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Article

Electric vehicles penetration in Thailand: Rationale, challenges and strategies

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Abstract: This paper provides an evolution of energy policy development of the Thai transport sector with an aim to analyze the driving forces that have shaped policy development and to identify the socio-economic and political challenges faced by the EV penetration. This evolution is divided into four time periods spanning from the pre-legislative era in 1970 to 2023. These periods mark pivotal shifts in energy policy directions within the transport sector. For each time period, analysis is carried out to delineate the influence of economic, environmental, social, political and other factors on shaping policy development in Thailand. The analysis reveals that the formulation of EV policies has been driven by several internal and external circumstances and influences. These include energy security issues, environmental threats, the economic and war crises, and global health crisis. Therefore, the impetus behind EV promotion policy in Thailand arose from the need to develop new strategies to tackle the energy import dependency, instability of energy costs, and the environmental consequences of fossil fuel consumption. However, limited attention has been paid on the socio-economic and political challenges that could emerge and hinder the effective implementation of EV promotion policy. Key emerging challenges include rising electricity tariffs, impacts on other related industries, and ineffective planning and practices for the rapid expansion of EVs. This paper further proposes several strategies could be adopted in order to address these challenges. The strategies, for example, coordinated charging with a time-of-use electricity tariff, workforce reskilling and upskilling, reinventing the business model of petrol stations, the development of new biofuel products, and establishing a platform to integrate various national energy and associated plans for harmonizing vision and objectives. These strategies could contribute to addressing emerging challenges and providing sustainable future of electric transportation in Thailand.

Keywords: policy evolution; socio-economic impacts; political influences; carbon neutrality

1. Introduction

Climate change issues have increasingly impacted human life. A change in climate brings about rising sea levels as well as alterations in weather patterns including droughts and floods. Countries around the world including Thailand have been impacted by an increase in the intensity and frequency of disasters arising from climate change. For Thailand, the country has been recognized as the world's most affected country by extreme weather events over the past fifteen years. The devastating 2011 flood in Thailand, the worst in fifty years, ranked as the world's fourth costliest disaster in 2011. Additionally, the drought experienced in 2016 marked the most severe in over a decade for the country (IMF, 2022). With the aim of mitigating climate-related disasters, the Thai government has set the target to decrease GHG

emissions by 30%–40% by 2030 and has pledged to attain carbon neutrality by 2050 and achieve net zero emissions by 2065 (ONEP, 2022a). In order to meet the objectives, the development of electric vehicles (EVs) has become one of the key policies for the country. In the case of Thailand, about 40% of the final energy consumption in 2022 was attributed to the transport sector (DEDE, 2022). In addition, due to limited domestic energy resources, crude oil supply in Thailand has been mainly dependent on imports over the past forty years. Crude oil imports in Thailand contributed for more than 90% of crude oil supply in 2022 (DEDE, 2022). Such a heavy dependence on imported oil has, therefore, resulted in a lessening of the country's energy security. The Thai government has put tremendous efforts to explore ways for reducing oil imports and GHG emissions from the transport sector. Accordingly, the Thai government has formally initiated policies on the EV development since 2015 (Wattana et al., 2022). The Thailand Integrated Energy Blueprint (TIEB) was formulated in 2015 and subsequently evolved into the National Energy Plan (NEP) in 2022. In addition to the blueprint, the electrical infrastructure development plan (EV roadmap) has also been initiated in 2016 (EGAT, 2016). Under the roadmap, increasing the number of EVs to 1.2 million by 2036 could help mitigating GHG emissions as well as reducing crude oil imports and lower the country's financial deficits. In 2021, the Thai government has further expedited EV adoption promotion by implementing the 30@30 policy to increase the proportion of zero-emission EVs (ZEVs) to 30% of all domestic vehicle production by 2030—representing about 725,000 EV cars and pick-up trucks plus 675,000 EV motorcycles (Morimoto et al., 2021). Such an ambitious target appears to be a challenging task due to various barriers arising from a shift towards EVs. Given concerns about the emerging challenges, a number of studies have been conducted on the impacts of EV adoption in several countries including Thailand. For example, numerous research works have assessed the implications of EVs and explored the benefits, challenges and possible solutions in the context of various countries (Alanazi, 2023; Chitgreeyan et al., 2024; Hassouna, 2022; Hassouna and Al-Sahili, 2020). In the case of Thailand, much of the studies has essentially focused on the challenges from EV adoption in terms of technological, financial, energy, and environmental (Wattana et al., 2022). Despite several research works that address the emerging challenges in terms of various dimensions, a discussion on the socio-economic and political challenges was still limited (Kongklaew et al., 2021; Thananusak et al., 2021). A discussion on the socio-economic and political context of EV adoption, this paper contends, is essentially important. This paper, therefore, aims to provide an evolution of the energy policy development of the Thai transportation sector with a view to analyze the driving forces that have influenced this policy development and to identify the socio-economic and political challenges faced by the EV penetration. In order to examine the transformation of energy policy development, a historical analysis is employed in this study. This would be beneficial for policy analysts and policy makers to develop and implement effective EV strategies for addressing emerging challenges and for providing a sustainable future for electric transportation in Thailand.

2. Energy policy evolution of the transportation sector in Thailand

This section provides an evolution of the energy policy development of the Thai transport sector. This evolution is divided into four time periods, from the pre-legislative period in the year 1970, to the year 2023. These time periods signify significant changes in the energy policy directions of the transport sector. For each time period, analysis is carried out to delineate the influence of economic, environmental, social, political and other factors on shaping the policy development in Thailand.

2.1. Pre-legislation on energy (1970–1989)

In this period, the occurrence of the oil crisis in 1973 and continued until 1981 had severely impacted Thailand. Prior to the oil crisis, the Thai government solely focused on supplying sufficient energy demand of the country. And, due to limited domestic energy resources, Thailand has heavily been dependent on energy imports to meet the rising demand of energy. Therefore, the Thai economy had suffered severely since the oil crisis (Wattana, 2010). As a consequence of these two oil crises, the Thai government was faced with a substantial debt. In the period of 1970s, oil prices had significantly increased from 5 US dollars in 1973, to 34 US dollars in 1981 (EPPO, 2003b). Thailand experienced a three-fold increase in its oil import expenditure, leading to a debt crisis where government debt reached its highest point at 39% of GDP (Pongpaichit and Baker, 1998). With a view to reduce oil import expenses as well as oil consumption dependency, the government began to implement temporary measures aimed at energy savings. In 1973, the royal decree on solving fuel shortages was issued in order to empower the Thai Prime Minister to enforce measures aimed at curbing energy consumption (EPPO, 2003b). These measures, for example, the restrictions on the operating hours and conditions for factories, theaters, cinemas, restaurants, and other entertainment venues. Despite several measures implemented for the purpose of energy savings, Thailand still faced with energy crisis. The Thai government, therefore, implemented additional measures on energy savings by developing a new program entitled “Demand Side Management (DSM)”. The DSM program was initiated with the aim to encourage manufacturers as well as importers produce and import energy-efficient equipment, to provide information and incentives for consumers to recognize the importance of energy conservation, and to promote the use of efficient energy management technologies to maximize benefits for the country (EPPO, 2003b).

