


## Article

# Examining Policy Strategies for Electrifying Transportation in ASEAN: A STEELUP Framework Evaluation

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**Abstract:** With the recent emphasis on carbon neutrality following COP27, many countries prioritise shifting to electric mobility as a crucial strategy to combat carbon emissions. A significant portion of this comes from transportation. Notably, countries such as Norway, China, and the United States have taken the lead in the electric vehicle (EV) industry, driven by their effective e-mobility policies. In contrast, the 10 member nations of the Association of Southeast Asian Nations (ASEAN) are still in the early stages of adopting this emerging trend. This paper conducts a comprehensive evaluation of the current e-mobility policies within the ASEAN region, employing the STEELUP (Sociocultural and demographic, Technological, Economic, Environmental, Legislative, Urban design, and Political) framework to provide a holistic perspective on the e-mobility landscape in the ASEAN countries. By critically assessing the implementation of e-mobility policies in each country, this paper aims to identify key gaps and challenges that hinder the acceleration of EV adoption in the region. The findings from the STEELUP framework, coupled with a thorough analysis of the current conditions in ASEAN, provide crucial insights for governments and policymakers to act upon. Through evidence-based recommendations, this study concludes by suggesting effective strategies to expedite the uptake of EVs in the ASEAN region.

**Keywords:** electrification; electric vehicles; zero-emission; sustainable transportation; policy evaluation



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## 1. Introduction

The transportation sector, heavily reliant on fossil fuels, stands as a major contributor to global carbon emissions, significantly exacerbating the challenges posed by climate change. A recent survey conducted by the European Commission in 2022 revealed that the transportation sector alone accounted for nearly one-fifth of the world's carbon dioxide (CO<sub>2</sub>) emissions in 2021, totalling a staggering 7643.5 billion metric tonnes of CO<sub>2</sub> [1]. Notably, passenger cars have emerged as the largest source of carbon emissions within this sector. According to the International Energy Agency (IEA), cars were responsible for approximately three billion metric tonnes of global CO<sub>2</sub> emissions in 2020, showing a steady upward trend from 2.2 billion metric tonnes in 2000 to a peak of 3.2 billion metric tonnes in 2019 [2]. This trajectory is expected to persist unless decisive action is taken to address the mounting environmental concerns. The recent Conference of Parties (COP27) marked a significant commitment to achieving carbon neutrality through collective global action, with an emphasis on the transition from fossil fuels to cleaner and more sustainable forms of mobility, particularly electric mobility. In recent years, various efforts have been undertaken to identify solutions that can mitigate greenhouse gas (GHG) emissions from the transportation sector. One of the most widely embraced strategies has been the promotion of electrification of mobility, involving a shift from internal combustion engine vehicles (ICEVs) to electric vehicles (EVs). Encouragingly, the IEA anticipates a substantial increase in the EV fleet, projecting at least 55% growth since 2017 (excluding 2020) [2]. This

burgeoning industry presents promising opportunities for various stakeholders, yielding benefits for governments, individuals, automobile companies, and the environment alike.

The predominant focus of existing research in the EV sector has been on Europe and the United States, reflecting their strong environmental consciousness and notable EV adoption. In contrast, Southeast Asia has remained comparatively overlooked in terms of EV research, highlighting the compelling necessity to scrutinise the EV landscape in ASEAN countries. These nations exhibit distinct socio-economic and environmental dynamics, divergent infrastructure needs, and unique urban challenges, necessitating tailored approaches. In the midst of ASEAN countries' rapid urbanisation, heightened environmental concerns, and fluctuating fuel and transportation costs, EVs emerge as a promising solution. Nonetheless, the lack of research in the region limits the full potential of these benefits.

To address this critical gap, this paper aims to introduce a novel assessment framework tailored to the unique challenges and opportunities presented in the Southeast Asia region. This framework is designed to facilitate a comparative analysis of EV policies across ASEAN countries, aiming to identify both differences and similarities in their approach and current status. By conducting a comprehensive evaluation of policies from diverse perspectives, encompassing sociocultural, technological, economic, environmental, legislative, urban design, and political factors, this paper seeks to offer valuable insights and recommendations for expediting EV adoption in the region. Ultimately, this research seeks to contribute to the broader effort of accelerating the global transition towards sustainable and environmentally friendly transportation solutions.

In the subsequent sections, this study will present a thorough examination of the existing literature, paving the way for the formulation of a comprehensive framework designed for the analysis of e-mobility policies. Subsequently, the study will conduct an in-depth evaluation of each ASEAN country's e-mobility policies and initiatives, utilising the established framework. The primary aim is to elucidate the progress and effectiveness of these policies in contributing to ASEAN's overarching objective of decarbonising its transportation sector.

## 2. Literature Review

The global shift towards EVs has garnered significant attention due to their potential long-term environmental benefits. In the wake of the COVID-19 pandemic, heightened environmental awareness has surged, motivating the public to embrace more sustainable practices [3,4]. Consequently, increasing environmental consciousness has driven greater interest and willingness among individuals to adopt EVs, creating a surge in demand. Notably, automakers, including industry leaders like Tesla, have intensified their efforts to meet this rising demand by expanding their EV offerings, leading to a broader array of EV choices and encouraging a shift away from ICEVs [5].

Advancements in EV technology have alleviated past concerns about range limitations and charging frequency. With increased battery capacity and extended vehicle range, consumer confidence in EVs has grown significantly [6]. Economic factors also contribute to the growing popularity of EVs. Escalating fuel and diesel costs, coupled with mounting environmental challenges, drive individuals to seek alternatives for their commuting needs, further motivating the adoption of EVs [7,8]. Moreover, embracing EV ownership projects a pro-environmental image, and this resonates with many individuals [7,8].

