SPMS
Spatial Planning & Management Science
SPMS 2(1): 50–63
ISSN 3088-9669

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Research trends on electric vehicle battery policy (2019-2024) a bibliometric analysis and implications for Indonesia

David Febraldo Panjaitan[1]*, Raldi Hendro Koestoer [1]
[1] *School of Environmental Science, Central Jakarta, 10430, Indonesia*
*Correspondence: david.febraldo@ui.ac.id

Received Date: January 19, 2025 Revised Date: February 15, 2025 Accepted Date: February 28, 2025

ABSTRACT

Background: The global transition to electric vehicles (EVs) is driven by the need to reduce greenhouse gas emissions and achieve sustainable transportation. Battery policies play a crucial role in shaping the EV market by influencing technology development, infrastructure, and regulatory frameworks. **Methods**: This study conducts a bibliometric analysis of EV battery policy research from 2019 to 2024, focusing on global trends and implications for Indonesia. Data was extracted from the Scopus database and analyzed using VOSviewer to identify research clusters, keyword trends, and geographic distribution. **Findings:** reveal that research is dominated by China, the United States, and the European Union, while Indonesia's policy framework remains underdeveloped. Infrastructure challenges, regulatory gaps, and sustainability concerns hinder EV adoption. **Conclusion**: strengthening policy alignment, investing in charging networks, and promoting public-private collaboration are critical for Indonesia's EV industry. **Novelty of this article:** The novelty aspect refers to this paper is that no prior research has conducted a bibliometric analysis using the keyword "Electric Vehicle Battery Policy" and compared the resulting papers with their implications in Indonesia.

KEYWORDS: electric vehicle; battery policy; bibliometric analysis; sustainability; Indonesia

1. Introduction

The global automotive industry is undergoing a profound transformation as electric vehicles (EVs) emerge as a key solution to mitigate greenhouse gas emissions and address climate change (Kurani, 2019). Many nations have enacted policies to encourage EV adoption, ranging from regulatory mandates to economic incentives (Hidayah et al., 2024). Battery policies are a critical component of this transition, influencing research, development, and the deployment of cleaner technologies. Solid-state batteries are emerging as a promising alternative due to their higher energy density and improved safety (Bindra, 2020). In addition, bibliometric analyses have shown a surge in EV battery research, with studies identifying key technological trends and policy implications (Veza et al., 2024).

A notable shift has occurred in the global automotive landscape, with countries like China and the European Union implementing aggressive EV mandates (Ou et al., 2021). Meanwhile, Indonesia, with its abundant nickel reserves, has the potential to be a key player

Cite This Article:
Panjaitan, D., & Koestoer, R. H. (2025). Research trends on electric vehicle battery policy (2019-2024) a bibliometric analysis and implications for Indonesia. *Spatial Planning & Management Science, 2*(1), 50-63. https://doi.org/10.61511/spms.v2i1.2025.1776

in the global EV supply chain (Yusgiantoro et al., 2021). The country's government has implemented policies to accelerate EV adoption, yet challenges remain in policy execution and infrastructure development (Maghfiroh et al., 2021). Indonesia's strategic position in the EV industry is underscored by its government's commitment to industrial development. The nickel export ban was intended to encourage domestic battery production, attracting foreign investors (Pandyaswargo et al., 2021). However, while industrial policies have been enacted, the adoption of EVs among consumers remains slow due to high costs and limited charging infrastructure (Utami et al., 2020).

The development of industrial clusters, such as the Morowali Industrial Park, exemplifies Indonesia's commitment to building a robust EV battery ecosystem. These clusters serve as catalysts for regional economic growth and technological advancement (Siahaan et al., 2021). Despite government incentives, Indonesia's EV adoption lags behind other ASEAN countries, highlighting the need for stronger policy frameworks and public awareness campaigns (Wiratmoko et al., 2023). To further propel the EV revolution, the Indonesian government has enacted regulatory measures and incentives aimed at promoting domestic manufacturing and market adoption (Yuniza et al., 2021). Despite these efforts, significant challenges remain in harmonizing Indonesia's EV battery policies with global sustainability standards (Haryadi et al., 2024). Addressing these challenges is vital to ensure that rapid industrialization does not compromise ecological and community well-being.

Emerging bibliometric techniques, particularly those utilizing tools like VOSviewer, have proven effective in mapping research trends and identifying critical knowledge gaps within the EV battery field (Veza et al., 2024). Such insights are invaluable for both academic inquiry and policy formulation. This study aims to conduct a bibliometric analysis of research trends on EV battery policies from 2019 to 2024, with a special focus on the implications for Indonesia, thereby integrating advanced bibliometric methods with policy analysis (Chen, 2024). Ultimately, the findings will contribute to more effective policy design that leverages Indonesia's natural resources while ensuring sustainable growth in the EV sector.

2. Methods

The bibliometric data for this study was obtained exclusively from the Scopus database, which is renowned for its extensive coverage of peer-reviewed literature. To ensure the relevance of our dataset to the environmental dimensions of electric vehicle research, we applied a subject area filter limited to Environmental Science (Wang, Lin, & Zhang, 2020). The search strategy was developed by combining key terms using Boolean operators; specifically, the following query was used:

> TITLE-ABS-KEY (electric AND vehicle AND battery AND policy) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (EXACTKEYWORD , "Transportation Sector")) AND (LIMIT-TO (SUBJAREA , "ENVI"))

The search was limited to publications from 2019 to 2024. This approach ensured that only the most current and pertinent research within the transportation sector was captured. The retrieved records were then carefully screened to eliminate duplicates and non-relevant articles. Metadata—including titles, abstracts, author affiliations, keywords, and references—were exported in CSV format for subsequent analysis (Hidayah *et al*., 2024). The screening process involved manual verification to maintain the integrity of the dataset and ensure that the focus remained on the intersection of electric vehicle battery policies and transportation within an environmental context.

Following data collection, the bibliometric information was imported into VOSviewer—a software tool widely recognized for constructing and visualizing bibliometric networks (Gao & Qiu, 2018). Within VOSviewer, the data was processed to

generate network maps that illustrate co-authorship, keyword co-occurrence, and citation relationships among the selected studies. This step was crucial for revealing the structural patterns and research clusters that characterize the literature on electric vehicle battery policies.

