한-아세안(신남방) 스마트도시수출 거점 HUB

GU&I R ISSUE PAPER

No. 21

2025. 03. 13

[기본연구] 태국의 전기차 정책과 기후 영향에 대한 생애주기 분석

국제도시 및 인프라연구센터
Global Urban & Infrastructure Research

GU&I RC Issue Paper Contents

Life Cycle Analysis of the Climate Impact of Electric Vehicle policy for Thailand

Manlika Wichalek

.

ABSTRACT

This study conducts a comprehensive Life Cycle Analysis (LCA) to assess the climate impact of Thailand's Electric Vehicle (EV) policy. As global efforts intensify to address climate change through sustainable mobility, Thailand has actively promoted EV adoption. The analysis covers the full life cycle of EVs—manufacturing, operation, and end-of-life—applying standard LCA methods to quantify greenhouse gas emissions, with a focus on electricity generation sources, battery production, and vehicle assembly. Importantly, the study accounts for both direct and indirect emissions across the supply chain.

Findings reveal that while EVs offer notable reductions in carbon emissions during the use phase, upstream emissions from battery production and fossil fuel-based electricity remain critical concerns. The research highlights both the environmental merits and limitations of Thailand's current EV policy, identifying key areas for improvement in waste management and energy transition. These insights are intended to support policymakers and industry actors in enhancing the environmental sustainability of EV development in Thailand.

본 연구는 태국의 전기차(EV) 정책이 기후변화에 미치는 영향을 종합적 생애주기분석(Life Cycle Analysis, LCA)을 통해 평가하였다. 전 세계적으로 지속가능한 교통수단 도입이 기후변화 대응의 핵심 전략으로 부각되며, 태국 또한 전기차 보급 확대 정책을 적극 추진하고 있다. 이 연구는 전기차의 제조, 운행, 폐기 전 과정을 아우르며, 전력 생산원, 배터리 생산, 차량 조립 과정 등에서 발생하는 온실가스 배출량을 정량적으로 분석하였다. 특히, 운행 중 직접 배출뿐 아니라 공급망 전반의 간접 배출도 함께 고려하였다.

분석 결과, 전기차는 운행 단계에서 탄소 배출 저감에 기여하나, 배터리 생산과 화석연료 기반 전력 사용으로 인한 상류 배출이 여전히 문제로 지적된다. 본 연구는 태국 EV 정책의 환경적 효과와 한계를 함께 조명하며, 배터리 폐기물 관리, 청정에너지 전환 등 개선이 요구되는 정책적 쟁점을 제시한다. 이러한 분석은 전기차 확산의 전반적 기후영향을 이해하고, 향후 지속가능한 교통정책 수립에 실질적인 시사점을 제공한다.

I Introduction

1.1 Global Climate Imperatives and the Role of Electric Vehicles

The escalating urgency of climate change has compelled governments worldwide to reimagine their transportation systems as part of broader decarbonization strategies. Among various measures, the promotion of electric vehicles (EVs) has emerged as a critical pathway toward reducing greenhouse gas (GHG) emissions in the mobility sector. According to the International Energy Agency (IEA), EVs are projected to constitute 7% of the global vehicle fleet by 2030 under current policy trajectories, and up to 12% under more ambitious sustainability-focused scenarios.

In alignment with these global trends, multilateral campaigns such as the Clean Energy Ministerial's "EV30@30" aim to accelerate the uptake of zero-emission vehicles (ZEVs), targeting 30% of new vehicle registrations as ZEVs by 2030. These projections reflect the growing consensus that achieving national and international climate goals requires a fundamental transformation in how transportation systems are powered, managed, and regulated.

In this context, assessing the environmental effectiveness of EV policies is crucial—not only in terms of tailpipe emissions but also across the entire life cycle of vehicle production, use, and disposal. Life Cycle Assessment (LCA) has therefore become a key methodological tool to understand the real climate implications of EV adoption, especially in countries with rapidly expanding EV markets.