Undoubtedly, governmental policies wield significant influence in accelerating the EV industry's growth. Leading nations like Norway, China, and the United States have implemented demand- and supply-oriented policies that play a pivotal role in stimulating the adoption of EVs within their respective borders [9]. Incentives, subsidies, and investments are commonly utilised to bolster EV uptake. Regulations such as fiscal advantages, dedicated EV lanes, and preferential parking have contributed to Norway's remarkable success, achieving a more than 70% EV adoption rate in 2021 [10].

Recognising the vast potential of the EV market, policymakers worldwide are actively supporting the industry's development by introducing a range of policies that facilitate a smooth transition from ICEVs to EVs. Tailoring policies to individual contexts and goals is crucial, as one-size-fits-all approaches may not be effective across diverse national landscapes.

The existing body of research predominantly revolves around policy assessments aimed at gauging the effectiveness of transitioning to electrification. Notably, China, as a frontrunner in the EV industry, has been extensively studied to understand policies that promote higher rates of EV adoption. Li, Yang, and Sandu (2022) delved into micro- and macro-level barriers, conducting a thorough assessment of policies to determine their efficacy in driving EV uptake [8]. Similarly, Qiu, Zhou, and Sun (2019) conducted a comparative analysis of demand-side and supply-side policies, evaluating their respective impacts on EV adoption [11]. Beyond the boundaries of China, electrification policy assessments in Europe and South America have employed theoretical frameworks such as total cost ownership analysis and multiple-criteria decision analysis [12,13]. These studies quantified financial incentives and evaluated government interventions, emphasising the need to foster EV penetration and bolster charging infrastructure.

Despite significant progress, disparities persist in EV adoption rates across different countries, underscoring the need for context-specific strategies and policies. While some studies have examined specific policies based on distinct goals, there is a gap in research within the context of emerging EV industries. In these countries, policymakers are striving to garner support from citizens and automobile companies to nurture the potential of the EV industry. However, due to a lack of experience and comparative data, policymakers may encounter challenges in designing effective policies and assessing their impacts. Consequently, there is a clear and pressing need for a comprehensive assessment framework that can evaluate existing policies in these emerging EV industries.

In recent years, ASEAN countries have been witnessing rapid urbanisation and economic growth, accompanied by a pressing need to address mounting environmental concerns. Notably, the prevalent use of motorcycles in the region has accentuated the urgency to protect the environment and reduce carbon emissions [14]. The IEA warned that CO<sub>2</sub> emissions in ASEAN have been on a steady rise, underscoring the necessity for proactive efforts to mitigate GHG emissions [15].

Moreover, ASEAN countries have established themselves as significant production hubs for the automotive industry, attracting multinational corporations due to lower labour costs in emerging economies. The global trend towards EVs has prompted these nations to position themselves as potential markets. The statistics further support the region's transition towards EV adoption, as the electric vehicle market in the region was valued at \$500 million in 2021, with projections indicating a remarkable growth to reach \$2.7 billion by 2027 [16]. Each of the 10 nations is actively engaging in efforts to curtail reliance on fossil fuels and embrace e-mobility solutions.

The development of an effective framework for evaluating electrification policies in ASEAN is critical to comprehensively measuring the impact and effectiveness of such policies. Existing literature has demonstrated the significance of utilising a standardised framework tailored to the regional context. Frameworks like PEST (Political, Economic, Social, Technological), STEEP (Social, Technological, Economic, Environmental, and Political), and PESTLE (Political, Economic, Social, Technological, Environmental, and Legal) have been employed in previous research to assess transport policies [17,18]. However, these frameworks exhibit certain limitations that make them less suited for addressing the specific challenges and opportunities encountered in the ASEAN region.

One of these limitations pertains to the lack of comprehensiveness in evaluating policies from multiple perspectives. As can be observed in the focus of each of the above frameworks through its name, each framework covers different facets with varying levels of comprehensiveness. To promote sustainable e-mobility in ASEAN, it is imperative to

take into account a broader spectrum of factors. Existing frameworks often narrow their focus to specific viewpoints, leaving gaps in the evaluation process.

Moreover, transport inherently intertwines with urban issues, and the effectiveness of electrification policies is intricately linked to urban design and infrastructure. Nonetheless, many existing frameworks do not adequately incorporate urban design as a pivotal component in the evaluation process, diminishing their applicability to the challenges faced by ASEAN countries as they transition towards e-mobility.

Additionally, some assessment frameworks, such as cost–benefit analysis and cost–effectiveness analysis, predominantly concentrate on financial aspects and may not capture the broader socio-environmental impacts of electrification policies [19,20]. In contrast, frameworks like multicriteria analysis and multiactor analysis offer a more comprehensive evaluation, taking into consideration multiple dimensions and stakeholders [13,21]. However, they often require extensive datasets and resources, which may not be readily available or feasible for emerging industries in the ASEAN region.

Furthermore, the implementation of electrification policies stands as a collective objective shared by all 10 ASEAN countries. To facilitate a coordinated approach that allows for meaningful comparisons, the establishment of a standardised framework becomes imperative. Consequently, an opportunity arises to discern both the distinctive and amalgamate them into a new comprehensive framework.