In addition to the energy saving measures for mitigating oil shortage crisis, the Thai government also began to support for biofuels research since 1977. The Ministry of Industry established the Committee for the ethanol production from sugar cane project in 1977. Two years later, it was renamed the Committee for Ethanol Production from Agricultural Products to reflect Thailand’s diverse range of high-potential agricultural products for ethanol production, including cassava, corn, and sorghum (EPPO, 2003c). Despite higher production costs of ethanol comparing to petroleum during that period, the committee decided to support the ethanol production with the objective to alleviate fuel shortages and to enhance the country’s energy security in the future. In order to promote the ethanol production, the committee enacted several

measures. These included excise tax exemptions for ethanol producers for energy purposes, collaborations between the petroleum authority and domestic petroleum producers to purchase ethanol production and sell fuel mixtures to meet demand, and investment incentives for ethanol production businesses. During the period 1978–1979, the Ministry of Industry further conducted a study on the use of fuel mixture between ethanol and gasoline in different brands and models of cars. Moreover, the government supported the establishment of the ethanol production industry and set the target to produce ethanol of 482 million litres per year in 1986 (EPPO, 2003c).

Based on the above discussion, one observes that the Thai energy policies on the transport sector initially arose from the oil crisis. The policies included the energy conservation, ethanol production promotion as well as a research and development of ethanol production from agricultural products such as sugar cane and cassava. Despite the fact that the oil crisis during that period could be considered as severe problems of the country but the opportunities for providing a foundation for rigorous energy development could also emerge from the oil crisis. For example, the research on ethanol production from agricultural products provided a new development on alternative fuels in addition to gasoline. This could provide several benefits including reduction in crude oil import, enhancement of energy security, improvement in strong economic, increase in agricultural product values, and decrease in environmental pollution.

2.2. The foundation for energy legislations and institutions (1990–1999)

Given concerns about the energy crisis issues, the Thai government initially developed the national energy policies and plans in 1992. The enactment of the National Energy Policy Council Act BE 2535 (1992) was carried out to establish the National Energy Policy Council (NEPC). The NEPC is responsible for presenting national energy policies and plans to the Council of Ministers. It also oversees, coordinates, supports, and expedites the operations of all entities whose responsibilities pertain to energy, including renewable energy (Sitdhiwej, 2005). The National Energy Policy Council Act also established the National Energy Policy Office (NEPO) formed as secretariat to the newly formed NEPC, which serves as a direct line to the Prime Minister's Office on energy issues (Wattana, 2010). In addition to the NEPO, the Department of Energy Development and Promotion (DEDP) was also established under the National Energy Policy Council Act in 1992. The DEDP operated under the jurisdiction of the Ministry of Science, Technology, and Energy (DEDE, 2019).

In line with the National Energy Policy Council Act, the Energy Conservation Promotion Act was also promulgated in 1992. This act essentially established in order to determine measures for promoting efficient energy conservation. In order to financially support the energy efficiency projects, the Energy Conservation Fund (ENCON Fund) was established under the Energy Conservation Promotion Act (Chemhengcharoen et al., 2014). After the establishment of the NEPO and DEDP, the Energy Conservation Plan (Phase 1: 1995–1999) was developed, in 1995, with a particular focus on enhancing energy efficiency in factories and buildings by modifying equipment to high performance, and human resource capacity development

in energy (EPPO, 2003a). The program in the Energy Conservation Plan comprised compulsory, voluntary and promotional. In terms of compulsory program, the energy conservation was mainly aimed at supporting factories and buildings for higher energy efficiency. For voluntary program, the energy conservation targets were the introduction, dissemination and technology transfer of renewable energy use in agricultural and industrial sectors for the rural areas. In the case of promotional program, the plan was focused on human resource capacity development in energy efficiency (EPPO, 2003a). Despite several promotional programs implemented as part of the Energy Conservation Plan, the alternative fuels development received minor attention. According to the plan, the development of alternative fuels for petroleum substitution was primarily reserved for research demonstration within royally initiated projects. Such a limited development on alternative fuels could be mainly attributed to the Asian financial crisis of 1997, which significantly curtailed Asian demand growth and hence a drop in the world crude oil price. For example, the crude oil price in 1998 had been significantly dropped by about 80% comparing with the crude oil price in 1980 when the price reached its peak during the oil crisis (OECD, 2023).

The foregoing discussion suggests that the government put a particular focus on the establishment of energy agencies in Thailand during this period. The energy measures were generally implemented in factories and buildings in terms of financial incentives, technical assistance, and energy efficiency standard enforcement. The decline in world crude oil prices during the period of the Asian financial crisis of 1997 could be another factor contributing to a stagnant development in biofuels. The energy policy on alternative fuels for petroleum substitutions in this period, therefore, appears to be less promotional than the period of pre-legislation on energy.

2.3. Initiation of energy development plans (2000–2014)

During this period, the Thai government persisted in implementing energy policies focused on energy conservation. Since the implementation of the Energy Conservation Plan Phase 1, the plan continued to be active covering 2 phases: Phase 2 (2000–2004) and Phase 3 (2005–2011) (Intarajinda and Bhasaputra, 2012). The focus of the plan for every phases still were the same targets including factories and buildings. The policy on biofuels development, however, began to materialize in 2003 due mainly to the sharp rise in crude oil prices in the 2000s. The Thai government formulated the first National Alternative Energy Development Plan (AEDP) in 2004, covering for the period 2004–2011 (Wattana, 2014). The primary aim of this plan was to promote the production of biofuels. As a result of the plan, oil companies commenced the sale of E10 (a biofuel blend consisting of 10% ethanol and 90% gasoline) in 2004. Between 2004 and 2011, the sales of E10 experienced steady growth, increasing from 0.2 million liters per day in 2004 to 10.9 million liters per day in 2011 (DOEB, 2012). Due to the success of E10 sales, the Thai government additionally launched promotional campaigns for E20 and E85 in 2007 and 2008 respectively. In 2011, the daily sales of E20 and E85 were merely 0.6 million liters and 0.02 million liters, respectively (DOEB, 2012). The increase in E10, E20 and E85 sales over the period 2004–2011 directly resulted in a significant reduction of gasoline sales. The sales of gasoline decreased from 8.1 million litres per day in 2004, to 0.11 million

litres per day in 2011 (DOEB, 2012). For biodiesel, B5, a biofuel blend comprising 5% methyl ester and 95% diesel, has been available for purchase since 2005. The daily sales of B5 increased considerably from 0.12 million litres in 2006, to 19.32 million litres in 2010 (DOEB, 2012).