1.2. Thailand's EV Policy Response and the Rationale for This Study

Thailand has positioned itself as a regional leader in the transition toward electric mobility. In support of the global "30@30" campaign, the Thai government has launched an ambitious EV policy framework designed to scale up production and domestic adoption of electric vehicles. Key measures include excise tax reductions on EVs, subsidies of up to THB 24 billion for domestic battery manufacturing, and regulatory initiatives to support the conversion of internal combustion engine (ICE) vehicles to electric models. These actions aim to make Thailand a major EV production hub in Southeast Asia.

However, significant concerns remain regarding the true environmental sustainability of this transition. While EVs are often promoted as low-emission alternatives, their full environmental impact depends heavily on upstream factors such as the carbon intensity of the national power grid, the resource- and energy-intensive nature of battery production, and the end-of-life treatment of EV components—particularly batteries. In Thailand, electricity is still predominantly generated from fossil fuels, and there is currently no dedicated regulatory framework for EV battery waste management. These structural limitations raise questions about whether the policy-driven expansion of EVs will lead to meaningful reductions in net GHG emissions.

This study applies a comprehensive Life Cycle Assessment (LCA) approach to evaluate the climate impact of Thailand's EV policy. By accounting for emissions across manufacturing, operation, and end-of-life stages, the research aims to provide a realistic and data-driven perspective on the environmental trade-offs of EV adoption in Thailand. The findings are intended to inform evidence-based policymaking and guide future improvements in the country's mobility transition strategy.

1.3. Research aims

This study aims to assess the environmental implications of Thailand's Electric Vehicle (EV) promotion policy through a comprehensive Life Cycle Assessment (LCA) approach. The specific objectives are as follows 1 and 2

1. To examine the impact of increased vehicle ownership on urban mobility and traffic conditions resulting from the national EV promotion policy;
2. To evaluate the net carbon emissions associated with EV adoption by analyzing emissions across the entire vehicle life cycle—including manufacturing, operation, and end-of-life phases—under the current Thai energy and policy context.

Ⅱ Literature Review

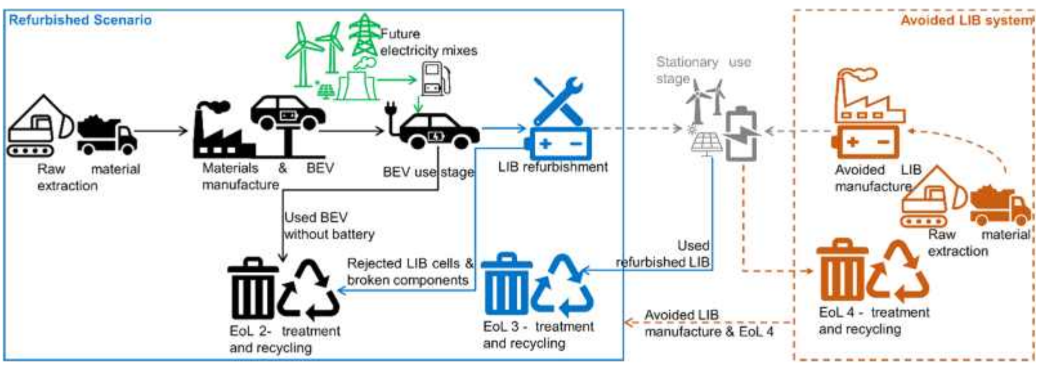
2.1. Life Cycle Assessment (LCA) in EV Environmental Evaluation

Life Cycle Assessment (LCA) has emerged as a widely accepted methodological framework to evaluate the full environmental impact of electric vehicles, encompassing manufacturing, operation, and disposal stages (Hawkins et al., 2013; Ellingsen et al., 2016). Unlike conventional tailpipe-based emission metrics, LCA captures upstream and downstream processes, such as material extraction, electricity generation, and end-of-life treatment, offering a more comprehensive understanding of EV-related emissions. Studies such as Majeau-Bettez et al. (2011) and Nordelöf et al. (2014) emphasize the importance of battery composition and power grid intensity in determining an EV's overall carbon footprint. In the Southeast Asian context, where electricity grids are still largely fossil-fuel dependent, LCA is especially crucial for assessing whether EV adoption actually contributes to net emissions reductions (Khajohnpong et al., 2022).