The adoption of a uniform assessment framework ensures consistency and comparability in the evaluation process across all nations. This not only enhances transparency but also promotes knowledge sharing. It also simplifies the process of identifying best practices and areas for improvement among the ASEAN countries. Policymakers can benchmark their policies against regional peers, learning from successful initiatives and addressing gaps to enhance their electrification strategies. This collective approach fosters collaboration among ASEAN nations, driving mutual progress in the pursuit of sustainable e-mobility.

### 3. Methodology

#### 3.1. Evaluation Framework

To carry out the comparative policy analysis, we employed our proposed STEELUP framework, which expanded upon existing frameworks to encompass seven vital aspects of policy evaluation. This comprehensive approach provided a holistic assessment of electrification policies in the ASEAN region, offering a deeper understanding of their current status. By evaluating policies from multiple perspectives, STEELUP promoted greater collaboration among ASEAN countries in their pursuit of sustainable and environmentally friendly transportation solutions. The framework includes the following aspects:

1. Sociocultural and demographic;
2. Technological;
3. Economic;
4. Environmental;
5. Legislative;
6. Urban design;
7. Political factors.

Each factor in the framework was aligned with the three primary objectives of EV adoption, charging infrastructure, and industrial promotion, which were identified as the critical components of the enabling environment for e-mobility in the literature review [22].

The evaluation process using the STEELUP framework involved grouping a total of 60 diverse indicators within each category. These indicators were adapted from previous frameworks (as elaborated in Section 2) and further tailored to the context of electric mobility. Each ASEAN country's policies and strategies, whether in the planning or implementation stages, were analysed against these indicators. The resulting scores provided an overall assessment of each country's efforts towards electrification, with higher scores indicating greater coverage and effectiveness in their electrification endeavours.

In the assessment phase, the results obtained from the STEELUP framework were analysed using two distinct approaches. First, a detailed evaluation of each component within STEELUP was performed, providing a comprehensive understanding of each country's performance across all aspects. Second, an analysis of each outcome was conducted to identify specific strengths and weaknesses in the electrification policies of the ASEAN nations. This multifaceted approach ensured a thorough and insightful evaluation of electrification efforts in the region (Table 1).

**Table 1.** STEELUP evaluation framework.

	EV Adoption	Charging Infrastructure	Industrial Promotion	Score
Sociocultural and demographic	<ul style="list-style-type: none"> <li>Pilot with EV (individuals)</li> <li>Increasing consumer awareness of EV technologies, policies, and the real cost of using EVs</li> <li>Advertisements on national broadcasting channels/events/exhibition</li> <li>Awareness through digital platforms</li> <li>Public education campaigns</li> </ul>			5
Technological		<ul style="list-style-type: none"> <li>Charging network digital integration</li> <li>Smart charging management system (e.g., smart metering)</li> <li>Strengthening and optimising power grid capacity</li> <li>Location of public chargers using an online platform</li> <li>Introduction of fast charging corridor/technology</li> <li>Development of smart grid/support V2X technology</li> </ul>	<ul style="list-style-type: none"> <li>Manufacturing process/model development award</li> <li>R&amp;D funding</li> </ul>	8
Economic	<ul style="list-style-type: none"> <li>Interest grants on loans</li> <li>Innovative business model for electric mobility as a service (e.g., EV sharing)</li> <li>Reduced parking fee</li> </ul>	<ul style="list-style-type: none"> <li>Concessional location</li> <li>Concessional infrastructure installation</li> <li>Preferential electricity charges for EV charging (e.g., peak and non-peak charging using a smart grid)</li> </ul>	<ul style="list-style-type: none"> <li>Attraction of FDI</li> <li>Incentive for local manufacturers</li> <li>Employment incentive</li> <li>Pilot with EV for taxi industries</li> <li>Special economic zone</li> </ul>	11
Environmental	<ul style="list-style-type: none"> <li>Low emission zones for EVs</li> <li>Green zones</li> </ul>	<ul style="list-style-type: none"> <li>Promotion of and integration with renewable energy in the power sector</li> </ul>	<ul style="list-style-type: none"> <li>Subsidies on the operation of EVs as public transport</li> <li>Environmental policy (green standards for EV manufacturers)</li> <li>Environmental policy (vehicle emission standards)</li> </ul>	6
Legislative	<ul style="list-style-type: none"> <li>Purchase subsidy</li> <li>Tax or toll exemption (for individuals)</li> <li>Reduction of purchase tax or VAT</li> <li>Ban on sales of ICEVs</li> <li>Subsidy for electricity</li> <li>Licence plate-related benefits/customed licence plate</li> </ul>	<ul style="list-style-type: none"> <li>Tax exemption (for charging)</li> <li>Battery fee exemption</li> </ul>	<ul style="list-style-type: none"> <li>Capital/interest subsidy on setting up EV operations</li> <li>Tax exemption (for industries)</li> <li>Subsidies on investment and operation of charging infrastructure</li> <li>e-Taxi licencing</li> </ul>	12
Urban design	<ul style="list-style-type: none"> <li>Priority lanes for EVs</li> <li>Dedicated EV parking spaces/priority parking</li> </ul>	<ul style="list-style-type: none"> <li>Improvement in infrastructure and road network</li> <li>Co-locating charging infrastructure in petrol stations</li> </ul>	<ul style="list-style-type: none"> <li>Improvement in public transport systems</li> <li>Integration of private e-transport modes (e.g., private buses, non-motorised bicycles, etc.)</li> </ul>	6
Political	<ul style="list-style-type: none"> <li>National EV standards</li> <li>Free or easy registration and licence plates for EVs</li> <li>Insurance policies for two- and three-wheel EVs</li> <li>Enact a policy package (e.g., a feebate)</li> </ul>	<ul style="list-style-type: none"> <li>National charging standards</li> <li>Increased availability of charging services</li> <li>Provision of battery swapping stations/services</li> <li>Industrial partnerships to improve charging facilities</li> </ul>	<ul style="list-style-type: none"> <li>Vehicle quality standards</li> <li>Fuel quality standards</li> <li>Multiagencies (government) coordination</li> <li>Multi-stakeholder coordination</li> </ul>	12