With the aim to further promote biofuels, the government has developed the Second AEDP (2008–2022) (DEDE, 2008). Under this plan, the proportion of alternative energy expected to increase to 20% of the country's total energy mix by 2022. The plan was divided into 3 phases. The first phase (2008–2011) focused on high potential renewable energy including biofuels, and co-generation from biomass and biogas. In the second phase (2012–2016), the target shifted towards fostering the growth of alternative energy technology industries and exploring new research and development (R&D) areas. The third phase (2017–2022) focused on the utilization of new alternative energy such as hydrogen. In terms of biofuel production, the government established ethanol production daily targets of 3.0 million litres for the initial period (2008–2011), 6.2 million litres for the second period (2012–2016), and 9.0 million litres for the third period (2017–2022) (DEDE, 2008). Biodiesel production was projected to increase steadily: from 1.35 million liters per day between 2008 and 2010, to 3.64 million liters per day in 2016, and eventually reaching 4.5 million liters per day by 2022 (DEDE, 2008). The production of feedstock for biodiesel, however, fell short of the target, mainly due to insufficient planting of oil palm trees and unfavorable climate conditions. Between 2010 and 2011, there was an inadequate palm oil to supply both consumer demand and the biodiesel production target. As a result, retail prices of cooking palm oil rose considerably by 30%. To alleviate shortages in cooking palm oil, the Thai government diverted 5000 metric tons of crude palm oil stocks originally allocated for producing biodiesel to cooking oil refineries (Wattana, 2014).

In 2012, the second AEDP was revised with the objective of transitioning the country towards becoming a low-carbon society. The development of the third AEDP (2012–2021) was, therefore, aimed to increase the share of alternative energy to 25% of the country's final energy consumption by 2021 (DEDE, 2012). According to the plan, biofuels were anticipated to replace approximately 44% of oil consumption by 2021. Ethanol production in 2021 was expected to grow to 9.0 million litres per day—nearly six times higher than the production in 2012. In 2021, biodiesel production was projected to rise to 5.9 million liters per day, with an additional 25 million liters per day of new fuel for diesel substitution anticipated to be introduced. The insufficient feedstock for palm oil, as discussed above, resulted in a new direction for diesel substitution with new fuel according to the third AEDP. The development of new fuel included the development of energy crops such as jatropha and microalgae, the enhancement of oil conversion technology and ethanol blending for diesel oil (DEDE, 2012).

In addition to the biofuels promotion policy, the government has also promoted Natural Gas for Vehicle (NGV) to be another alternative fuel for reducing the dependency on imported oil. Given that Thailand has been self-sufficient in natural gas consumption during the 1990s, an initiative promoting the broader adoption of NGV was launched in 2002 (IISD, 2013). With the objective of promoting NGV

consumption and NGV compatible vehicles adoption, several measures have been implemented. These include providing financial support for vehicle owners, offering low-interest loans for engine conversions, subsidizing NGV retail prices, and granting tax exclusions and reductions for NGVs (Bloyd, 2017). As a consequence of the NGV promotion policy, the consumption of NGV has continuously increased, from 3 Million Standard Cubic Feet (MMSCF) per day in 2004, to 317 MMSCF per day in 2014 (EPPO, 2023b). However, the Thai government's decision to end NGV subsidies, in 2015, led to a relative rise in the cost of NGVs (Bloyd, 2017). The rising costs of NGVs combining with a drop in petroleum prices have led to a decline in the popularity of NGVs since 2015.

In view of the energy institution establishment in this period, The Ministry of Energy (MOE) was established in 2002 with the aim of consolidating over 20 government agencies from nine ministries and State-Owned Enterprises (SOEs) that were directly involved in energy planning and policy (Sirasoontorn and Koomsup, 2018). Following the establishment of MOE, was set up in 2007 to delineate the roles and responsibilities of policymakers, regulators, and operators, while also consolidating regulatory functions.

On the basis of the forgoing discussion, it is observed that biofuels and NGV appeared to be an alternative fuel for petroleum substitution for Thailand. Over this period, NGV consumption witnessed a decade-long increase primarily driven by promotional measures. However, it subsequently declined due to the rising cost of NGVs following the discontinuation of subsidies. In contrast to NGVs, the production and utilization of biofuels increased substantially and continued to grow consistently. In fact, the promotion of biofuels production and utilization provided numerous benefits for the country, for example, enhancement of energy supply security, greenhouse gas emissions mitigation, and value addition for agricultural products. Nevertheless, the significant growth in biofuels production also caused several challenges including food insecurity, scarcity of water supply, and issues surrounding land use for biofuel production (Wattana et al., 2022). As previously discussed, the rapid increase in biodiesel target resulted in a severe shortage of cooking palm oil and hence a sharp rise in retail prices. The promotion policy on biofuels should be, therefore, cautiously considered by taking into account the implications arising from the interlinkages between energy, water and food systems.

2.4. Transition to sustainable energy development (2015–2023)

The period for sustainable development emerged from the integration of the five country's energy strategic plans including the Power Development Plan (PDP), the Energy Efficiency Plan (EEP), the Alternative Energy Development Plan (AEDP), the Oil Plan and the Gas Plan. In 2015, the government has developed the Thailand Integrated Energy Blueprint (TIEB) by integrating the five energy plans covering the same period (2015–2036). With a view to step towards a sustainable energy sector, the TIEB focused on the energy security, economy and ecology of the country. In this period, the policy on biofuel promotion continued to play a key role in the fourth AEDP (AEDP, 2015). Under the AEDP 2015, production of ethanol was expected to rise to 11.3 million litres per day in 2036. And, biodiesel production would increase

continuously to 14 million litres per day in 2036 (DEDE, 2015). In addition to the biofuels promotion, the policy on EV adoption was expected to be an effective strategy for stepping towards sustainable energy sector. The government has, therefore, introduced a measure to encourage the penetration of EVs in the EEP2015. With a view to successfully implement the EV promotion policy, the development of the electrical infrastructure plan to bolster EVs in Thailand, known as the EV roadmap, was also initiated in 2016 (Wattana and Wattana, 2022). According to the EV roadmap, the government has established a goal of reaching 1.2 million EVs by 2036. In order for achieving the objective, the roadmap was divided into 3 phases (EGAT, 2016):

1) The first phase (2016–2017) focused on preparing for EV adoption, with a particular emphasis on electric public buses due to their public benefits and the ease of infrastructure support development and other preparations made to support the future promotion of EV adoption;
2) The second phase (2018–2020) entailed ongoing preparations for personal electric vehicles (EVs) concentrated on refining the design and standards of charging infrastructure, conducting studies on service charges for charging stations, and expanding the charging station network to meet the growing demand for EV charging; and
3) The third phase (2021–2036) covered the extension for further implementation for personal EVs, with an emphasis on developing an electricity demand management system in conjunction with the utilization of EVs (Vehicle to Grid: V2G).