Once the network maps were generated, various analytical parameters were adjusted to optimize visualization. Co-occurrence analysis of keywords provided insights into predominant research themes and emerging trends, while co-authorship and citation analyses helped identify influential researchers and core publications in the field. These analyses were conducted in line with best practices in bibliometric research, ensuring that the resultant maps accurately represented the intellectual structure of the literature.

The insights gained from VOSviewer were then synthesized to address the study's objectives. By integrating the refined bibliometric data with visual analyses, the study offers a comprehensive overview of how research on electric vehicle battery policies has evolved, particularly within the environmental and transportation sectors. This robust methodological framework, leveraging the Scopus database and VOSviewer, provides a solid foundation for understanding current trends and informing future policy development.

3. Results and Discussion

3.1 Sub-section headings

This paper presents three visualization results generated using VOSviewer, each offering distinct insights into the research landscape on electric vehicle battery policies within the transportation sector. These visualizations include a network map, an overlay map, and a density map, each highlighting different aspects of keyword relationships, temporal research trends, and research concentration. Together, these results provide a comprehensive understanding of how research on electric vehicle policies has evolved and where future studies may be directed.

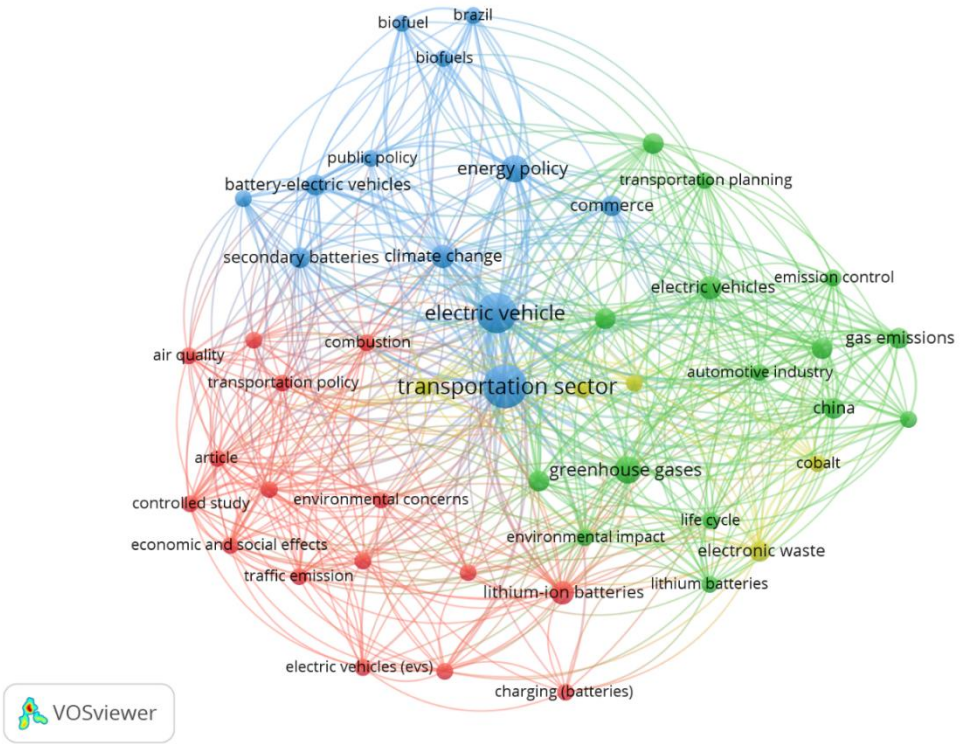

Fig. 1. Network visualization result

Figure 1 presents a VOSviewer-generated network map illustrating the interconnections among key terms in EV research within the transportation sector. Three primary clusters green, red, and blue, along with a smaller but significant yellow cluster, represent distinct yet interrelated thematic focuses. At the core of the network, *electric vehicle* and *transportation sector* serve as central nodes, linking various aspects of research, from policy and environmental concerns to battery technology and industrial development.

The green cluster emphasizes policy and environmental dimensions, centering on topics such as *climate change*, *greenhouse gases*, and *gas emissions*, which underscore the role of regulatory frameworks in advancing EV adoption. The presence of terms such as *transportation planning* and *commerce* suggests that policy discussions extend beyond emission reductions to include broader socio-economic implications. The interlinkages within this cluster highlight the importance of government intervention, emission control strategies, and market mechanisms in shaping the transition to EVs.

In contrast, the red cluster focuses on economic analysis, infrastructure concerns, and public acceptance. Terms such as *transportation policy*, *economic and social effects*, and *traffic emission* indicate that research in this area primarily addresses the financial feasibility of EV adoption and its societal impacts. The strong link between *air quality* and *environmental concerns* suggests that while EV policies aim to reduce emissions, their success is often evaluated in the context of improving public health and urban air quality. The inclusion of *controlled study* and *article* suggests that this cluster is heavily supported by empirical research assessing the effectiveness of EV policies and their impact on stakeholders.

The blue cluster revolves around industrial development, energy sources, and public policy, with terms such as *battery-electric vehicles*, *energy policy*, and *public policy* serving as key focal points. The connection between *biofuels*, *battery technology*, and *climate change* suggests that research in this domain is exploring alternative energy solutions and hybrid approaches to reduce carbon footprints. Notably, the presence of *Brazil* within this cluster indicates that specific case studies or regional policies are contributing to the global discourse on EV adoption and energy diversification.

The yellow cluster, while smaller, plays a critical role in bridging discussions on sustainability, battery technology, and industrial supply chains. Key terms such as *lithium batteries*, *electronic waste*, *cobalt*, and *life cycle* highlight growing concerns about resource dependency, battery disposal, and the environmental impact of EV production. The strong connection between *China*, *automotive industry*, and *emission control* underscores the country's leading role in global EV battery manufacturing and regulatory approaches. Additionally, the linkage between *gas emissions* and *life cycle* indicates that research is increasingly focused on assessing the net environmental benefits of EV adoption, particularly in relation to the sustainability of raw material extraction and end-of-life battery management.