### 3.2. Data Collection

To conduct our policy analysis, data collection was a pivotal component of our research methodology. Our quest for a comprehensive understanding of EV-related policies involved a meticulous and thorough exploration of various sources, aligning with the rigorous standards of academic research. Our data collection process encompassed a diverse array of sources, including official policy documents originating from the relevant government ministries or agencies in each country. These official policy documents served as foundational pillars, providing an authoritative and in-depth view into the policy landscape governing electrification initiatives within each country.

However, we recognised that an all-encompassing understanding of these policies necessitated more than a review of official documents alone. To ensure that our analysis reflected the dynamic nature of policy development, we extended our data collection efforts to official press releases, briefings, and websites. These sources provided a contemporary perspective, enabling us to capture the latest policy evolutions and nuances in the realm of EV.

The data collection process focused on documents published prior to 2023. This time frame was thoughtfully selected to enable a comprehensive analysis of policy trends and transformations over the years.

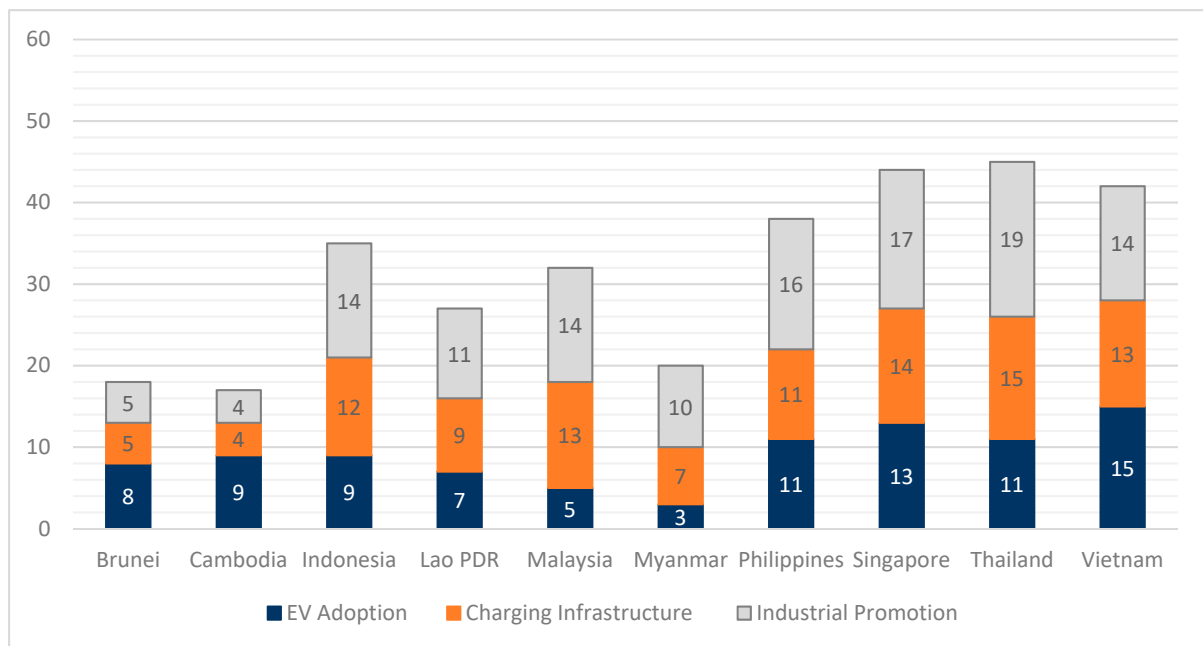
## 4. Results

### 4.1. Current E-Mobility Policies

Table 2 provides an overview of the findings for the different countries based on the seven aspects of the STEELUP framework. To determine the total score for each country, the scores for all seven aspects are added together. The higher the total score (maximum of 60), the more comprehensive the country's policies are in terms of promoting e-mobility. This visual tool allows for a quick comparison of different countries' e-mobility policies based on the STEELUP framework. It helps to identify the strengths and weaknesses of each country's approach to electrification and provides valuable insights for policymakers and researchers in understanding the current state of e-mobility initiatives in the ASEAN region. Figure 1 represents the results totalled according to the three electrification goals, and the maximum score is 60.

**Table 2.** STEELUP scores by each country.

	Maximum Score	Brunei	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam
Sociocultural and demographic	5	5	4	0	1	0	0	4	5	4	5
Technological	8	1	0	3	2	5	0	4	6	7	6
Economic	11	0	2	6	3	5	2	6	7	8	4
Environmental	6	1	0	2	3	3	3	3	4	4	5
Legislative	12	1	5	12	5	6	3	6	7	8	9
Urban design	6	3	2	2	5	4	6	5	5	4	4
Political	12	7	4	10	8	9	6	10	10	10	9
Total	60	18	17	35	27	32	20	38	44	45	42
Rank	-	9	10	5	7	6	8	4	2	1	3



**Figure 1.** Results based on electrification goals.

#### 4.1.1. Brunei

Brunei is actively committed to combating climate change, with the Brunei Darussalam National Climate Change Policy (BNCCP) serving as the overarching framework for decarbonisation efforts [23]. Spearheaded by the Ministry of Transport and Infocommunication and the Ministry of Energy, the Electric Vehicle Joint Task Force (EVJTF) is tasked with achieving a low-carbon and climate-resilient Brunei [2]. The policy outlines objectives, performance indicators, and strategies for transforming the country's land transportation sector, including the implementation of educational and awareness programmes to promote EV adoption [24,25].