Following the roadmap, the government has enacted several initiatives, such as encouraging foreign direct investment, boosting the domestic market, developing infrastructure, setting EV standards, and implementing protocols for managing end-of-life batteries (Kaewtatip, 2019). To promote the adoption of EVs, the Thai government agencies have offered several tax and non-tax incentives. For instance, the Ministry of Industry began to establish the national standard for EVs and prepare for EV battery end-of-life management. The Ministry of Finance has reduced the excise tax for EVs from the range of 20%–40% to 2%–8% (Thananusak et al., 2021). The Board of Investment has also implemented several measures to promote investment in the electric vehicle supply chain. These measures consist of exempting corporations from paying income tax for a maximum of 13 years and removing import duties on machinery, raw materials, essential manufacturing materials, and research and development goods (Ploymee, 2020).

The aforementioned EV promotional measures have effectively led to an increased number of EVs in Thailand since 2015. A number of registered EVs in Thailand has increased by more than four times, from 7701 units in 2015, to 32,248 units in 2019 (Wattana and Wattana, 2022). Despite a growing increase in new EV registration, the emergence of the COVID-19 pandemic, in 2020, poses new challenges to the rising EV market in Thailand. In response to the pandemic, the Thai government has enforced stringent measures including lockdowns, social distancing protocols, and restrictions on travel. These measures have led to a decline in petroleum consumption, consequently causing a decrease in oil prices in 2020. On 20 April 2020, the West Texas Intermediate crude oil price experienced an unprecedented plunge,

dropping to a historic low of negative 37.63 US dollars per barrel (Le et al., 2021). Such a decline in oil prices has, therefore, resulted in a deceleration in the growth rate of EVs in 2020. Prior to the COVID-19 outbreak, new EV registrations witnessed a surge of approximately 50%, rising from 20,669 units in 2018 to 32,248 units in 2019. However, an increased number of new EVs for the period 2019–2020 was significantly dropped to 9% after the emergence of COVID-19 pandemic (EVAT, 2021).

After the post-COVID-19 period, the popularity of EVs in Thailand has been increasing. This could be due to a disruptive technology transition enabling the feasible and affordable adoption of EVs in Thailand. Therefore, the Thai government has further expedited EV adoption promotion by establishing the National Electric Vehicle Policy Committee in 2020. This national committee has the responsibility of identifying the direction and target of EVs in consistent with the 20-Year National Strategy. Since the establishment of the committee, the Thai government has implemented the 30@30 policy to increase the proportion of zero-emission EVs (ZEVs) to 30% of all domestic vehicle production by 2030—representing about 725,000 EV cars and pick-up trucks plus 675,000 EV motorcycles (Morimoto et al., 2021). In addition, the 30@30 EV policy also aims to replace all vehicles utilized by government agencies and public fleets manufactured in Thailand with ZEVs. This objective aligns with the Thai government's pledge to achieve carbon neutrality by 2050 and net-zero greenhouse gas emissions by 2065. The commitment emerged from the participation of the Thai Prime Minister in the 26th session of the Conference of the Parties (COP 26) to the United Nations Framework Convention on Climate Change (UNFCCC) in 2021 (ONEP, 2022a). During COP 26, Thailand committed to achieve carbon neutrality by 2050 and attain net-zero GHG emissions by 2065. Thailand has also committed to strengthening its Nationally Determined Contributions (NDC), aiming to achieve a 30%–40% reduction in GHG emissions by 2030, an increase from the previous target of 20%–25%. This adjustment accords with the nation's goals of reaching carbon neutrality and net zero emissions. Due to the fact that the transport sector contributes by about 30% of total GHG emissions, reducing emissions in this sector would play a pivotal role in decarbonization efforts and promoting environmental sustainability (Prasad et al., 2022).

In consistent with the 30@30 policy, the Ministry of Transport has formulated the EV Development Plan (2022–2037) (Laoonual, 2023). According to the EV Development Plan, the government aims to have 4412 electric buses operational in the Bangkok Metropolitan Area by 2030. Of the total 4412 buses, the Bangkok Mass Transit Authority (BMTA) has the plan to replace 2511 existing conventional buses with electric buses. Moreover, the BMTA is preparing to announce a service contract for the operation of 1500 electric buses. And, the Department of Land Transport has approved concession agreements for electric bus operations on 13 routes within the Bangkok Metropolitan area in 2022. The Transport Co., Ltd. has outlined a plan to substitute 401 old conventional buses with new electric buses.

In terms of the incentives for promoting EVs, the Thai government has offered extensive incentives to encourage the utilization of battery EVs in Thailand including passenger cars, electric pickups and electric motorcycles. On 15 February 2022, Thailand's cabinet preliminarily approved an EV tax incentive package aimed at

encouraging the adoption of EVs in Thailand, with the objective to establish the country as a leading EV manufacturing hub in Asia (Chantanusornsiri, 2023). The package included supply-side measures, demand stimulation measures and supporting measures covering the period of 2022–2025. **Table 1** summarizes the incentive measures for promoting EV industry for the period 2022–2025.

Table 1. Incentive measures package for promoting the Thai EV industry for the period 2022–2025.

Types of measures	Incentive measures	Responsible authorities
Supply-side measures	Investment incentives for producers including • Production of BEV/PHEV/HEV/FCEV and BEV Platforms • Battery electric bus and truck • Battery electric motorcycle, tricycle, bicycle and boat • Batteries and essential components for EV plus supplementary parts & components • Charging stations for batteries and facilities for battery swapping • Software & application related to EV	Board of Investment
Demand stimulation measures	Subsidies and tax incentives for battery EVs including • Exemption/reduction of import duties for CBU vehicles • Reduction in excise tax for CBU and CKD vehicles • Cash subsidy for CBU and CKD vehicles	Ministry of Finance
Supporting measures	Provision supports on the following: • Charging infrastructure • Standard and testing facility • Soft loan for EV supply chain	Ministry of Energy, Ministry of Industry and Ministry of Finance

Sources: (Prasad et al., 2022; Therdsteerasukdi, 2023).
Notes: BEV—Battery Electric Vehicle, PHEV—Plug-in Hybrid Electric Vehicle, HEV—Hybrid Electric Vehicle, FCEV—Fuel Cell Electric Vehicle, CBU—Completely Built Up, CKD—Completely Knocked Down.

From **Table 1**, the package was divided into 2 phases including the first period covering from 2022 to 2023 and the second period spanning from 2024 to 2025. In the first period, the measures aimed to incentivize the extensive adoption of EVs in Thailand by offering exemptions on import duties and excise tax, along with subsidies to bolster EV demand and attract investment in the EV industry (Therdsteerasukdi, 2023). Both the importation of CBU cars and motorcycles, as well as the local assembly of CKD vehicles within Thailand (Prasad et al., 2022). For the second period 2025–2024, the initiative aimed to boost the adoption of domestically manufactured EVs by discontinuing import duty exemptions for CBU vehicles, while retaining other incentives such as reduced excise tax rates and subsidies. The objective of this initiative is to elevate the cost of CBU vehicles above that of locally produced counterparts, thereby motivating operators to manufacture EVs within the country and meet the rising demand. Additional information regarding the incentive measures package can be found in a report on the future potential of EVs in Thailand by Prasad, Uchida, and Tran (Prasad et al., 2022).

