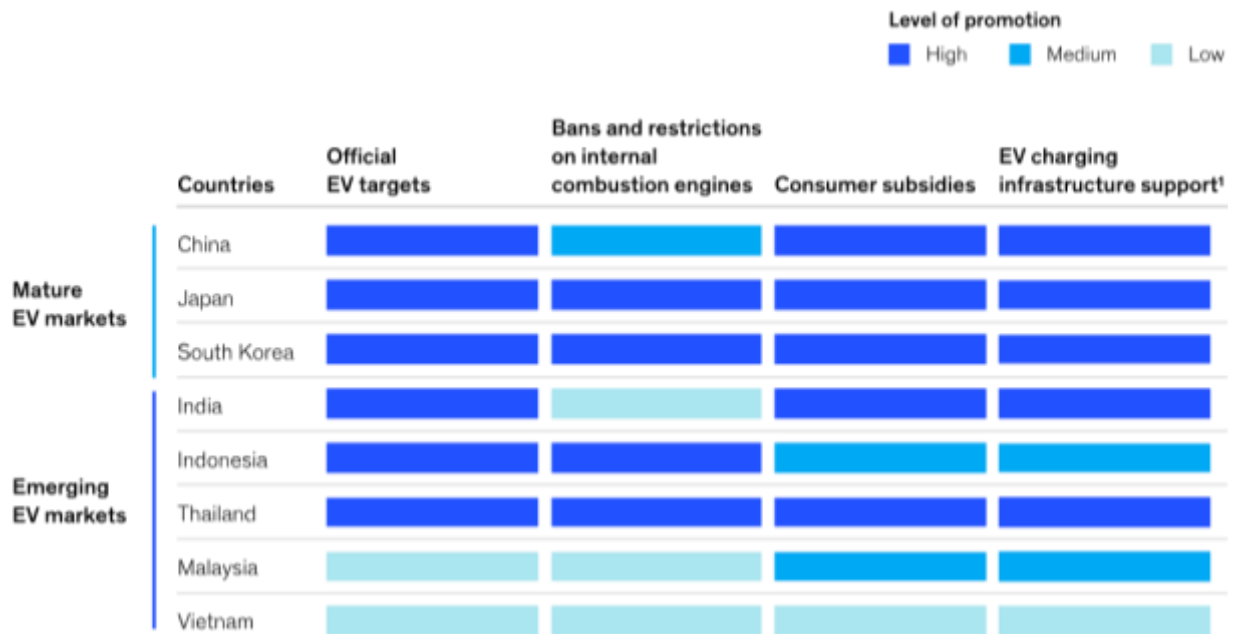


Fig. 3. The level of promotion for transportation electrification differs among Asian governments [13]

### 3.1 EV or HEV Malaysia

Malaysia encourages the use of EVs relatively. This is because of the mixed motives of the environment, energy, and Malaysia's consideration of EVs [14]. The establishment of Greentech Malaysia under the Ministry of Energy, Green Technology, and Water was established to promote EV usage policies [14]. The Malaysian government also introduced a 100% import duty exemption to encourage its citizens to use EVs or HEVs [15]. This can be proven by the price of the Toyota Prius, which ranges from RM175,000 to RM139,900 [16].

Malaysia is one of the automotive-producing countries in ASEAN. Proton Holding Berhad (PROTON) and *Perusahaan Otomobil Kedua Sendirian Berhad* (Perodua) are the country's local cars [17]. The introduction of electric or hybrid-based cars in Malaysia causes demand to increase. This can be proven in 2017 and 2018, when as many as 9000 EV units were registered in Malaysia [18]. As of today, more than 31,000 EV units are registered on Malaysian roads. With the number of EVs increasing, by 2030, the government aims for 125,000 EVs to be on the road [19].

Furthermore, it is anticipated that overall sales of PHEVs and EVs in Malaysia will increase over the next few years due to several factors, including the growing acceptance of hybrid cars among consumers, the government of Malaysia's extended tax incentives for PHEVs, and EVs, and the latest models that automakers are promoting. Additionally, PHEVs and EVs are made to perform better in terms of cost savings and fuel efficiency. Furthermore, compared to 8334 units in 2011, the total number of PHEV/EV trades in Malaysia in 2012 was approximately 15,355 units, Lexus (266 units), Toyota (2456 units), and Honda (4595 units) were the top 3 PHEV/EV suppliers [20].

### 3.2 EV or HEV Indonesia

Indonesia developed a policy towards EVs, although it took a long time. The President of Indonesia, Joko Widodo, supports EVs and has created many ideas to create and produce EVs in Indonesia [14]. In addition, Indonesia introduced the *Kendaraan Bermotor Listrik Berbasis Baterai* (KBLBB) Program, or the Battery Electric Vehicle (BEV) Program. Through this program, a total of

132,000 EVs and 245,000 electric motorcycles will be purchased by the Indonesian government by 2030 [21]. As for taxes, Indonesia does not tax EVs in full, and for HEVs, the tax is 15%, 25%, or 30% depending on engine displacement [22].