Overall, this network visualization demonstrates the complexity of EV research and the multifaceted challenges associated with transitioning to sustainable transportation. The dense linkages among clusters indicate that EV research is inherently interdisciplinary, encompassing policy frameworks, economic viability, technological advancements, and environmental considerations. The integration of policy-oriented discussions (blue cluster), sustainability concerns (green cluster), market-driven factors (red cluster), and battery supply chain issues (yellow cluster) underscores the need for holistic approaches to EV adoption.

Figure 2 presents a VOSviewer-generated network visualization of research trends on electric vehicles (EVs) and transportation policy, incorporating a time-based overlay. The color gradient, ranging from blue (earlier research, around 2021) to yellow (more recent research, around 2023), provides insights into the temporal evolution of key research topics and thematic developments within the field. At the core of the network, electric vehicle and transportation sector remain central nodes, indicating their fundamental role in the discourse. These terms are highly interconnected, bridging policy, environmental concerns, economic impacts, and technological advancements. The color variation within the core

suggests that while EVs have been a focal point of research since 2021, new aspects of the discussions such as gas emissions, automotive industry, and transportation planning—have gained prominence in more recent studies (highlighted in yellow).

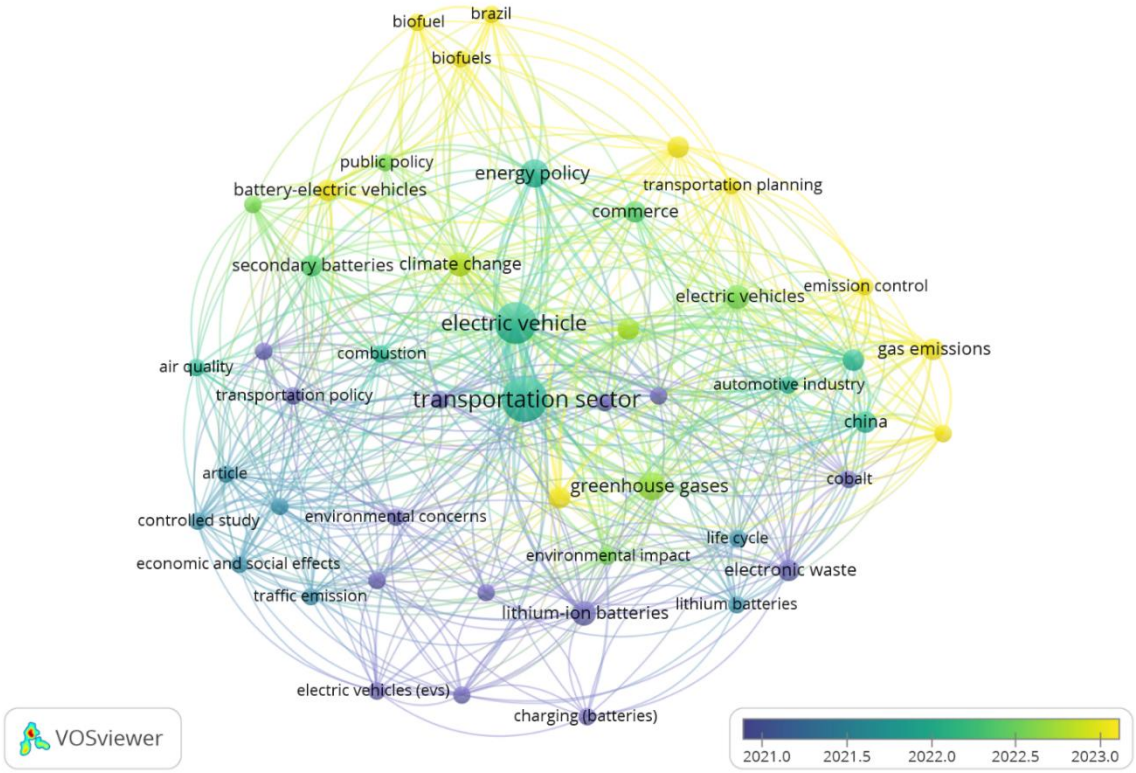

Fig. 2. Overlay visualization result

The yellow-colored nodes, representing research areas that have emerged or gained momentum in 2023, predominantly cluster around policy and industrial development. Terms such as energy policy, commerce, transportation planning, and gas emissions indicate that recent studies have focused on regulatory frameworks, economic integration, and emission reduction strategies. The strong presence of China within this cluster underscores the country's increasing role in EV market expansion and industrial policy. Additionally, the emphasis on cobalt and electronic waste highlights growing concerns over supply chain sustainability and battery material recycling.

In contrast, blue and purple-colored nodes, concentrated in the lower left region, signify research themes that were more dominant around 2021. These include environmental concerns, traffic emissions, and economic and social effects, suggesting that earlier studies were more focused on evaluating the broader societal and ecological impacts of EV adoption. The terms controlled study and article further indicate that empirical assessments were central to early research efforts, likely aiming to establish baseline evaluations of policy effectiveness.

The green-colored cluster, which represents research conducted primarily between late 2021 and early 2022, focuses on battery technology and its environmental implications. Key terms such as lithium-ion batteries, life cycle, and environmental impact suggest that during this period, there was an increasing interest in assessing the long-term sustainability of EV batteries. The connection between greenhouse gases and secondary batteries indicates a shift in focus toward improving battery efficiency as a means of reducing overall emissions. A notable pattern in this visualization is the dynamic interplay between policy-oriented discussions (upper section) and technology-driven themes (lower section). The transition from blue to yellow across clusters suggests that while early studies focused on environmental impact assessments and battery efficiency, recent research has shifted toward policy design, market implementation, and industrial regulation. This evolution

underscores the growing recognition that effective EV deployment requires an integrated approach, balancing technological advancements with supportive policies and sustainable supply chain management.

Overall, network visualization illustrates the progression of EV research, highlighting the field's shift from foundational environmental assessments (2021) toward more policy-driven and industry-focused studies (2023). The findings suggest that future research will likely continue to explore regulatory mechanisms, economic incentives, and resource sustainability as the EV sector matures and expands globally.