Brunei has set an ambitious goal of achieving a minimum of 60% EV sales out of total vehicle sales by 2035, supported by financial incentives like excise tax exemptions and reduced fees [26,27]. Plans to expand charging infrastructure and develop fast charging stations are in place, with the EVJTF identifying locations based on the demands of the pilot project [24,27,28].

Brunei exhibits a low overall score of 18 in the STEELUP framework, with a focus on sociocultural indicators but limited progress in other aspects. Their policies mostly target EV adoption, covering only 36% of the policies in that category. The country's two-year pilot project explains the relatively few implemented policies compared to advanced economies. With 70% private vehicle ownership, effective policies are needed for EV adoption. The public transport system's efficiency and appeal need improvement to reduce reliance on private vehicles. Addressing EV cleanliness is vital as Brunei relies heavily on natural gas. Transitioning to renewable energy sources for EV charging will enhance environmental benefits. Policies promoting renewable energy adoption and clean charging are essential for Brunei's e-mobility future. The lack of standout goals indicates room for improvement in aligning policies with clear objectives.

#### 4.1.2. Cambodia

According to the Long-Term Strategy for Carbon Neutrality, Cambodia has set national targets to aim for 40% of EV cars and urban buses and 70% of electric motorcycles by 2050 [29]. Under this plan, EVs will enjoy a 30% reduction in annual road tax and priority parking in public areas and at charging stations. Together with other monetary incentives, people will be more willing to make the switch.

The government also intensified efforts to attract more foreign automobile companies to set up their factories in the country. They lowered import duty taxes for EVs to about 50% lower than the taxes on ICEVs [30]. The initiative has the potential to create more green jobs and investments and help Cambodia position itself in the emerging global and regional EV supply chain.

Unfortunately, Cambodia did not perform well, implementing 17 policies in the STEELUP framework. They only focused on the sociocultural aspects, achieving four out of five indicators. In considering electrification objectives, half of the policies implemented were directed towards EV adoption. The remaining policies were divided equally between developing the charging infrastructure and the EV industry itself.

#### 4.1.3. Indonesia

Indonesia targets to only sell electric motorcycles by 2040 and electric cars by 2050 [31]. They implemented various demand-side policies, such as issuing subsidies for purchasing EVs and enforcing the banning of ICEVs. The government also involved their national energy company, Pertamina, in the manufacturing of EV batteries. As the largest global exporter of nickel, Indonesia will leverage its comparative advantage to produce more batteries locally [32].

Indonesia's strong desire to shift towards electrification of their transportation sector is reflected in their willingness to include policies reducing import duties on machinery and raw materials and providing financial support for charging stations in Presidential Decree 55/2019 [26].

Indonesia fares relatively well, implementing 58% of the policies, primarily through legislative and political means. Charging infrastructure and supply-side policies are well established, leveraging their position as the world's largest exporter of nickel and the region's largest car exporter. However, EV adoption lags with a score of nine out of 23. Concerns also arise from generating about 60% of electricity from coal and the locals' inclination towards personal transport.

#### 4.1.4. Lao PDR

Lao People's Democratic Republic, or Laos, presents an intriguing case study, having initiated a pilot project with a Japanese EV company in 2013. This project aimed to facilitate Laos' transition towards transport electrification, involving multiple governmental agencies such as the Ministry of Public Works and Transport and the Ministry of Information, Culture, and Tourism [33]. The pilot sites in Luang Prabang and Vientiane Capital were designed to incorporate EVs into public transport [34].

Following the project, Laos set a target for at least 30% of automobiles to be EVs by 2030 [35]. Monetary incentives, including tax exemptions for automotive companies and individuals, were introduced to lower EV costs. EV users also benefit from dedicated parking areas, and Electricite du Laos (EDL) was assigned to provide charging station services without charging metre fees [35]. Plans are underway to expand charging stations in major cities and along highways [36].

Despite a lower overall score of 27 indicators from the STEELUP framework, Laos has policies covering each aspect, though unevenly distributed. Notably, they implemented 83% of urban design policies but only 20% of sociocultural policies. Policies are not focused on specific objectives, with 26% on EV adoption, 33% on charging infrastructure, and 41% on industrial promotion. Enhancing sociocultural policies and aligning efforts with clear objectives can bolster Laos' electrification initiatives. The country's low score is influenced by its reliance on clean hydroelectric power, reducing the need to attract foreign investors. However, the impact of climate change on hydroelectric plants warrants attention. With a small car ownership base, Laos can explore developing e-motorcycles or electrifying public transport for a more sustainable future.



#### 4.1.5. Malaysia

Malaysia has been at the forefront of the EV movement within ASEAN, initiating policies as early as 2014. The third revision of the National Automotive Policy (NAP) reflects the country's commitment to developing an environmentally friendly transport system. To align with global trends, Malaysia is positioning itself as a hub for 'energy efficient vehicle' (EEV) manufacturing, supported by fiscal incentives such as corporate tax exemptions and reduced import and excise duties [26,37].