The introduction of EVs in Indonesia is increasing with various initiatives and incentives introduced by the Indonesian government. Since the introduction of EVs and electric motors in Indonesia, the current focus is more on electric motors, also known as electric two-wheeled units. Therefore, there will be as many as 16,000 electric motor units in Indonesia in 2019 [23]. Indonesia has announced plans to prohibit the sale of all fossil fuel motorcycles by 2040 and fossil fuel-powered cars by 2050 [24].

### *3.3 EV or HEV Thailand*

Thailand is one of the largest producers in the world. Therefore, Thailand has a policy to manage the growing technology, especially for local production involving EV components. This is also Thailand's decision and initiative to introduce a policy to promote Thailand as an ASEAN EV hub and promote the use of EVs on Thailand's roads [25]. Thailand has set up taxes to encourage the use of EVs. The Ministry of Finance took steps by lowering the excise tax on EVs for its citizens from 20–40% to 2–8% [26].

EV popularity is still low despite having been launched since 2009–2010 in Thailand. A total of 84,236 PHEV units and 63 BEV units have been registered in Thailand, according to statistics from the Land Transport Department. Therefore, Thailand's government, through the incentives of the Board of Investment (BOI), encourages the production of HEV parts. This is because Thailand is one of the vehicle manufacturing hubs. In 2025, Thailand expects EVs to be commercially launched in the market. In 2036, as many as 1.2 million electric vehicles will be targeted by the Thai government [27].

The first EV policies in Thailand were introduced by the government in 2015, to promote electric vehicles. Only 0.32% of all vehicles are registered; that is, 123,967 EVs out of 38.31 million cars registered with the Department of Land Transportation [28]. The Thailand government has put in place a variety of incentives and subsidies, such as tax breaks and subsidies for cars and motorcycles made both domestically and abroad, to promote the market penetration of EVs. Electric vehicle subsidies range from 2000 to 4000 USD, based on the make and model of the vehicle, and the excise tax has been lowered from 8% to 2%. According to [28], they also state that a plan to establish Thailand as an ASEAN BEV hub was released by the National Science and Technology Development Agency (NSTDA). This plan includes the ability to produce 1000 electric buses annually and develop prototype-modified EVs.

Based on the analysis discussed, it can be summarised in Table 1 about the comparison of Malaysia with Indonesia and Thailand based on their government policies and market status.

**Table 1**  
 Comparison of Government Policy and Market Status

| Country           | Malaysia  | Indonesia   | Thailand  |
|-------------------|---|---|---|
| Government Policy | <ul style="list-style-type: none"> <li>Introduced 100 % import duty exemption to use EV or hybrid electric vehicle (HEV).</li> <li>Malaysia is reassessing its EV policy and has recently announced new measures, such as tax exemptions for locally manufactured and imported EVs, as well as significant expansion plans for the country's EV charging infrastructure by 2025</li> </ul>                  | <ul style="list-style-type: none"> <li>Introduced the <i>Kendaraan Bermotor Listrik Berbasis Baterai</i> (KBLBB) Program or the Battery Electric Vehicle (BEV) Program.</li> <li>Not tax EVs in full and for HEV the tax is 15 %, 25 %, or 30 %.</li> </ul> | <ul style="list-style-type: none"> <li>Introduced a policy to promote Thailand as an ASEAN EV hub and promote the use of EV on Thailand's roads.</li> <li>Lowering the excise tax for EVs from 20-40% to 2-8%.</li> <li>The first EV policies in Thailand were introduced in 2015, to promote electric vehicles.</li> <li>Thailand introduced 3030 EV Production Policy, aiming to achieve 30 percent of domestic vehicle production by 2030</li> </ul> |
| Market Status     | <ul style="list-style-type: none"> <li>In 2017 and 2018 as many as 9000 EV units have been registered.</li> <li>Today, more than 31,000 EV units are registered.</li> <li>Compared to 8334 units in 2011, the total number of PHEV/EV trades in Malaysia in 2012 was approximately 15,355 units, Lexus (266 units), Toyota (2456 units), and Honda (4595 units) were the top 3 PHEV/EV suppliers</li> </ul> | <ul style="list-style-type: none"> <li>In 2019, as many as 16,000 units of electric motors.</li> <li>Plans to prohibit the sale of all fossil fuel motorcycles by 2040 and fossil fuel-powered cars by 2050</li> </ul>                                      | <ul style="list-style-type: none"> <li>2009-2010, 84,236 PHEV units and 63 BEV units have been registered.</li> <li>Plan includes the ability to produce 1000 electric buses annually and develop prototype-modified EV</li> </ul>  |