As a result of the above EV promotion package, the annual number of newly registered EVs in Thailand has considerably increased from 35,270 units in 2020, to 196,991 units in 2023 (DLT, 2023). Interestingly, it is observed from **Figure 1** that the number of BEVs in Thailand has significantly rise by about 26 times, from 2999 units in 2020, to 100,219 units in 2023. This indicates that the incentive package has effectively led to a significant rise in EVs. In addition to the rapid growth in BEVs,

the number of HEVs has also continuously increased from 24,464 units in 2020, to 85,069 units in 2023 (as shown in **Figure 1**). However, it is further noticed that the growth in PHEVs has been stagnant for the whole period in contrast to HEVs and BEVs. It is likely that the incentive package has also played a role in a stagnant growth in PHEVs. This is attributed to two primary reasons. Firstly, the package has attracted Chinese EV manufacturers to invest in the Thai EV market, with a predominant focus on BEVs. Secondly, the primary car manufacturers in Thailand are Japanese companies with a more dominant portfolio toward HEVs. In contrast, PHEVs are mostly manufactured by European and US companies—accounting for only 10% of total car market in Thailand (DLT, 2023). Consequently, the number of PHEVs has slightly increased by about 10,000 units each year, as shown in **Figure 1**.

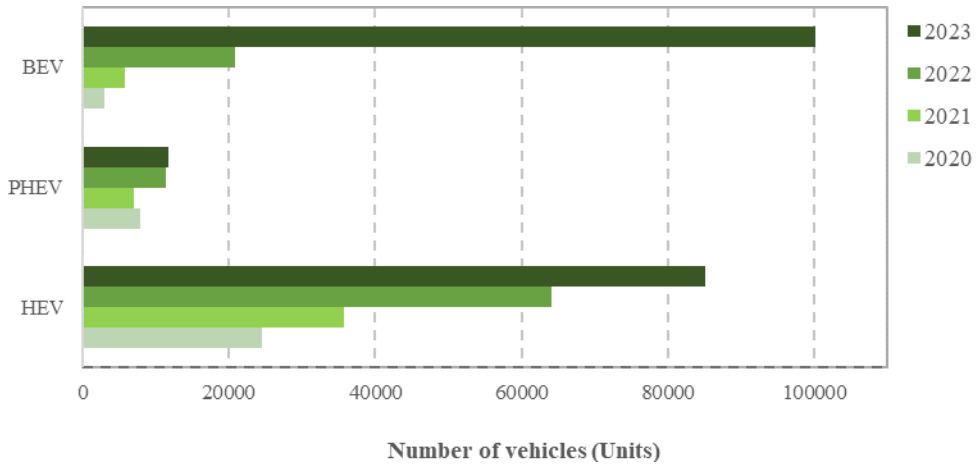

Figure 1. Number of newly registered EVs by various EV types for the period of 2020–2023.
Source**:** DLT, 2023; EVAT, 2023.

The foregoing section presents the evolution of the energy policy development of the Thai transport sector. This evolution enables one to gain insights into the nature of the changes that have taken place in the transport sector's energy policy development as well as the underlying reasons for these changes, focusing on the influence of economic, environmental, social, political and other factors on shaping the policy development in Thailand. A summary of the evolution of energy policy development of the Thai transport sector is provided in **Table 2**.

Table 2. Evolution of the energy policy development of the Thai transport sector.

	1970–1989	**1990–1999**	**2000–2014**	**2015–2023**
Contextual backdrop & influential factors	• The Oil Crisis of 1970s	• The Asian financial crisis of 1997/98 • A decline in the world crude oil prices	• The Oil Price Shock of 2000s • A severe shortage in palm oil supply • High retail cooking palm oil prices • Russia-Ukraine war	• The COVID-19 pandemic • Disruptive technology transition • 2021 United Nations Climate Change Conference (COP26)

Table 2. (*Continued*).

	1970–1989	1990–1999	2000–2014	2015–2023
Policies, Regulations, Plans & Measures	• Implementation of energy conservation policy • Ethanol production promotion • Research & development on the use of fuel mixture between ethanol and gasoline for vehicles • Cooperation between petroleum authority and domestic petroleum producers to purchase the ethanol production and sell fuel mixture	• Enactment of the National Energy Policy Council Act • Establishment of the National Energy Policy Office (NEPO) and Department of Energy Development and Promotion (DEDP) • Enactment of the Energy Conservation Promotion Act • Implementation of Energy Conservation Plan • Initiation of the development of alternative fuels for petroleum substitution applied for research demonstration in royal projects	• Development of the first national Alternative Energy Development Plan (AEDP) focusing on biofuels production promotion • Implementation of pricing policy resulting in E10 and B5 being cheaper than premium gasoline and normal diesel • Initiation of NGV adoption promotion measures • Establishment of the Ministry of Energy (MOE) and Energy Regulatory Commission (ERC)	• Development of the Thailand Integrated Energy Blueprint (TIEB) • Implementation of EV adoption promotion policy • Development of EV roadmap • Establishment of the National Electric Vehicle Policy Committee • Implementation of 30@30 EV policy • Development of EV Development Plan (2022–2037)
Incentives & Subsidies	• Exemption of excise tax for ethanol producers for energy purposes	• No incentive for promoting energy conservation in the transport sector	• Provision of investment promotion incentives to manufacturers of ethanol • Reduction in excise tax in new cars capable of using E20 • Provision of financial support for NGV vehicle owners, low interest loans for engine conversions, subsidized NGV retail prices, and tax reductions for NGVs	• Provision of EV tax incentive package (as shown in **Table 1**)

Notes**:** E10 refers to a biofuel blend consisting of 10% ethanol and 90% gasoline, E20 refers to a biofuel blend consisting of 20% ethanol and 80% gasoline, B5 refers to a biofuel blend consisting of 5% methyl ester and 95% diesel.

3. Rationale behind EVs policies

The analysis of the evolution of energy policies on the transportation sector in Thailand reveals that the formulation of EV policies has been driven by several internal and external developments and influences. These include energy security issues, environmental threats, disruptive technology transition, economic and war crises, and global health crisis.

3.1. Energy security issues

The issues of energy security have been apparently major concerns in Thailand over the last four decades. Because of a scarcity of domestic energy reserves, the nation has heavily depended on imported energy, especially crude oil. Over the period 2000–2022, energy import accounted for more than 55% of total commercial primary energy supply in Thailand (EPPO, 2023a). Within these imports, crude oil consistently dominated – accounting for more than 60% throughout the entire period. A substantial dependency on imported oil certainly has a negative impact on the security of energy supply. With an aim to enhance the energy security, several strategies to reduce oil importation have been implemented including oil saving campaign, promotion of

biofuels substitution of petroleum products, and EV adoption promotion as previously discussed in Section 2. A review of the evolution suggested that the success of each strategy varied. For example, the oil saving campaign received cooperation primarily during periods of high oil prices. Biofuels substitution of petroleum products gained popularity only when using blends with a low percentage of biofuels, such as E10—A mix containing 10% ethanol and 90% gasoline. The promotion of EV penetration has been, therefore, expected to be new effective pathway to help enhancing the country's energy security.