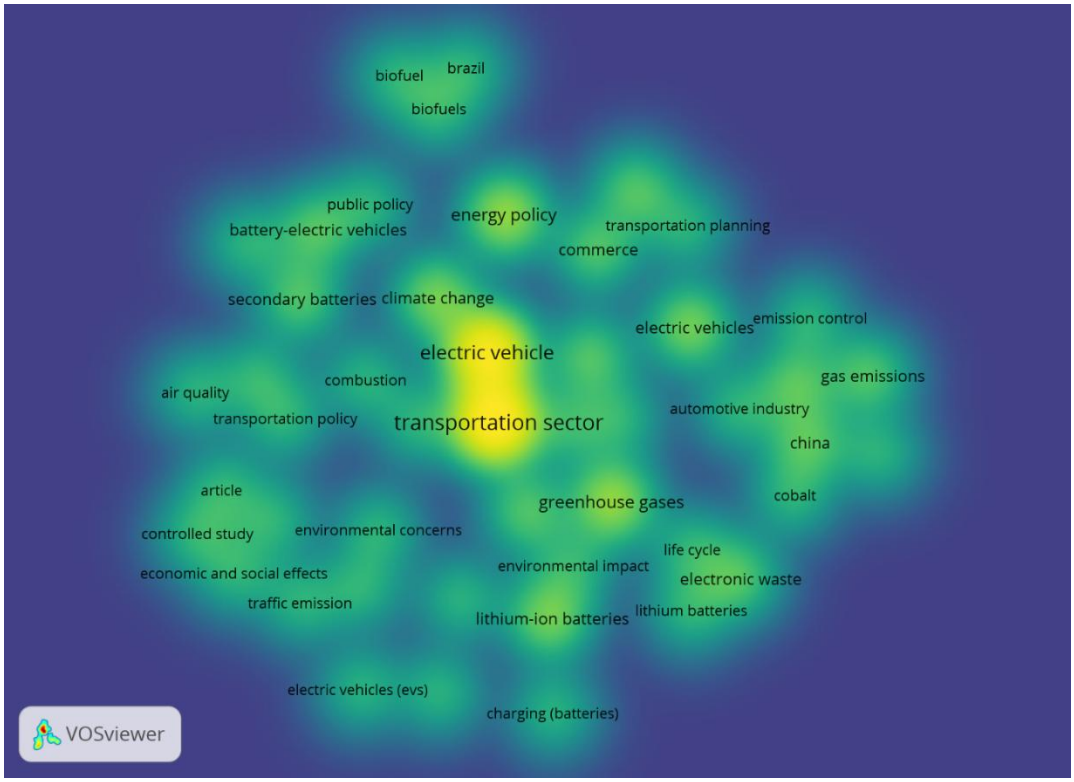

Fig. 3. Density Visualization Result

Figure 3 presents a density visualization of research trends on electric vehicles (EVs) and transportation policies, generated using VOSviewer. The heatmap-style visualization indicates the concentration of research interest across various topics, with bright yellow areas representing high research density and darker blue regions signifying lower research intensity. At the core of the network, electric vehicle and transportation sector exhibit the highest research density, highlighted in bright yellow. This suggests that these topics serve as focal points within the literature, receiving the greatest scholarly attention. Their central positioning indicates their integrative role in connecting different research domains, including policy discussions, environmental impact assessments, and battery technology advancements.

Surrounding the core, greenhouse gases, energy policy, and transportation policy form a secondary layer of research density. The prominence of greenhouse gases and emission control reinforces the fact that EV adoption is primarily studied within the context of emission reduction and climate change mitigation. Additionally, energy policy and public policy suggest an increasing focus on regulatory frameworks and government interventions to promote EV adoption. The presence of biofuels and battery-electric vehicles in this moderately dense area indicates ongoing discussions about alternative energy sources and technological competition.

Further from the core, lithium-ion batteries, electronic waste, and life cycle are located in less densely researched areas, represented in green. This suggests that while sustainability concerns related to battery materials and recycling are recognized, they

remain secondary compared to policy and emissions-related discussions. The inclusion of China, automotive industry, and cobalt within this zone indicates emerging research interest in supply chain dynamics and resource dependency, but at a relatively lower density than central topics.

In contrast, the periphery of the network, where topics such as air quality, controlled study, and economic and social effects reside, is characterized by lower research intensity (darker blue areas). This suggests that while these themes are present in literature, they are not primary areas of focus. The limited research on economic and social effects may highlight a gap in studies exploring the socio-economic implications of EV adoption, pointing to potential future research opportunities.

In research on EVs within the transportation sector, various studies have employed bibliometric approaches using software such as VOSviewer to analyze research trends, battery policies, and factors influencing EV adoption. This study can be compared with other bibliometric analyses to gain a broader understanding of the evolving landscape of EV research. A study by Veza et al. (2024) examines EV research trends using a comprehensive bibliometric approach, covering EV policies, lithium-ion batteries, battery management, charging infrastructure, and smart charging concepts. Their findings highlight that, in addition to policy and technological aspects, the integration of EVs with the power grid (V2X) has become a key focus of recent research.

Shang et al. (2024) investigated the large-scale environmental impact of EV adoption in China using a Life Cycle Assessment (LCA) approach. Their study emphasizes the carbon emissions associated with EV life cycles and explores how transportation policies can contribute to reducing the overall carbon footprint. Poolsawat et al. (2024) conducted a cost-benefit analysis of transitioning from conventional vehicles to EVs in Thailand. Their findings shed light on the economic and social aspects of EV adoption while also assessing the implications for transportation infrastructure. Almeida Neves et al. (2020) applied a Data Envelopment Analysis (DEA) model to evaluate the technical efficiency of EV deployment across European Union countries. Their study reveals that disparities in policy frameworks and infrastructure readiness significantly impact the success of EV adoption across different nations.

Sommer and Vance (2021) analyzed the correlation between the availability of charging stations and the adoption rate of EVs in Germany. Their study demonstrates a direct relationship between improvements in charging infrastructure and the growth of EV adoption. Hsieh et al. (2020) explored the impact of EV adoption in China on motorization rates and the battery market. Their findings reinforce the role of regulations and subsidies as key drivers in accelerating the expansion of the EV market. Yang et al. (2021) conducted a comparative study on the environmental and economic performance of EVs versus conventional vehicles in the United States. Their research highlights temporal shifts in the economic impacts and carbon emissions associated with EV adoption. The previous VOSviewer analysis consisted of 13 journals identified from the Scopus database using predefined filters. The following is the list of these 13 journals.