Collaboration between key agencies, including the Malaysia Automotive Robotics and IoT Institute (MARii), the Malaysian Green Technology and Climate Change Centre (MGTC), and various ministries, has led to significant progress. The NAP2020 emphasises the development of next-generation vehicles (NxGV), including EVs, while the Low Carbon Mobility Blueprint (LCMB 2021-2030) aims to boost EV penetration by establishing 10,000 charging stations by 2025 [38–40].

Initiatives such as 'chargEV' and 'EV Connection Sdn Bhd' have expanded charging infrastructure in major states and along highways [40]. The Zero Emission Vehicle Association (ZEVA) has proposed grants to support charger installations and R&D in the automotive industry [37]. To achieve the target of 700,000 EVs by 2030, the Malaysian government plans to procure locally manufactured battery electric vehicles (BEVs), with all government vehicles being electric starting in 2024 [41]. The increase in supporting infrastructure will help strengthen its position as a key automotive manufacturer.

Malaysia showcases a goal-oriented approach, emphasising charging infrastructure (72%), and expanding the automotive industry (75%), while EV adoption policies remain limited (23%). Uneven distribution is evident, with a focus on political and technological aspects, neglecting economic and sociocultural indicators.

#### 4.1.6. Myanmar

The 2015 Myanmar Energy Plan outlined targets for renewable energy sources, aiming for a 15% to 20% share of clean energy by 2020 [42]. The country's 2019 Automotive Policy further reflects their dedication to clean energy, focusing on defining and enforcing vehicle emission standards to minimise environmental impact [43]. Specific guidelines and emission standards have been established for gasoline- and diesel-fuelled vehicles to regulate lead content in imported motor gasoline vehicles [43].

In recent years, efforts to improve infrastructure for electric mobility have included encouraging partnerships with private companies to develop charging stations and leasing factory space for local EV assembly [26,44]. The government introduced a trial period for electric vehicle importation, ensuring compliance with safety guidelines for new imported cars and chargers [45,46]. Additional charging stations are installed in key cities (Nay Pyi Taw and Yangon) to facilitate the growth of EV adoption [47]. Recognising the significance of the EV industry, the authority has identified it as a priority sector, offering tax exemptions to businesses operating in this domain [46].

Myanmar falls short in various areas, obtaining an overall low rating of 20 out of 60, largely attributed to pressing domestic institutional issues that need immediate attention. While urban design policies are established, sociocultural and technological aspects require improvement. Half of the e-mobility policies prioritise the development and promotion of the EV industry, with the remaining policies divided between EV adoption and charging infrastructure. To progress, Myanmar can strive to become an electric bus exporter in the region and learn from other nations by formulating a clear EV roadmap.

#### 4.1.7. The Philippines

On 15 April 2022, Philippine President Duterte signed the Electric Vehicle Industry Development Act (EVIDA), significant legislation outlining the country's agenda for transport electrification. EVIDA introduced the Comprehensive Roadmap for the Electric Vehicle Industry (CREVI), aiming to accelerate electric mobility adoption [48,49]. CREVI delegates specific responsibilities to government ministries; the Energy Regulation Commission

oversees charging station rates and guidelines. Additionally, CREVI mandates that at least 5% of the government fleet consists of EVs, while new buildings must allocate dedicated parking areas with charging stations [48].

The Public Utility Vehicle Modernisation Programme aims to improve public transport by replacing old jeepneys with EVs, enhancing transportation quality, and converting tricycles and motorcycles into electric vehicles [26,50,51].

According to the STEELUP framework, the Philippines performs relatively well, with 38 out of 60 policies in place. However, more emphasis is placed on political, urban design, and socio-cultural aspects (80–83%). Other domains cover only about 50% of the indicators. The Philippines exhibits a strong commitment to ensuring a sufficient EV supply (80%), promoting higher adoption rates (50%), and boosting charging infrastructure (61%). The Philippines' unique transportation modes (i.e., jeepneys/tricycles) necessitate a focus on developing local EV production (Department of Trade and Industry and Board of Investment, n.d.). A major concern is the serious problem of high carbon emissions leading to pollution-related deaths, making the transition to EVs imperative for a cleaner and healthier environment [52].

#### 4.1.8. Singapore

Singapore's commitment to sustainability is evident in its 2030 Singapore Green Plan, where the Land Transport Authority aims to reduce land transport emissions by 80% by 2050, with the National Electric Vehicle Centre leading electrification efforts [53]. To achieve this, various measures to accelerate EV adoption include rebates of up to \$20,000 off the Additional Registration Fee for EVs registered by 2023 and tax reductions [54].

The country is also investing in charging infrastructure, with over 2000 charging stations in housing estates and integration via the MyTransport.SG app for enhanced convenience [55,56]. Stakeholder engagement ensured improved charging standards and infrastructure, supported by the 'Power Every Move' campaign to raise public awareness about EV benefits and charging etiquette [56].

Collaboration with the public transport sector, including taxi operators and public buses, further drives EV adoption. Strides Taxi deployed 300 fully electric taxis in 2021, and plans for approximately 400 new electric buses are set for 2024 [57]. Monetary incentives for taxi drivers and ongoing tenders to install chargers at bus depots support the transition.

Singapore showcases comprehensive policies, achieving 44 out of 60 indicators in the STEELUP framework. It performs well in most areas, especially in attracting more foreign investors, creating an attractive environment for EV industry growth. While also excelling in engaging stakeholders and enhancing charging infrastructure, the lower take-up rate may be attributed to fewer individual-level policies (13 out of 22). Considering the significant number of car users in Singapore [58], addressing this concern becomes crucial for accelerating the transition to sustainable and eco-friendly electric mobility.