#### 4. Conclusions

In conclusion, Malaysia's approach and progress in hybrid and EV adoption are moderate, with a growing interest in and adoption of EVs among consumers. However, there are still challenges to overcome, such as the lack of infrastructure and low consumer awareness. Malaysia can learn from the experiences of other countries in promoting EV adoption and addressing the challenges to accelerate the transition to a more sustainable transportation system. While Malaysia has shown promising initial steps towards HEV and EV adoption, progress remains slower compared to many other countries. Addressing high upfront costs, limited charging infrastructure, and low public awareness are crucial to accelerating the transition.

By learning from leading countries and refining its approach, Malaysia can position itself as a regional leader in sustainable mobility. While Malaysia has taken positive steps, significant acceleration is needed to keep pace with the global EV transition. Addressing affordability, infrastructure limitations, and public awareness through improved policies, strategic investments, and industry collaboration is crucial. By proactively learning from leading countries and refining its approach, Malaysia is able to overcome its current weaknesses and establish itself as a regional leader in sustainable mobility. Malaysia is also able to overcome its current weaknesses and establish itself as a regional leader in sustainable mobility. This requires concerted efforts from the

government, the private sector, and the public, but potential benefits for the environment, economy, and public health are important.

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### References

- [1] Huang, Bernice, Yunkyung Choi, Samuel Chng, and Harvey Neo. "Examining Policy Strategies for Electrifying Transportation in ASEAN: A STEELUP Framework Evaluation." *Sustainability* 15, no. 22 (2023): 15708. <https://doi.org/10.3390/su152215708>
- [2] Majekodunmi, Temitayo B., Mohd Shahidan Shaari, Noorazeela Zainol Abidin, and Abdul Rahim Ridzuan. "Green technology, exports, and CO2 emissions in Malaysia." *Heliyon* 9, no. 8 (2023). <https://doi.org/10.1016/j.heliyon.2023.e18625>
- [3] Hossain, M. S., Laveet Kumar, Mamdouh El Haj Assad, and Reza Alayi. "Advancements and future prospects of electric vehicle technologies: a comprehensive review." *Complexity* 2022 (2022): 1-21. <https://doi.org/10.1155/2022/3304796>
- [4] Iqbal, Muhammad Yousof, Tie Wang, Guoxing Li, Dongdong Chen, and Mohammad Mahbubur Al-Nehari. "A study of advanced efficient hybrid electric vehicles, electric propulsion and energy source." *Journal of Power and Energy Engineering* 10, no. 7 (2022): 1-12. <https://doi.org/10.4236/jpee.2022.107001>
- [5] Deng, Jie, Chulheung Bae, Adam Denlinger, and Theodore Miller. "Electric vehicles batteries: requirements and challenges." *Joule* 4, no. 3 (2020): 511-515. <https://doi.org/10.1016/j.joule.2020.01.013>
- [6] Rezvani, Zeinab, Johan Jansson, and Jan Bodin. "Advances in consumer electric vehicle adoption research: A review and research agenda." *Transportation research part D: transport and environment* 34 (2015): 122-136. <https://doi.org/10.1016/j.trd.2014.10.010>
- [7] Waseem, Mohammad, Mohammad Amir, G. Sree Lakshmi, S. Harivardhagini, and Mumtaz Ahmad. "Fuel cell-based hybrid electric vehicles: An integrated review of current status, key challenges, recommended policies, and future prospects." *Green Energy and Intelligent Transportation* (2023): 100121. <https://doi.org/10.1016/j.geits.2023.100121>
- [8] Stephens, Thomas, Yan Zhou, Andrew Burnham, and Michael Wang. "Incentivizing adoption of plug-in electric vehicles: a review of global policies and markets." (2018). <https://doi.org/10.2172/1480507>
- [9] Wellings, Jonathan, David Greenwood, and Stuart R. Coles. "Understanding the future impacts of electric vehicles—An analysis of multiple factors that influence the market." *Vehicles* 3, no. 4 (2021): 851-871. <https://doi.org/10.3390/vehicles3040051>
- [10] Paudel, Ashok, Watcharakorn Pinthurat, and Boonruang Marungsri. "Impact of Large-Scale Electric Vehicles' Promotion in Thailand Considering Energy Mix, Peak Load, and Greenhouse Gas Emissions." *Smart Cities* 6, no. 5 (2023): 2619-2638. <https://doi.org/10.3390/smartcities6050118>
- [11] Mursalim, Muliana, and Agung Susanto. "Ambivalence of Renewable Energy: Electric Vehicles for Reducing Carbon Emissions and Its Impact on Environmental Damage in Indonesia."
- [12] Chua, Shing Chyi, and Tick Hui Oh. "Green progress and prospect in Malaysia." *Renewable and Sustainable Energy Reviews* 15, no. 6 (2011): 2850-2861. <https://doi.org/10.1016/j.rser.2011.03.008>
- [13] Farmer, R., R. Gupta, V. Lath, and N. Manuel. "Capturing growth in Asia's emerging EV ecosystem." *Mckinsey & Company, Jun* (2022).
- [14] Schröder, Martin, Fusanori Iwasaki, and Hideo Kobayashi. "Promotion of Electromobility in ASEAN: States, Carmakers, and International Production Networks." (2021).
- [15] Veza, Ibbam, Mohd Azman Abas, Djati Wibowo Djamar, Noreffendy Tamaldin, Fitri Endrasari, Bentang Arief Budiman, Muhammad Idris, Anthony C. Opia, Firman Bagja Juangsa, and Muhammad Aziz. "Electric vehicles in malaysia and indonesia: opportunities and challenges." *Energies* 15, no. 7 (2022): 2564. <https://doi.org/10.3390/en15072564>
- [16] Tan, Paul. 2010. "New Toyota Prius Lowered Price - RM139,900 - Paultan.org." Paul Tan's Automotive News. October 28, 2010.
- [17] Hamid, Umar Zakir Abdul, Siti Zaharah Ishak, and Fitriani Imaduddin. "Current Landscape of the Automotive Field in the ASEAN Region: Case Study of Singapore, Malaysia and Indonesia-A Brief Overview." *Asean Journal of Automotive Technology* 1, no. 1 (2019): 21-28.