3.2. Environmental threats

Environmental threats appeared to be another significant factor driving the promotion of EVs deployment in Thailand. The ongoing expansion of the Thai economy has led to a rise in energy consumption due to an inseparable relationship between energy consumption and economy development. For the past four decades, Thailand has been mainly relied on fossil fuels—accounting for more than 95% of total commercial primary energy consumption, of which crude oil and coal constitute more than half of the share (EPPO, 2023a). Such a high share of crude oil and coal consumption has, therefore, severe consequences on the environment, for example, air pollution, global warming and climate-related disasters. With a view to address environmental concerns, the Thai government has enacted a strategic policy aimed at substituting ICEVs with EVs for alleviating the growing environmental consequences.

3.3. Disruptive technology transition

Despite the fact the issues of energy security and environment appeared to be strong drivers for promoting the EV deployment in Thailand, the EV adoption has been stagnant in the early years. This is mainly because of the EV primary drawbacks of the limited driving range per single cycle of a fully charged battery, and the high expenses associated with the materials for battery manufacturing (Preedakorn et al., 2023). The disruptive technology transition has enabled the viable and economically feasible adoption of EVs in Thailand. The recent adoption of EVs is driven primarily by technological advancement. Such an advancement, for example, increased battery range, faster charging, and reduced manufacturing costs, have made EVs a more attractive option comparing with their petroleum-powered counterparts.

3.4. Economic and war crises

Another significant influence for promoting EV adoption arose in the context of major economic crises, for example, the oil price shocks witnessed during the 1970s and the 2000s, as well as the Asian financial crisis of 1997/98. Oil prices spike and oil price volatility caused by the oil and financial crises have significantly resulted in trade and current account deficits due to oil imports. The surge in oil prices directly led to a rise in government spending on importing crude oil. Moreover, the depreciation of the Thai Baht (THB) during the financial crisis further supplemented the increased expenditure on crude oil imports. In addition to the economic crisis, war crisis has also played a role in oil prices surge and oil price volatility. For example, the Russia-Ukraine conflict, which began in 2014, caused a significant increase in price

instabilities across various energy-related commodities, disrupting global economic activities to a greater extent than the world experienced during the oil crises of the 1970s and the 2000s (Chen et al., 2023). The strategy to reduce oil consumption by incentivizing EV deployment, therefore, could help alleviating the impacts arising from the economic and war crises.

3.5. Global health crisis

One factor influencing the policy for adopting EVs in Thailand was the contemporary global health crisis. The Public health issues in the recent years have stemmed from environmental threats including GHG emissions and air pollution (as discussed earlier). These environmental threats caused infectious respiratory disease, such as asthma, rhinitis and mortality due to respiratory diseases. Combining with the newly emerged global health crisis, for example, COVID-19 pandemic, the intensity of infectious disease gains higher vulnerable to death rate. With an aim to improve public health system, the substitution of ICEVs with EVs is expected to help mitigating the impacts on environmental health, thereby reducing the prevalence of respiratory diseases.

4. Emerging challenges faced by EVs penetration in Thailand

This paper discusses the evolution of energy policy for the Thai transport sector as well as analyses the driving forces shaping the EV policy development. The discussion indicates that the formulation of energy policy for the transportation sector, over the last four decades, has predominantly depended on energy, economic and environmental circumstances. The policy on EV promotion in Thailand, therefore, stemmed from the need to develop new strategies to address the issues of energy costs instability and environmental consequences of fossil fuel consumption. However, limited attention has been paid on the socio-economic and political challenges that could emerge and hinder the effective implementation of EV promotion policy. The key emerging challenges include rise in electricity tariffs, impacts on other related industries, and ineffective planning and practices for the rapid expansion of EVs.

4.1. Rise in electricity tariffs

High EV penetration could lead to a rise in electricity tariffs in Thailand. This could be contributed by various factors, for example, investments for upgrading electricity infrastructure and increased fuel costs of electricity generation. In terms of investments for upgrading electricity infrastructure, a growing in EV would undoubtedly lead to a substantial increased load on the electricity grid. To meet the rising demand adequately, the electricity infrastructure would require additional capacity, enhanced transmission, and expanded distribution networks. It is, therefore, the government that has the responsibility for providing significant investments in the upgrade of the electricity infrastructure to be ready for a substantial increase in electricity demand due to high EVs adoption. Such an investment would inevitably result in higher cost of producing electricity and hence increased electricity tariffs. This is due to the fact that the electricity tariff structure in Thailand is separated into base rate and variable rate (Ft) (ERC, 2021). Base tariffs have been determined based

on the planned infrastructure investment in generation, transmission and distribution segments as well as the operating and maintenance cost of the three state electric utilities which are responsible for some parts of generation and all of the transmission and distribution networks (Wattana and Wattana, 2020). These base tariffs have been regularly revised every 3–5 years by taking into account various factors, including economic, financial, social or even political factors. The electricity tariffs are, therefore, expected to increase as a consequence of higher investment cost.

In addition to the base tariffs, higher electricity prices have also attributed to variable tariffs (Ft). The variable tariffs comprise fuel cost of electricity generation from the state generating utilities, purchased electricity cost from the private power producers, and cost arising from the government's policies (ERC, 2014). The government has considered variable tariffs in terms of short periods, typically every 4 months. It's worth mentioning that fuel cost for producing electricity could have an impact on increased electricity tariffs. In Thailand, electricity production has been mainly dependent on fossil fuels. For example, electricity generation from fossil fuels, in 2022, accounted for more than 70% of total electricity generation (DEDE, 2022). And, nearly two-third of total fossil fuels consumption for producing electricity has been imported. Consequently, a rise in electricity demand due to high EV deployment is expected to cause higher fuel consumption driving up fuel costs of power generation, and hence raising electricity tariffs. This could have been worsening if there are economic and war crises. As previously discussed, fossil fuels for power production in Thailand has been mainly imported. Importing more energy under the currency instability situation could cause substantial expenses in fuel costs.

4.2. Impacts on other related industries

A sharp increase in EVs would certainly have an impact on other related industries. These industries, for example, the automotive, oil and biofuel industries. For the automotive industry, the emerging EV industry have direct and severe impacts on the car manufacturers in Thailand. Thailand has traditionally been a robust automotive market in the Southeast Asian region, reaching its peak production of 2.5 million units in 2013, and after the COVID-19 pandemic, it produced 1.7 million units in 2021 (Prasad et al., 2022). EVs promotion policy would pressure car manufacturers to restructure their supply chains with an emphasis on EVs. The shift to EVs requires changes in manufacturing processes, production lines, and needs new investments in technology and infrastructure. Moreover, the transition to EVs also impacts employees in the automotive industry. To maintain their employment, employees in the automotive industry need to possess new technical skills and knowledge to adapt to EV manufacturing processes.