2.2. Production Phase: Battery and Vehicle Manufacturing

The environmental burden of EVs is disproportionately concentrated in the production phase, especially in battery manufacturing. Battery production is energy-intensive and requires materials such as lithium, cobalt, and nickel, which have high embedded emissions and geopolitical supply constraints (Dunn et al., 2015; Wang et al., 2020). In Thailand, the government has actively supported domestic battery production through tax reductions and subsidies, but few studies have assessed the environmental impact of scaling this industry (Office of the National EV Policy Committee, 2023).

A study by Winyuchakrit et al. (2017) warns that without clean electricity, battery production could negate much of the operational benefits of EVs. Moreover, while vehicle manufacturing in Thailand benefits from existing industrial infrastructure, it still relies on carbon-intensive processes. Recent research also suggests that lightweight materials and modular production techniques could reduce emissions in this stage (Del Pero et al., 2018).



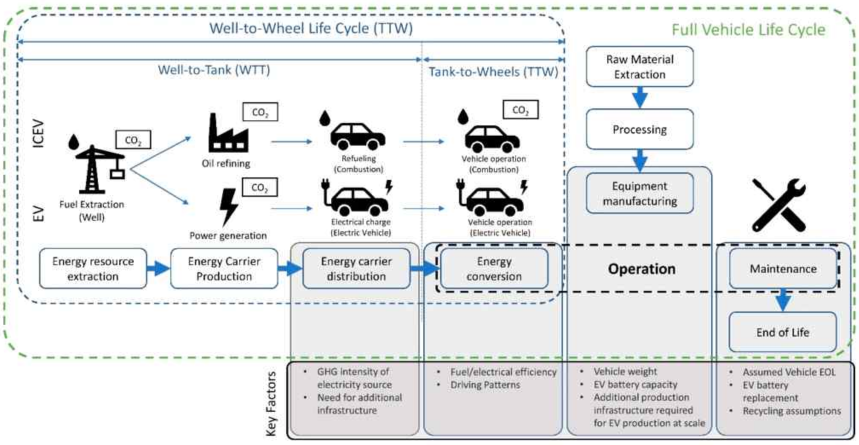
[Figure 1] Battery Manufacturing

As shown in [Fig. 1], the battery manufacturing process entails multiple sub-phases, including material extraction, cell assembly, and module integration. In Thailand, the rapid scaling of battery production—encouraged through government subsidies—raises concerns regarding the embedded carbon emissions and resource intensity of this stage (Dunn et al., 2015; Wang et al., 2020).

2.3. Use Phase: Electricity Generation and Operational Emissions

While EVs produce zero tailpipe emissions, their climate advantage heavily depends on how the electricity used to power them is generated. In Thailand, over 60% of electricity still comes from natural gas and coal (Thailand BUR4, 2023), which significantly offsets the operational benefits of EVs (IEA, 2022). Studies have modeled EV adoption scenarios and found mixed results depending on the decarbonization rate of the national grid (Xie & Fan, 2021).

Furthermore, EV incentives may increase total vehicle ownership rather than replacing existing internal combustion engine vehicles. As shown in studies by Creutzig et al. (2015), this rebound effect can lead to greater congestion and urban energy demand, especially in megacities like Bangkok. This underscores the importance of aligning EV promotion with broader transport demand management policies.