- [18] Azizi Khairul, Alya Atrisyia, Muhammad Farid Mazlan, Maisarah Nor Azlan, and Suriana Ramli. "Empowering future generation with renewable solar energy: a conceptual paper." In *1st International e-Conference on Green and Safe Cities 2022 (IeGRESAFE)*, pp. 500-512. 2022.
- [19] N.d. Trade.gov. Accessed March 15, 2024a.
- [20] Adnan, Nadia, Shahrina Md Nordin, and Imran Rahman. "Adoption of PHEV/EV in Malaysia: A critical review on predicting consumer behaviour." *Renewable and Sustainable Energy Reviews* 72 (2017): 849-862. <https://doi.org/10.1016/j.rser.2017.01.121>
- [21] CNN Indonesia. 2021. "Target RI 2030, 25 Ribu SPKLU dan 3 Juta Kendaraan Listrik." *cnnindonesia.com*. August 5, 2021
- [22] "Home." 2021. Archyworldys. November 2, 2021.
- [23] Gomółka, Krystyna, and Piotr Kasprzak. "Directions and Prospects for the Development of the Electric Car Market in Selected ASEAN Countries." *Energies* 14, no. 22 (2021): 7509. <https://doi.org/10.3390/en14227509>
- [24] Liu, Kangjie, Stephanie Ly, Eleanor Jackson, Hamilton Steimer, Sarah Cassius, Xiangyi Li, Erika Myers, L. Hernandez Duarte, and Lydia Freehafer. "Developing an Electric Mobility Roadmap: International Experiences from Subnational Case Studies for Vietnamese Cities." *World Resources Institute: Washington, DC, USA* (2022). <https://doi.org/10.46830/wriwp.21.00009>
- [25] Raharyo, Anggara, and Saffira Dellavia. "THAILAND AND MALAYSIA'S COMPETITIVENESS ON ELECTRIC VEHICLE MANUFACTURING DEVELOPMENT TO INCREASE THE FOREIGN DIRECT INVESTMENT IN 2014-2019." *AEGIS: Journal of International Relations* 7, no. 1 (2023). <https://doi.org/10.33021/aegis.v7i1.1645>
- [26] Thananusak, Trin, Prattana Punnakitikashem, Sitthichai Tanthasith, and Boonying Kongarchapatara. "The development of electric vehicle charging stations in Thailand: Policies, players, and key issues (2015–2020)." *World Electric Vehicle Journal* 12, no. 1 (2020): 2. <https://doi.org/10.3390/wevj12010002>
- [27] N.d. Kpmg.com. Accessed March 15, 2024.
- [28] Kongklaew, Chanwit, Khampho Phoungthong, Chanwit Prabpayak, Md Shahariar Chowdhury, Imran Khan, Nuttaya Yuangyai, Chumpol Yuangyai, and Kuaanan Techato. "Barriers to electric vehicle adoption in Thailand." *Sustainability* 13, no. 22 (2021): 12839. <https://doi.org/10.3390/su132212839>