#### 4.1.9. Thailand

Thailand, committed to fossil fuel eradication at COP26 in 2021, is actively promoting transportation decarbonisation and improving electrification infrastructure. The EV roadmap focuses on achieving carbon neutrality by 2050, with two main goals: 100% zero-emission EV (ZEV) sales by 2030 and 30% of locally produced vehicles being ZEVs by 2030. The government leads the way by mandating all government vehicles to be ZEVs by 2030 [59,60].

Monetary incentives entice manufacturers to produce more EVs. The Board of Investment significantly reduces corporate income tax for EVs and EV battery manufacturers, with up to eight years of exemption for battery-powered EVs and three years for battery manufacturers [61]. Import duty and excise tax reductions further attract foreign firms and enhance local manufacturing. These policies extend to other vehicles like buses, ferries, motorcycles, scooters, and tuk-tuks.

Private EV adoption is encouraged through grants and incentives, including reduced annual registration fees and tax exemptions. Thailand explores technology for efficient charging infrastructure [62].

Thailand stands as a prime example of effective policy implementation, exhibiting its commitment to electrification by fulfilling 45 out of 60 indicators in the STEELUP framework. Policies are evenly distributed across aspects, performing well in the technological domain (7 out of 8 policies). While industrial promotion achieves 95% implementation, charging infrastructure and EV adoption show 78% and 50% implementation, respectively. By leveraging its status as the world's largest exporter of automotive parts and its substantial resources, Thailand aims to solidify its competitive advantage in the EV market. As a result, the country has successfully implemented 95% of policies pertaining to industrial promotion. To sustain its progress, Thailand should focus on converting more car users to electric vehicles, considering that the majority of vehicles on the road are still fuelled by traditional fossil fuels.

#### 4.1.10. Vietnam

Vietnam strives to develop a green transport system that is able to achieve a net-zero emissions goal by 2050. Likewise, tax incentives and a waiver of registration fees for three years incentivise the locals to purchase an EV. The government also puts much emphasis on educating the public through public campaigns. This helps to raise public awareness of the advantages of adopting EVs and to gain the confidence of people in this emerging technology [26].

Under the National Automobile Development Strategy, the country provides extra funding for research and development to encourage both local manufacturers and foreign investors to improve the quality of EVs [63]. They also set environmental standards for the manufacturers to meet. However, the government enforces regulations favouring local car manufacturers like VinFast rather than aggressively attracting foreign car manufacturers [63].

The situation in Vietnam is completely different. Not only is the coverage of policies undertaken large, but the distribution of policies based on the three goals is also rather balanced. Among the seven aspects, it only falls short in the economic aspect, implementing only 36% in that domain. Vietnam's efforts, like those of Singapore and Thailand, are very comprehensive. By comparing the overall performance with the goals, Vietnam is concentrating on all three of them. Given motorcycles as the primary mode of private transportation, Vietnam emphasises efforts at the individual level to promote EV adoption and enhance charging infrastructure, applicable to all transport modes. This approach ensures a more inclusive and comprehensive approach to e-mobility promotion in the country.

## 5. Discussion

The STEELUP framework offers a comprehensive and versatile approach to evaluating e-mobility policies, enabling a meaningful comparison among ASEAN countries with diverse perspectives. This framework allows the assessment of multiple policies simultaneously, categorised by different perspectives or objectives. Additionally, the framework's applicability extends beyond e-mobility, making it relevant for assessing other emerging transport technologies. Crucially, the evaluation remains objective, grounded in implemented policies rather than subjective opinions.

Our analysis reveals significant variations among ASEAN countries in their approaches to electrification policies. Thailand takes the lead regionally with 45 policies, closely followed by Singapore with 44 and Vietnam with 42. ASEAN-5 (Indonesia, Malaysia, the Philippines, Singapore, and Thailand) and Vietnam outperformed their counterparts, surpassing the regional mean score of 31.8 (see Table 2 and Figure 1). Their effective policy-making demonstrates the potential to accelerate the electrification of mobility. However, some countries, such as Brunei, Cambodia, Lao PDR, and Myanmar, exhibit gaps that require increased investment to develop a robust e-mobility ecosystem. Regionally, the

emphasis is placed on political and urban design aspects, while the economic component receives relatively less attention.

Regarding electrification goals, our findings indicate that ASEAN nations prioritise industrial promotion, yet they allocate minimal attention to incentivising individual EV adoption. Closing this gap could accelerate the transition to electrification and bolster sustainable transport initiatives in the region. As the framework identifies areas of strength and opportunities for improvement, policymakers can strategically focus on bridging gaps to foster successful e-mobility adoption in ASEAN countries.

Discrepancies among the countries stem from various factors. First, the political will of governments is instrumental in driving e-mobility adoption. The substantial number of political-related policies reflect their dedication and promise to decarbonise the transportation sector. Most of the countries had set clear targets and revised their roadmap for achieving their goals [26]. Authorities in Malaysia, the Philippines, and Thailand also included EVs as part of the government fleet.

Second, economic background influences financial capacity, with countries with higher GDP per capita investing in advanced technological resources like fast charging systems. The average GDP per capita for ASEAN-5 nations and Vietnam was almost twice the average of the other four nations (US\$17,086 versus US\$9205 in 2021) [64]. More charging stations can be installed, but this has to keep up with the number of private transport users.