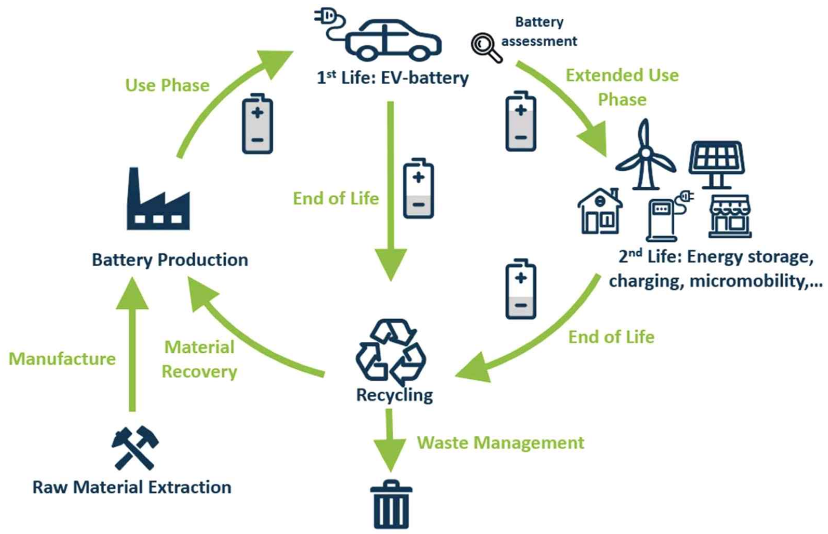
[Figure 2] The CO2 emission from Vehicle In-Use phase

[Fig. 2] contrasts the CO_2 emissions between conventional internal combustion engine vehicles (ICEVs) and battery electric vehicles (BEVs) during the use phase. While BEVs produce no tailpipe emissions, their upstream emissions—mainly from electricity generation—remain significant under Thailand's fossil fuel-based energy mix (Khajohnpong et al., 2022).

2.4. End-of-Life Phase: Battery Waste Management and Circularity

The end-of-life phase is increasingly recognized as a critical dimension of EV sustainability. Battery recycling and reuse present opportunities to recover valuable materials and mitigate toxicity, but infrastructure and regulations in Thailand remain underdeveloped. Currently, EV batteries fall under general e-waste categories governed by the Hazardous Substances Act and the Act on Enhancement and Conservation of National Environmental Quality. However, these frameworks are insufficient for the scale and specificity of EV battery waste (Pongthanaisawan & Sorapipatana, 2013).

Recent policy discussions have proposed the “Act on the Management of Waste Electrical and Electronic Equipment B.E.”, but its implementation is pending. Literature emphasizes that establishing a closed-loop battery economy is essential to realizing the long-term environmental benefits of EVs (Harper et al., 2019; Tsiropoulos et al., 2018).



[Figure 3] The EV Battery circular

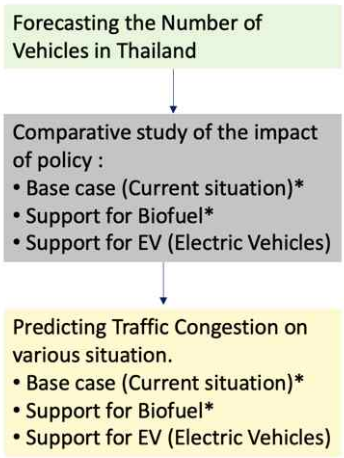
[Fig. 3] illustrates the concept of the EV battery circular economy, highlighting pathways such as second-life use, materials recovery, and recycling. The lack of institutional infrastructure in Thailand to support this circularity underscores the urgency of battery-specific waste regulation (Harper et al., 2019; Tsiropoulos et al., 2018).

Ⅲ Analytical Framework and MethodologyData

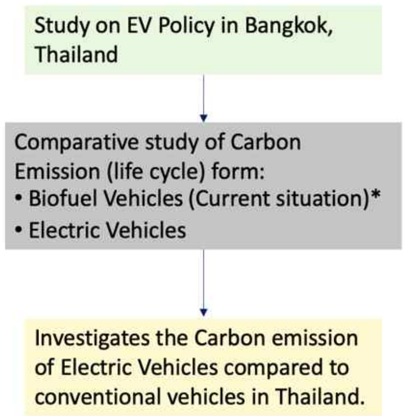
3.1 Overview of the Analytical Approach

To evaluate the environmental effectiveness of Thailand's electric vehicle (EV) policy, this study adopts a dual-method analytical framework. The first stream focuses on forecasting changes in vehicle ownership and urban traffic conditions under different EV policy scenarios. The second stream involves a quantitative assessment of carbon emissions across the life cycle of electric vehicles, conventional internal combustion engine vehicles (ICEVs), and biofuel vehicles. These two components—mobility dynamics and environmental performance—are designed to capture the interconnected effects of EV adoption on urban systems and climate goals.