The oil industry appears to be another sector affected by EV penetration promotion policy. The transition towards EVs would have a substantial impact on the oil companies in Thailand. A sharp drop in oil demand would result in reduced revenues from oil sales, decreased profits for oil companies, and, importantly, disruptions to the job market within the oil industry. In Thailand, the oil companies employ a significant workforce to provide services at their petrol stations. A change in the provision of services at petrol stations could lead to substantial job losses.

The impacts on the biofuel industry are also significant. Since the 2000s, the biofuel industry in Thailand has gained growing prominence within the transportation sector. Given its limited domestic energy reserves, Thailand relies heavily on imported oil to meet the growing energy needs of the country. For example, petroleum products accounted for over half of the country's total final energy consumption from 1986 to 2020 (EPPO, 2021). Since 2003, the government has initiated the implementation of a biofuel promotion policy aimed at reducing oil imports, mitigating GHG emissions, and crucially, utilizing local energy resources i.e., sugar cane, cassava, and oil palm (Wattana, 2014). As a result, the EV penetration promotion would have a direct impact on Thailand's biofuel industry. It is clear that the increased adoption of EVs would inevitably lead to a decline in the demand for biofuels and also have a subsequent impact on the agricultural sector. Reduced biofuel demand would lead to fewer energy crops required for their production, thus resulting in less income for farmers.

4.3. Ineffective planning and practices for the rapid expansion of EVs

As previously discussed in Section 2, the planning of policies to promote EVs in Thailand has primarily been motivated by the need to develop innovative strategies to address the volatility of energy costs and the environmental impacts arising from fossil fuel consumption. It seems that the existing planning and policy for EV adoption promotion have essentially focused on increasing the number of EVs. Several incentives provided for attracting new EVs buyers and encouraging investment from EV manufacturers, for example, subsidies and tax incentives package, and investment incentives for producers. There is, however, a deficiency in the development of plans to accommodate various issues arising from the extensive penetration of EVs. The emerging issues include the policy transition from promoting biofuel consumption to fostering higher EV adoption, and the delayed development of infrastructure to support the rapid surge in Evs.

In terms of the policy transition issues, the promotion of oil substitution with biofuels in the transport sector has been one of the major strategies by the Thai government for enhancing energy security and addressing environmental concerns for the last 20 years. As a consequence of this strategy, various stakeholders in the supply chain such as farmers, crop factories, and biofuel refineries, have been incentivized to increase their production for biofuels. Significant investments across related sectors were necessary to meet the government's ambitious biofuel production targets. Nevertheless, EV promotion policy has been initiated after the implementation of biofuels policy for only 10 years. And importantly, the introduction of the EV promotion policy emerged without developing plans for accommodating policy changes in reducing biofuel consumption and instead prioritizing the increased adoption of EVs. Such a policy transformation without providing accommodating plan could significantly impact all stakeholders in the biofuel industry. For example, farmer would gain less income from selling energy crop for biofuel production. Moreover, crop factories and biofuel refineries could face lower returns on their investments which might lead to company closures and subsequent job losses for employees.

Regarding the delayed infrastructure development issues, it seems that the existing infrastructure development inadequately support the growing number of EVs

despite the implementation of EV promotion policy since 2015. For instance, the total of PHEVs and BEVs in Thailand reached nearly 100,000 units in 2023 (DLT, 2023; EVAT, 2023). However, the number of public charging stations available to customers was only about 2600 stations in 2023, and the stations mostly located in the metropolitan areas (EVAT, 2023). In addition, upgraded grid infrastructure need to expand widely across the country and its capacity increased to supply sufficient growing electricity demand for such a high number of EVs. In fact, the EV roadmap, aimed at bolstering the electrical infrastructure to support EVs, has been put into action since 2016 (EGAT, 2016). According to the plan, the expansion of charging stations to accommodate the increasing need for EV charging is expected to be implemented in the period 2018–2020, as previously discussed in Section 2.4. The plan has, however, failed to provide adequate demand for EV charging.

5. Proposed strategies for addressing emerging challenges

With the aim of providing strategies for advancing the sustainable future of electric transportation in Thailand, this paper examines the evolution of the energy policy development of the Thai transportation sector. In addition, the driving forces influencing the policy development as well as the socio-economic and political challenges faced by the EV penetration have been analyzed in this paper. The analysis suggests that current policies for EV adoption promotion primarily focus on boosting the number of EVs. According to the 30@30 policy, the Thai government has set targets of increasing the proportion of ZEVs to 30% of all domestic vehicle production by 2030. In order to achieve these ambitious targets, a number of incentives has been provided for attracting new EVs buyers and encouraging investment from EV manufacturers. It is, therefore, appeared that the focus only limited dimensions (i.e., boosting the number of EVs and attracting investments in EVs industry) could raise several challenges. These challenges include rise in electricity tariffs, impacts on other related industries, and ineffective planning and practices for the rapid expansion of EVs. In order to tackle these challenges, this paper outlines the following strategies.

An increase in electricity prices has been primarily resulted from the investment in electricity capacity expansion and upgraded electricity infrastructure, as discussed earlier in Section 4.1. To tackle this issue effectively, a comprehensive strategy involving coordinated EV charging alongside a time-of-use electricity tariff could be adopted. The coordinated charging strategy would help transforming EVs from being a grid management challenge into a beneficial electricity resource. This strategy involves charging EVs in periods of low demand and discharging them during peak times. This could effectively flatten load curves, improving equipment utilization rates, and especially reducing the need for extensive investments in power system planning and construction. This strategy would optimize existing power supply capabilities, particularly to support EV operations, thereby help delaying the need for power system expansion while maintaining system reliability. The slowdown in investment in electricity infrastructure expansion would, therefore, help reducing the electricity costs and consequently delaying the rise in electricity tariffs. Moreover, it is worth mentioning that effective coordinated charging could also enable EVs to function as a mobile energy storage system known as Vehicle-to-Everything (V2X). V2X refers to

the use of EV batteries to offer energy services and extract added value from the battery asset when not in use (Thompson and Perez, 2020). By utilizing bi-directional charging, V2X services have the potential to generate revenue by offering benefits to the electricity grid, reducing energy consumption in buildings and homes, or providing backup power to loads. In addition, the deployment of a Time-of-Use (ToU) tariff scheme would further enhance the effectiveness of the charging coordination strategy. This scheme would incentivize customers to adjust their charging behaviors by selecting charging times during low-cost tariff periods, thereby maximizing savings on EV charging costs.