Table 1. List of paper from scopus database

No	Title	Authors	Source	Country	Year
1	Cost-benefit analysis for transitioning Thailand passenger cars to electric drives	Poolsawat K.; Wongsapai W.; Achariyaviriya W.; Tachajapong W.; Mona Y.; Wanison R.; Thawon I.; Suttakul P.	Journal of Energy Systems	Thailand	2024
2	Life cycle assessment of atmospheric environmental impact on the large-scale promotion of electric vehicles in China	Shang H.; Sun Y.; Huang D.; Meng F.	Resources, Environment and Sustainability	China	2024

3	Deployment planning tool for environmentally sensitive heavy-duty vehicles and fueling infrastructure	Lane B.; Kinnon M.M.; Shaffer B.; Samuelsen S.	Energy Policy	United States	2022
4	Temporal environmental and economic performance of electric vehicle and conventional vehicle: A comparative study on their US operations	Yang F.; Xie Y.; Deng Y.; Yuan C.	Resources, Conservation and Recycling	United States, China	2021
5	Two-stage DEA model to evaluate technical efficiency on deployment of battery electric vehicles in the EU countries	Almeida Neves S.; Cardoso Marques A.; Moutinho V.	Transportation Research Part Transport and Environment	Portugal	2020
6	The impacts of critical metal shortage on China's electric vehicle industry development and countermeasure policies	Liu B.; Zhang Q.; Liu J.; Hao Y.; Tang Y.; Li Y.	Energy	China	2022
7	Transition to electric vehicles in China: Implications for private motorization rate and battery market	Hsieh I.-Y.L.; Pan M.S.; Green W.H.	Energy Policy	United States	2020
8	Drivers and barriers of electric vehicle usage in Malaysia: A DEMATEL approach	Asadi S.; Nilashi M.; Iranmanesh M.; Ghobakhloo M.; Samad S.; Alghamdi A.; Almulihi A.; Mohd S.	Resources, Conservation and Recycling	Malaysia,Lithuania, Australia, Saudi Arabia	2022
9	Refurbished and Repower: Second Life of Batteries from Electric Vehicles for Stationary Application	Sanghai B.; Sharma D.; Baidya K.; Raja M.	SAE Technical Papers	India	2019
10	Do more chargers mean more electric cars?	Sommer S.; Vance C.	Environmental Research Letters	Germany	2021
11	Brazilian light vehicle fleet decarbonization scenarios for 2050	Glyniadakis S.; Balestieri J.A.P.	Energy Policy	Brazil	2023
12	Feasibility Analysis of Solar Energy and Role of Lithium-Ion Battery Reserved in Electric Vehicle Market: A Path Towards Green Transportation	Amir M.; Ansari A.R.; Khan M.A.; Kaur J.; Bakhsh F.I.; Khosla A.	Strategic Planning for Energy and the Environment	Australia, India	2024
13	Energy transition scenarios in the transportation sector in Brazil: Contributions from the electrical mobility	Grangeia C.; Santos L.; Ferreira D.V.; Guimarães R.; de Magalhães Ozorio L.; Tavares A.	Energy Policy	Brazil	2023

Based on the listed papers, the visualization of the countries can be seen in the following figure. The geographic distribution of the referenced studies, as illustrated in Figure 4, highlights the involvement of various countries in the analyzed literature. The United States and China are the most frequently cited countries, indicating their significant contribution to the research landscape. These countries, represented in red, likely dominate due to their extensive academic output and investment in research. Additionally, countries such as India, Thailand, and Australia (highlighted in yellow) are also present, although with a lower frequency. This suggests a growing participation of emerging economies in the academic discourse related to the studied topic. Countries represented in green, including some European and Asian nations, indicate a more limited presence in the selected studies.

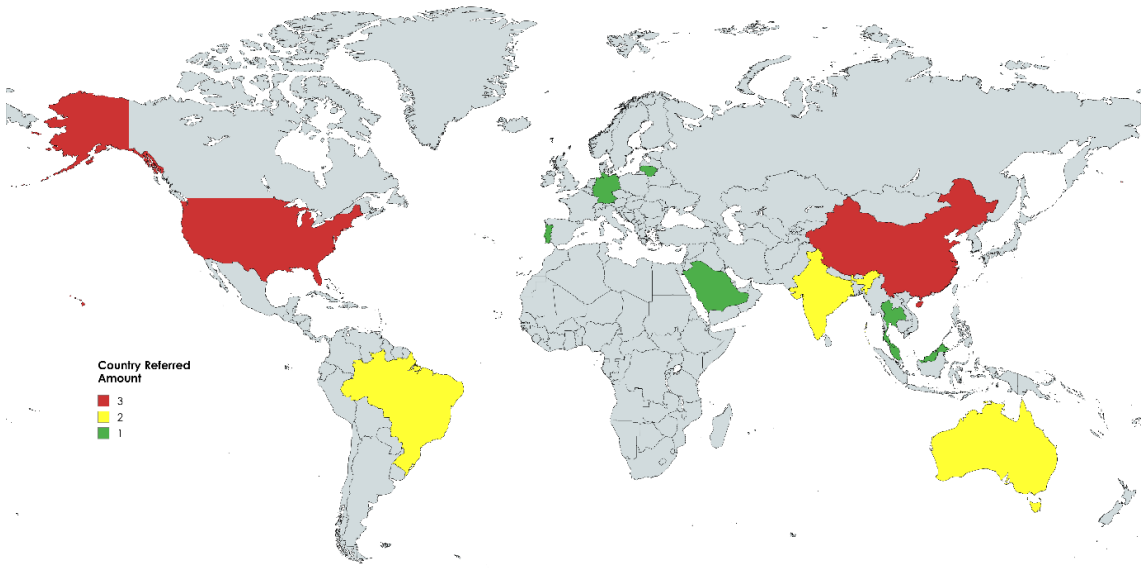

Fig. 4. Geographic Paper Distribution

The dominance of developed countries such as the United States and China suggests that research in this field is primarily driven by institutions with strong academic infrastructures and funding capabilities. However, the presence of developing nations highlights the increasing relevance of global collaboration and the diversification of research contributions. This geographic distribution provides insights into the global research landscape, emphasizing the need for broader representation. Future research may benefit from incorporating perspectives from underrepresented regions to enhance the comprehensiveness of findings and promote inclusive academic collaboration.