[Fig. 3] illustrates the research approach for forecasting new vehicle registrations and traffic impacts. [Fig. 4] outlines the life cycle carbon emission model used for comparative analysis.



[Figure 4] Estimation of New Vehicle Registration method



[Figure 5] Carbon Emission method

3.2 Vehicle Registration Forecast and Traffic Impact Model

3.2.1 Forecasting Vehicle Growth under EV Policy

The first component of this study estimates future trends in vehicle ownership in Bangkok, Thailand, from 2017 to 2042, using the Extended Bangkok Urban Area Model (eBUM). The base scenario assumes modest EV expansion, while alternative scenarios integrate policy interventions such as tax incentives, EV conversion programs, and fuel subsidies. These projections allow for evaluating the degree to which EV policy may influence not only the composition of the vehicle fleet but also the total number of vehicles on the road.

3.2.2 Policy Analysis through Documentary and Comparative Research

To inform the model parameters and policy assumptions, extensive documentary research was conducted. Key policy documents—such as the National EV Promotion Plan, Clean Energy Master Plan, and Thailand Power Development Plan (PDP)—were analyzed to assess the evolution of transportation and energy policies relevant to EV adoption. Cross-country comparisons were also made with Indonesia, Malaysia, and Vietnam to understand policy diffusion, technology readiness, and institutional barriers.

3.2.3 Consumer Behavior Analysis

Understanding the demand-side response to EV policy is crucial for accurate forecasting. The study incorporates secondary data on consumer preferences, risk perception, and price sensitivity toward EVs and biofuel vehicles. Behavioral patterns from previous vehicle transitions in Thailand and regional trends were used to refine the adoption rates and substitution scenarios between ICEVs and EVs.

3.3 Carbon Emission Impact Assessment through LCA

3.3.1 Life Cycle Comparison: EV vs. ICEV vs. Biofuel Vehicles

The second methodological component quantifies greenhouse gas (GHG) emissions from different vehicle types using a Life Cycle Assessment (LCA) approach. The system boundary includes vehicle and battery production, infrastructure development, electricity or fuel consumption during use, and end-of-life disposal and recycling. The functional unit is one vehicle over a 15-year lifespan.

The calculation is based on the following formulae:

- Emissions = Activity Data (AD) × Emission Factor (EF), using IPCC 2006 emission coefficients
- Total Emissions = Manufacturing + Use Phase + End-of-Life

For EVs, emissions during the use phase are driven by the electricity grid mix, which is currently dominated by natural gas and coal. For biofuel vehicles, tailpipe and upstream fuel emissions are included. For ICEVs, conventional fuel combustion and maintenance-related emissions are incorporated.

3.3.2 Emissions Scenario Modeling

Scenarios were constructed to compare carbon emissions under the current energy mix (baseline), a modest grid decarbonization trajectory (intermediate), and an accelerated clean energy transition (optimistic). This sensitivity analysis allows for testing the dependency of EV environmental benefits on electricity sector reform.

3.4 Integration of Results for Policy Relevance

By combining vehicle registration forecasts and LCA-based emission estimates, this integrated framework reveals the trade-offs between increased vehicle numbers and emission reductions per unit. For instance, while EVs can reduce per-vehicle emissions, their net climate benefit may be offset if the policy simultaneously stimulates total vehicle ownership or draws electricity from high-carbon sources. The dual-track methodology thus provides critical insights for designing policies that align transport decarbonization with urban mobility sustainability.