For the impacts on other related industries, the issues would arise in the form of new skilled labor shortages, job insecurity, inadequate return on investment, and reduced income. In the case of new skilled labor shortages in the automotive industry, implementation of reskilling and upskilling strategies could be adopted to address this issue. Both employees and automakers could play a role in preparing the next-generation workforce with e-mobility skill. For employees, in order to safeguard their existing positions, employees would need to acquire new technical skills and knowledge to adjust to the manufacturing processes related to EVs. And, in view of automakers, to retain their skilled workers, car manufacturers could collaborate with technology partners, universities, community colleges, and industry experts to organize training initiatives. Regarding job insecurity in oil companies, reinventing the business model of petrol stations could be a key to preserving employment opportunities for their existing workers. A shift in service provision patterns from traditional petroleum fueling to EV charging would lead to significant job losses for filling station attendants. The introduction of new business model for petrol stations could serve as an effective solution for retaining existing filling station attendants by transferring them to new responsibility. The business model involves offering a variety of popular new services such as laundry facilities, restaurants, cafes, retail stores, banking services, entertainment options, or even co-working spaces. These services could enable consumers to maximize their time during vehicle charging. Interestingly, this new business model would enable the business operators to gain higher return on investment from non-oil services and importantly, to transition filling station attendants into new service roles. In terms of inadequate return on investment in biofuel industry and reduced income for farmers, the development of new biofuel products by employing technological advancement appears to be an effective strategy for sustaining a continuous demand for biofuel and energy crops used in biofuel production. The advancement in technology could pave the way for the adoption of new biofuels products, such as aviation biofuels known as Sustainable Aviation Fuels (SAF). SAF, a biofuel utilized for aircraft propulsion, possess similar properties to conventional jet fuel while offers a reduced carbon footprint (Cabrera and Melo de Sousa, 2022). Increasing SAF production could contribute to maintaining the profitability of the biofuel industry, establishing additional economic gains, and fostering extra income for farmers.

In the case of Thailand, challenges related to ineffective planning and practices emerge in the form of a deficiency in the development of plans to accommodate various issues stemming from the widespread adoption of EVs. In fact, a number of

energy plans in the last three decades have been initiated, developed and revised by various policy-making authorities. These plans, for example, Power Development Plan (PDP), Alternative Energy Development Plan (AEDP), Energy Efficiency Plan (EEP), Gas Plan, Oil Plan, EV roadmap, Smart Grid Master Plan and Grid Modernization Plan. The development of these plans, however, inconsistent due to each authorities having its own individual operational plan. For example, the starting and ending times of the plans were not synchronized. It was until 2015 that the Thai government approved the integration of five energy master plans namely PDP, AEDP, EEP, Gas plan and Oil Plan and changed to Thailand Integrated Energy Blue Print (TIEB) (DEDE, 2018). The integration aimed to ensure alignment and avoid redundancy among the operations of authorities supervised by the Ministry of Energy. Since 2018, the TIEB has undergone consistent revision and later changed its name to the National Energy Plan (NEP) in 2022. It is noteworthy that despite the integration of five energy master plans, there remains a lack of alignment between the goals outlined in the PDP, EV roadmap, Smart Grid Master Plan, and Grid Modernization Plan (EGAT, 2016, 2018; EPPO, 2020; MOE, 2015). For instance, the EV roadmap implemented since 2016 established a precise target for the quantity of EVs. Interestingly, the latest PDP (PDP 2018: Revision 1) did not incorporate specific targets for EVs. Also, the Smart Grid Master Plan, developed in 2015, mainly considered the factors driving the expansion of Distributed Energy Resources (DERs) but other disruptive technologies including EVs received minor attentions. Then, the Grid Modernization Plan, implemented in 2018, has turned to focus on embracing the growing penetration of EVs and identified new business opportunities of disruptive technologies.

In addition to the inconsistency in plan development, Political uncertainty is also important factor contributing to deficiencies in energy plan development. Political uncertainties have long been recognized as a major challenge to the economic and social development of Thailand. For more than half century, Thailand has encountered numerous political instabilities including constitutional reforms, political coup, government elections, and political protests (Trakarnsirinont et al., 2023). These instabilities have directly impacted the government's planning and policy direction. For example, the latest general election was just held in Thailand on 14 May 2023 (Phoonphongphiphat, 2023). It was, however, nearly three months after the May 14 general elections that the new Srettha Thavisin Cabinet has been officially appointed by the royal decree. The delays in government formation could affect the approval of energy plans and policies, particularly during periods of disruptive energy transitions that require efficient and prompt actions. For Thailand, the energy plans have been revised several times due to various influential factors, such as domestic energy situations, the urgency of environmental issues, and rapid technological advancement. It is worth mentioning that the latest energy plan called National Energy Plan (NEP) has been developed since 2022 (ONEP, 2022b). As of February 2024, the publication of NEP has been postponed, currently pending approval from the new cabinet despite being scheduled for release by mid-2023 (Chandler, 2023).

In order to address the issues of ineffective planning and practices, regulatory and policy actions should begin with aligning various national energy and associated plans.

This alignment will enable stakeholders to deliberate on the objectives of EVs adoption, biofuels utilization adaptation and integrating EVs into generation, transmission, and distribution planning. A platform to integrate various national energy and associated plans is, therefore, essentially needed. This platform would harmonize vision and objectives, and initiates clear workflows across energy plans to achieve each objective. Subsequently, regulatory and policy designs for technical aspects, tariffs, infrastructure investment supports and business model development could be further refined. This platform would serve as an essential mechanism for transitioning towards the development of sustainable transportation and electricity systems.

6. Conclusion

This paper presents a historical evolution of energy policy within Thailand's transportation sector, aimed at analyzing the influential factors driving policy formation and identifying the socio-economic and political challenges impeding EV penetration. Spanning from the pre-legislative era in 1970 to 2023, the analysis delineates four periods marking significant shifts in energy policy paradigms within the transport sector. Each period undergoes scrutiny to uncover the multifaceted impacts of economic, environmental, social, and political dynamics on Thailand's policy landscape.

The analysis reveals an influence of internal and external factors driving the formulation of EV policies, including concerns about energy security, environmental sustainability, economic and war crises, and global health emergencies. Consequently, the policy on EV promotion in Thailand stemmed from the need to develop new strategies to address the issues of energy import dependency, energy costs instability, and environmental consequences of fossil fuel consumption. Nonetheless, limited attention has been given to potential socio-economic and political challenges that may arise, hindering the effective implementation of EV promotion policies. Key emerging challenges include rising electricity tariffs, impacts on other related industries, and ineffective planning and practices for the rapid expansion of EVs.

To address these challenges, the paper proposes several strategic approaches. These include coordinated charging mechanisms aligned with time-of-use electricity tariffs, initiatives for workforce reskilling and upskilling, reinventing the business models of petrol stations, advancement of new biofuel products, and the establishment of an integrated platform to synchronize national energy plans and associated plans. Such strategies, this paper contends, could contribute to fostering sustainable future of electric transportation in Thailand.

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