3.2 Implication for Indonesia

The bibliometric analysis of electric vehicle (EV) battery policies highlights several critical implications for Indonesia as it seeks to establish itself as a key player in the global EV supply chain. With abundant nickel reserves, Indonesia holds a strategic advantage in battery production, yet challenges remain in aligning its policies with international standards (Pandyaswargo et al., 2021). The dominance of research from China, the United States, and the European Union underscores the need for Indonesia to enhance its regulatory framework, particularly in battery sustainability, recycling, and life-cycle management (Apriliana & Hutami, 2021). Without strong policy alignment, Indonesia risks falling behind in the rapidly evolving global EV landscape.

One of the primary challenges facing Indonesia is its underdeveloped EV infrastructure, particularly in terms of charging networks and grid readiness. Lessons from leading EV markets suggest that substantial government intervention is necessary to accelerate infrastructure expansion and incentivize private-sector participation (Wiratmoko et al., 2023). Without a well-established charging ecosystem, consumer

adoption will remain slow, despite the presence of policy incentives (Hidayah et al., 2024). In parallel, Indonesia must prioritize investment in research and development (R&D) to drive battery innovation, reducing reliance on foreign technology and strengthening its role in the international EV industry (Suherman et al., 2021).

Public awareness and market incentives are also crucial factors influencing EV adoption. Global case studies indicate that financial incentives, such as tax reductions and purchase subsidies, have played a significant role in increasing EV uptake (Yuniza et al., 2021). Indonesia must implement similar measures while addressing consumer concerns regarding vehicle affordability, battery longevity, and maintenance costs (Utami et al., 2020). Additionally, policies should focus on sustainable resource management, ensuring that nickel mining and battery production adhere to environmental best practices (Pandyaswargo et al., 2021). The long-term success of Indonesia's EV industry will depend on balancing economic growth with ecological sustainability (Saputra & Andajani, 2023).

Key lessons from global EV policy trends highlight the importance of a holistic and integrated approach. Countries that have successfully transitioned to EVs have adopted comprehensive policies that interconnect transportation, energy, and environmental sectors (Khairani dan Nurcahyo, 2023). Indonesia must follow a similar approach, ensuring that its policies not only encourage EV adoption but also support the broader ecosystem, including charging infrastructure, energy supply, and emissions control. Furthermore, government-led initiatives have been instrumental in driving market growth in countries like China. By implementing strong incentives and regulatory mandates, Indonesia can create a conducive environment for EV development (Hidayah et al., 2024).

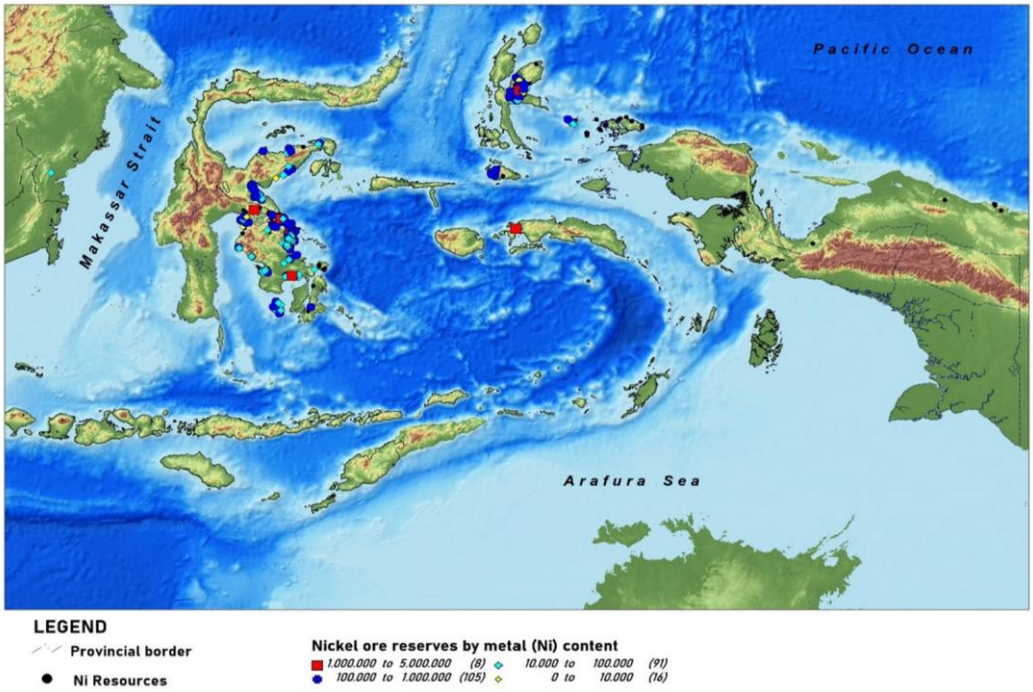

Fig. 5. Map of the distribution of Indonesia's Nickel Resources and Reserves (Sunuhadi *et al*., 2024)

Public-private collaboration is another crucial aspect of EV industry expansion. Many successful EV markets have benefited from partnerships between governments, private companies, and academic institutions (Budiono & Virgianita, 2024). Encouraging investment in charging stations, battery recycling programs, and energy-efficient grids will be essential for Indonesia's long-term success. Additionally, sustainability must be a core principle of Indonesia's EV strategy. As concerns over resource depletion and electronic waste grow, adopting a circular economy model for battery reuse and recycling will be critical to ensuring environmental responsibility (Apriliana & Hutami, 2021).

Indonesia holds one of the world's largest nickel reserves, primarily concentrated in Sulawesi and Maluku. As shown in the map, the highest nickel metal content is found in Southeast Sulawesi, Central Sulawesi, and North Maluku. With the government's policy to ban raw nickel exports, efforts are being directed toward downstream industrialization, particularly in the production of battery materials for EVs. Given the increasing global demand for EV batteries, Indonesia's abundant nickel resources position the country as a crucial player in the international supply chain.