Third, countries aim to maintain their comparative advantage by promoting the EV industry as a crucial automotive manufacturing hub. With cheap labour and raw materials in the region, ASEAN will continue to be a hub for attracting more foreign direct investments to boost this nascent industry in the region. Some countries also impose regulations to safeguard their interests. This includes ensuring some forms of local production and prohibiting the export of nickel, which is crucial for EV batteries [65].

However, the results also expose gaps, emphasising the importance of public acceptance in determining the effectiveness of electrification policies. Sociocultural practices show inconsistency in implementation, with Singapore and Vietnam focusing on educating citizens about the intangible benefits of EVs, while other countries lack the means to reach the masses, contributing to low adoption rates. Brunei's Instagram account (@BruneiEV) serves as a communication platform for the country's e-mobility progress, highlighting the significance of public engagement. Education and advocacy efforts can dispel myths surrounding EVs, promote the benefits of clean transportation, and encourage behavioural changes towards sustainable mobility choices [61].

Challenges persist, notably in oil-exporting countries with abundant oil reserves where lower fuel costs promote private vehicle usage [58]. This heightened reliance on private vehicles underscores the urgency of transitioning to EVs as a viable alternative. Furthermore, the use of non-renewable energy sources for electricity generation within the countries presents a significant challenge, potentially hindering EV adoption efforts and perpetuating high carbon emissions levels if not addressed.

## 6. Implications and Conclusions

E-mobility initiatives are widely promoted as a strategy to reduce carbon emissions, but their application may vary in different contexts. In ASEAN, the promotion of a car-lite vision for reducing private vehicle usage represents an ideal, though challenging, approach, especially for long-distance commuting. Promoting public transport as the preferred mode is paramount, demanding substantial improvements in existing systems. Despite attracting prominent automobile manufacturers, affordability and accessibility of electric vehicles remain concerns due to a lower GDP per capita in the region. Diversifying the focus to include electric motorcycles and other affordable modes can address this issue.

Given the inexorable momentum of e-mobility, establishing a centralised platform to consolidate and update relevant data becomes imperative for effective policymaking and decision-making. The STEELUP framework serves as a foundation for tracking progress and guiding future e-mobility developments in the region. This platform will foster a

data-driven approach, enabling policymakers to make informed decisions and align their strategies with regional goals and targets.

To further enhance regional cooperation and collaboration, ASEAN can take a more collective approach towards advancing e-mobility. Leaders of each member country should engage in more frequent forums to facilitate open discussions and provide mutual support. These forums can serve as a platform to share best practices, exchange knowledge, and learn from each other's experiences, fostering a cooperative environment that accelerates the adoption of electrified mobility solutions across the region.

Recognising the financial challenges that some member countries may face in transitioning towards e-mobility, ASEAN can consider establishing a centralised fund dedicated to supporting these nations. This fund can offer financial assistance, technological expertise, and capacity-building resources to help bridge the gaps and ensure that all countries in the region have equal opportunities to participate in and benefit from the e-mobility transition.

The presence of regional events such as the upcoming ASEAN Sustainable Energy Week 2023 and Electric Vehicle Asia 2023 in Bangkok acts as a platform for companies and other stakeholders to showcase their electrification efforts. More such events and forums can be organised for governments to discuss and propose ideas to benefit fellow member countries in ASEAN.

Further, with existing close economic and non-economic cooperations between ASEAN countries, there could be a concerted effort to develop a strategy and plan for electrification of mobility at the regional level, across all ten member states, that pools expertise and resources to develop a common standard and ambition. Considering the substantial cross-border mobility-related activities and demand within ASEAN, this might also have positive spillovers to strengthen connectivity and trade, which would reinforce the impetuosity for the transition to e-mobility.

In summary, a comprehensive approach that encompasses technology-related policies and clean power generation is vital to effectively decarbonise the transportation sector. Regional collaboration, innovation, and awareness-raising efforts will position ASEAN as a leading force in the global e-mobility landscape, setting an example for others to emulate and follow. The road is challenging, but with collective effort and determination, ASEAN can steer towards a sustainable and electrified future. Despite the valuable insights gained from this analysis, it is important to acknowledge the inherent limitations encountered during this research. First, securing access to comprehensive documentation of policies and initiatives was challenging, limiting our analysis to documents available in the public domain. Given that e-mobility represents a relatively new area of development and growth for all ASEAN countries, there may be a time lag before the latest policies are officially documented, potentially hindering our access to up-to-date information.

Second, the ASEAN region's multicultural nature results in various countries releasing official press releases in their respective national languages. This may lead to potential difficulties in interpreting certain information accurately, possibly resulting in misinformation. Additionally, the presence of outdated data may impact the accuracy and relevance of the analysis of the results.

Third, the evaluation framework that was developed based on a literature review can be improved in future research. This is because indicators in the framework are gathered primarily from examples in Latin America, Europe, and China, which may not be applicable in the ASEAN context. For instance, V2X technology is rather common in Europe, but the technological level in ASEAN may not have reached those standards. Some modifications may be required to consider the ASEAN environment. This framework also only considers three outcomes. As such, amendments can be made, but they are very unlikely to be used to evaluate e-mobility policies.

Notwithstanding, it is crucial to underline that this paper represents the first comprehensive and independent analysis of e-mobility policies in ASEAN. Our findings are positioned to serve as a catalyst, further strengthening the commitment of ASEAN countries to adopt and transition towards electric and more sustainable mobility solutions. As

the e-mobility landscape continues to evolve, this study lays the foundation for ongoing research and policy development in the region.

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