IV Research Findings

4.1 Trends in Vehicle Ownership and Mobility Demand

The projection model confirms a steady upward trajectory in vehicle ownership in Thailand, particularly in urban areas such as Bangkok. This increase is driven not only by population growth and urbanization but also by policy-induced incentives that promote both new electric and traditional vehicle acquisitions. While the promotion of EVs is designed to replace internal combustion engine vehicles (ICEVs), the findings suggest a potential "vehicle addition effect" rather than a complete substitution, raising concerns about increasing road congestion, infrastructure burden, and urban energy consumption.

4.2 Energy Efficiency Gains and Emissions Trade-offs

Electric vehicles, by design, offer greater energy efficiency than ICEVs, especially in the use phase. The research reaffirms that, on a per-vehicle basis, EVs result in significantly lower operational energy consumption, thereby contributing to reduced sectoral energy demand. This aligns with global climate objectives and supports Thailand's broader transition towards energy-efficient mobility.

However, the study also reveals a sectoral trade-off: the increasing electrification of transportation shifts the burden of emissions from the tailpipe to the electricity generation sector. Given that over 60% of Thailand's electricity is still sourced from fossil fuels—primarily natural gas and coal the anticipated GHG reductions from EVs may be partially offset by upstream emissions. This highlights the necessity of synchronizing EV adoption with a parallel decarbonization of the national power grid.

4.3 Systemic Implications for Policy Design

The findings underscore the interdependency between transportation and energy sectors. A narrow focus on EV promotion—without corresponding reforms in energy policy and urban planning—risks producing suboptimal environmental outcomes. Moreover, the potential absence of dedicated policy frameworks for battery waste recycling could undermine the long-term sustainability of EV adoption. As such, the study advocates for an integrated systems-based policy approach that simultaneously addresses vehicle emissions, grid decarbonization, and waste lifecycle governance.

V Conclusion

This study confirms that the transition to electric vehicles (EVs) presents a viable and impactful strategy for reducing greenhouse gas (GHG) emissions within Thailand's transportation sector. When analyzed through a life cycle perspective, EVs exhibit lower emissions compared to internal combustion engine vehicles, especially during the operational phase. This strengthens the argument for EV adoption as a cornerstone of sustainable urban mobility policy.

Nevertheless, the analysis also exposes three critical areas of concern that must be addressed to ensure the long-term environmental integrity of EV policies:

1. Electricity Source Dependence

   The extent of EVs' carbon reduction potential is highly contingent upon the carbon intensity of electricity generation. Without significant progress in grid decarbonization, the environmental benefits of EVs will remain constrained.

2. Battery End-of-Life Management

   The lack of a specialized regulatory framework for EV battery disposal and recycling presents a major sustainability challenge. Issues of metal depletion, material toxicity, and unmanaged hazardous waste require urgent institutional responses.

3. Policy-Induced Demand Effects

   If EV policies stimulate additional vehicle purchases rather than substitution, there may be unintended consequences such as increased traffic congestion, land use pressure, and elevated aggregate energy demand—undermining urban sustainability goals.

In conclusion, while EVs offer a promising pathway for climate mitigation, their sustainability must be secured through a holistic strategy encompassing:

- Clean energy transition in the power sector;
- Circular economy policies for battery reuse and recycling;
- Integrated transportation and land-use planning to manage vehicle demand.

These insights are especially relevant for policymakers and planners seeking to implement environmentally responsible EV strategies not only in Thailand but also in other rapidly motorizing emerging economies.