Despite this potential, several challenges hinder Indonesia's ability to fully capitalize on its nickel reserves for EV battery production. A key issue is infrastructure readiness, as many nickel-rich regions lack the industrial facilities necessary for large-scale processing and refining. The development of smelters and sustainable nickel processing technologies requires significant investment, both from the public and private sectors. Additionally, logistical constraints in remote areas contribute to high production costs, reducing Indonesia's competitiveness against countries with more advanced industrial ecosystems, such as China and Australia.

Environmental sustainability also remains a pressing concern. Nickel mining and processing have substantial ecological impacts, including deforestation, soil degradation, and water pollution. Without strict environmental policies, the rapid expansion of the nickel industry could lead to long-term ecological damage, undermining Indonesia's commitment to sustainable industrialization. Therefore, the government must enforce stringent environmental standards and invest in cleaner extraction technologies to minimize adverse impacts.

Finally, Indonesia's approach to EV adoption must consider localized solutions tailored to its diverse economic and geographical conditions. Unlike uniform policy models seen in some developed countries, Indonesia must develop region-specific strategies that address urban-rural disparities and varying levels of energy accessibility (Ramadhan & Khoirunurrofik, 2024). Targeted policies will ensure that EV adoption benefits a broader segment of the population, fostering inclusive and sustainable growth.

4. Conclusions

The bibliometric analysis of EV battery policies from 2019 to 2024 reveals significant global research trends and critical implications for Indonesia's sustainable transportation development. The findings indicate that while developed nations such as China, the United States, and the European Union dominate research and policy innovations in EV battery technology, Indonesia holds considerable potential due to its abundant nickel resources and growing industrial base. However, challenges persist in policy alignment, infrastructure readiness, consumer adoption, and environmental sustainability. The study highlights the necessity for Indonesia to integrate international best practices into its EV policies, particularly in battery sustainability, recycling, and life-cycle management. Moreover, investment in research and development, the expansion of charging infrastructure, and the implementation of strong regulatory frameworks are crucial for accelerating the transition toward widespread EV adoption. The study also underscores the importance of public-private partnerships in enhancing Indonesia's EV ecosystem, emphasizing the need for incentives to stimulate market growth. Furthermore, localized policy approaches tailored to the country's diverse geographic and socio-economic conditions will be instrumental in ensuring equitable EV adoption.

Acknowledgement

The authors would like to express our gratitude to School of Environmental Science Universitas Indonesia and people who helps in this study.

Author Contribution
The authors solely contributed to the study's conception, design, data collection, analysis, and manuscript preparation. The author was responsible for drafting, reviewing, and approving the final version of the manuscript for publication.

Funding
This research received no external funding.

Ethical Review Board Statement
Not available.

Informed Consent Statement
Not available

Data Availability Statement
Not available

Conflicts of Interest
The authors declare no conflict of interest.

References
Almeida Neves, S., Cardoso Marques, A., & Moutinho, V. (2020). Two-stage DEA model to evaluate technical efficiency on deployment of battery electric vehicles in the EU countries. *Transportation Research Part D: Transport and Environment, 86*, 102497. https://doi.org/10.1016/j.trd.2020.102489

Amir, M., Ansari, A. R., Khan, M. A., Kaur, J., Bakhsh, F. I., & Khosla, A. (2024). Feasibility analysis of solar energy and role of lithium-ion battery reserved in electric vehicle market: A path towards green transportation. *Strategic Planning for Energy and the Environment, 43*(1), 5–23. https://scispace.com/papers/feasibility-analysis-of-solar-energy-and-role-of-lithium-ion-1a5eyj6vew

Apriliana, G. M. C., & Hutami, W. P. (2021). Indonesian Electric Vehicle Policy, Realization and Development.

Asadi, S., Nilashi, M., Iranmanesh, M., Ghobakhloo, M., Samad, S., Alghamdi, A., Almulihi, A., & Mohd, S. (2022). Drivers and barriers of electric vehicle usage in Malaysia: A DEMATEL approach. *Resources, Conservation and Recycling, 177*, 105965. https://doi.org/10.1016/j.resconrec.2021.105965

Bindra, A. (2020). Electric vehicle batteries eye solid-state technology: Prototypes promise lower cost, faster charging, and greater safety. *IEEE Power Electronics Magazine, 7*(1), 16-19. https://doi.org/10.1109/MPEL.2019.2961203

Budiono, B., & Virgianita, A. (2024). Indonesia's Movement to Become the Main Player in The Electric Vehicle (EV) Market in Southeast Asia. *Asian Journal of Engineering, Social and Health, 3*(4). /https://ajesh.ph/index.php/gp/issue/view/20

Chen, C. (2024). Analysis and forecast of electric vehicle sales in the United States with comparative studies. *Highlights in Business, Economics and Management.* https://doi.org/10.54097/wmjfhk57

Glyniadakis, S., & Balestieri, J. A. P. (2023). Brazilian light vehicle fleet decarbonization scenarios for 2050. *Energy Policy, 172*, 113308. https://doi.org/10.1016/j.enpol.2023.113682

Grangeia, C., Santos, L., Ferreira, D. V., Guimarães, R., de Magalhães Ozorio, L., & Tavares, A. (2023). Energy transition scenarios in the transportation sector in Brazil: Contributions from the electrical mobility. *Energy Policy, 169*, 113182. https://doi.org/10.1016/j.enpol.2023.113434

Haryadi, H., Suseno, T., Herlina, U., Nurjaman, F., Prasetyo, E., Handoko, A. S., Okfarina, S., & Susanti, D. (2024). SWOT analysis (strengths, weaknesses, opportunities, threats) of nickel to reach global electric battery market in Indonesia. *Mineral Processing and Extractive Metallurgy, 133*(1), 21-32. https://doi.org/10.1177/08827508231225025

Hidayah, N., Rusdiana, A., & Sadat, A. M. (2024). Measuring the effectiveness of subsidy policies in increasing electric vehicle sales in Indonesia: A study based on sales data of all brands and statistical methods. *International Student Conference on Business, Education, Economics, Accounting, and Management (ISC-BEAM).* https://doi.org/10.21009/isc-beam.012.112

Hsieh, I.-Y. L., Pan, M. S., & Green, W. H. (2020). Transition to electric vehicles in China: Implications for private motorization rate and battery market. *Energy Policy, 144*, 111682. https://doi.org/10.1016/j.enpol.2020.111654

Khairani, A., & Nurcahyo, R. (2023). Study on Electric Vehicle Policy in Indonesia. In *Proceedings of the First Australian International Conference on Industrial Engineering and Operations Management* (pp. 1878-1884). https://index.ieomsociety.org/index.cfm/article/view/ID/12216

Kurani, K. (2019). The state of electric vehicle markets, 2017: Growth faces an attention gap. *University of California.* https://doi.org/10.7922/G2D50K51

Lane, B., Kinnon, M. M., Shaffer, B., & Samuelsen, S. (2022). Deployment planning tool for environmentally sensitive heavy-duty vehicles and fueling infrastructure. *Energy Policy, 162*, 112780. https://doi.org/10.1016/j.enpol.2022.113289

Liu, B., Zhang, Q., Liu, J., Hao, Y., Tang, Y., & Li, Y. (2022). The impacts of critical metal shortage on China's electric vehicle industry development and countermeasure policies. *Energy, 239*, 122280. https://doi.org/10.1016/j.apcatb.2020.119008

Maghfiroh, M., Pandyaswargo, A. H., & Onoda, H. (2021). Current readiness status of electric vehicles in Indonesia: Multistakeholder perceptions. *Sustainability, 13*(23), 13177. https://doi.org/10.3390/su132313177

Ou, S., Yu, R., Lin, Z., He, X., Bouchard, J., & Przesmitzki, S. (2021). Evaluating China's passenger vehicle market under the vehicle policies of 2021–2023. *World Electric Vehicle Journal, 12*(2), 72. https://doi.org/10.3390/WEVJ12020072

Pandyaswargo, A. H., Wibowo, A. D., Maghfiroh, M., Rezqita, A., & Onoda, H. (2021). The Emerging Electric Vehicle and Battery Industry in Indonesia. *Batteries, 7*(4). https://doi.org/10.3390/batteries7040080

Poolsawat, K., Wongsapai, W., Achariyaviriya, W., Tachajapong, W., Mona, Y., Wanison, R., Thawon, I., & Suttakul, P. (2024). Cost-benefit analysis for transitioning Thailand's passenger cars to electric drives. *Journal of Energy Systems, 8*(4), 207–220. http://dx.doi.org/10.30521/jes.1524048

Ramadhan, R. G., & Khoirunurrofik, K. (2024). Does The BBN KB Incentive Policy Increase Ownership Of Battery-Based Electric Vehicles? Indonesia Case Study. *Jurnal Ekonomi Teknologi dan Bisnis (JETBIS), 3*(2), 691-706. https://dx.doi.org/10.57185/jetbis.v3i2.84

Sanghai, B., Sharma, D., Baidya, K., & Raja, M. (2019). Refurbished and repower: Second life of batteries from electric vehicles for stationary application. *SAE Technical Papers, 2019-28-0111.* https://doi.org/10.4271/2019-26-0156

Saputra, M. C., & Andajani, E. (2023). Analysis of Factors Influencing Intention to Adopt Battery Electric Vehicle in Indonesia. *ADI Journal on Recent Innovation (AJRI), 5*(1). https://repository.ubaya.ac.id/44765/1/jurnal-ajri-muhammad-candra-saputra

Shang, H., Sun, Y., Huang, D., & Meng, F. (2024). Life cycle assessment of atmospheric environmental impact on the large-scale promotion of electric vehicles in China. *Resources, Environment and Sustainability, 10*, 100148. https://doi.org/10.1016/j.resenv.2024.100148

Sommer, S., & Vance, C. (2021). Do more chargers mean more electric cars? *Environmental Research Letters, 16*(7), 074031. https://iopscience.iop.org/article/10.1088/1748-9326/ac05f0

Sunuhadi, D. N., Ernowo, Hilman, P. M., & Suseno, T. (2024). Availability of Indonesian nickel reserves and efforts to improve reserves resistance and its impact to economic growth. *Mineral Economics, 1*-17. https://doi.org/10.1007/s13563-024-00443-0

Utami, M. W. D., Yuniaristanto, Y., & Sutopo, W. (2020). Adoption intention model of electric vehicle in Indonesia. *Jurnal Sistem dan Manajemen Industri, 19*(1), 70-81. https://doi.org/10.25077/josi.v19.n1.p70-81.2020

Veza, I., Syaifuddin, M., Idris, M., Herawan, S., Yusuf, A. A., & Fattah, I. (2024). Electric vehicle (EV) review: Bibliometric analysis of electric vehicle trend, policy, lithium-ion battery, battery management, charging infrastructure, smart charging, and electric vehicle-to-everything (V2X). *Energies.* https://doi.org/10.3390/en17153786

Yang, F., Xie, Y., Deng, Y., & Yuan, C. (2021). Temporal environmental and economic performance of electric vehicle and conventional vehicle: A comparative study on their US operations. *Resources, Conservation and Recycling, 174*, 105762. https://doi.org/10.1016/j.resconrec.2020.105311

Yuniza, M. E., Pratama, I., & Ramadhaniati, R. C. (2021). Indonesia's incentive policies on electric vehicles: The questionable effort from the government. *International Journal of Energy Economics and Policy.* https://doi.org/10.32479/ijeep.11453

Yusgiantoro, L. A., Hanan, A., Sunariyanto, B. P., & Swastika, M. B. (2021). Mapping Indonesia's EV potential in the global EV supply chain. *Bulletin of Renewable Energy, 4*(1). https://doi.org/10.33116/br.004

Biographies of Authors

David Febraldo Panjaitan, School of Environmental Science, Central Jakarta, 10430, Indonesia

- Email: david.febraldo@ui.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Raldi Hendro Koestoer, School of Environmental Science, Central Jakarta, 10430, Indonesia

- Email: raldy.hk@ui.ac.id
- ORCID: 0000-0003-1701-0419
- Web of Science ResearcherID: N/A
- Scopus Author ID: 57418579200
- Homepage: N/A