References:

1. Creutzig, F., Jochem, P., Edelenbosch, O. Y., Mattauch, L., van Vuuren, D. P., McCollum, D., & Edenhofer, O. (2015). Transport: A roadblock to climate change mitigation? Science, 350(6263), 911-912. https://doi.org/10.1126/science.aac8033
2. Del Pero, F., Delogu, M., & Bonoli, A. (2018). Life cycle assessment in the automotive sector: A comparative case study of Internal Combustion Engine (ICE) and electric vehicle. Journal of Cleaner Production, 190, 463-473. https://doi.org/10.1016/j.jclepro.2018.04.150
3. Dunn, J. B., Gaines, L., Sullivan, J., & Wang, M. Q. (2015). Impact of recycling on cradle-to-gate energy consumption and greenhouse gas emissions of automotive lithium-ion batteries. Environmental Science & Technology, 49(17), 11226-11233. https://doi.org/10.1021/acs.est.5b00899
4. Ellingsen, L. A. W., Singh, B., & Strømman, A. H. (2016). The size and range effect: Lifecycle greenhouse gas emissions of electric vehicles. Environmental Research Letters, 11(5), 054010. https://doi.org/10.1088/1748-9326/11/5/054010
5. Harper, G., Sommerville, R., Kendrick, E., Driscoll, L., Slater, P., Stolkin, R., ... & Anderson, P. (2019). Recycling lithium-ion batteries from electric vehicles. Nature, 575(7781), 75-86. https://doi.org/10.1038/s41586-019-1682-5
6. Hawkins, T. R., Singh, B., Majeau-Bettez, G., & Strømman, A. H. (2013). Comparative environmental life cycle assessment of conventional and electric vehicles. Journal of Industrial Ecology, 17(1), 53-64. https://doi.org/10.1111/j.1530-9290.2012.00532.x
7. International Energy Agency. (2022). Global EV Outlook 2022: Securing supplies for an electric future. https://www.iea.org/reports/global-ev-outlook-2022
8. Khajohnpong, S., Phuangphol, S., & Sutthirat, C. (2022). Evaluating carbon emissions from electric vehicles under Thailand's electricity mix. Energy Reports, 8, 11891-11901. https://doi.org/10.1016/j.egyr.2022.09.020
9. Majeau-Bettez, G., Hawkins, T. R., & Strømman, A. H. (2011). Life cycle environmental assessment of lithium-ion and nickel metal hydride batteries for plug-in hybrid and battery electric vehicles. Environmental Science & Technology, 45(10), 4548-4554. https://doi.org/10.1021/es103607c
10. Nordelöf, A., Romare, M., & Tivander, J. (2014). Life cycle assessment of electric vehicles - a framework to support decision making. IVL Swedish Environmental Research Institute. https://www.ivl.se/download/18.343dc99d14e8bb0f58b51f/1445515719595/B2138.pdf
11. Office of Natural Resources and Environmental Policy and Planning. (2023). Thailand's Fourth Biennial Update Report (BUR4). https://climate.onep.go.th/wp-content/uploads/2023/01/Thailand_BUR4_A4_final_revised_24022023-compressed-1.pdf
12. Office of the National Electric Vehicle Policy Committee. (2023). National EV Promotion Plan Summary (in Thai). Retrieved from https://www.evsp.or.th/
13. Pongthanaisawan, J., & Sorapipatana, C. (2013). Sustainable transportation planning and role of electrical vehicles in Thailand. Energy Policy, 61, 597-607. https://doi.org/10.1016/j.enpol.2013.06.004
14. Tsiropoulos, I., Tarvydas, D., & Lebedeva, N. (2018). Li-ion batteries for mobility and stationary storage applications - Scenarios for costs and market growth. European Commission

Joint Research Centre. https://doi.org/10.2760/87175
15. Wang, Y., Sun, X., Zhang, C., & Li, C. (2020). Environmental implications of lithium−ion battery recycling in China: The impact of the recycling process and energy mix. Journal of Environmental Management, 260, 110124. https://doi.org/10.1016/j.jenvman.2019.110124
16. Winyuchakrit, P., Sukamongkol, Y., & Limmeechokchai, B. (2017). Do electric vehicles really reduce GHG emissions in Thailand? Energy Procedia, 138, 397-402. https://doi.org/10.1016/j.egypro.2017.10.143
17. Xie, Y., & Fan, Y. (2021). Carbon mitigation potential of electric vehicles in developing countries: A case study of Thailand. Environmental Science and Pollution Research, 28(2), 2073-2085. https://doi.org/10.1007/s11356−020−10584−5