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Managing the Energy Transition for Sustainable Land Transportation in Indonesia: A Systematic Review of Policy and Socio-Economic Implications for Road and Rail

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Abstract: Managing the energy transition in the land transport sector is a critical managerial challenge for achieving Indonesia's 2060 Net Zero Emission target. This study aims to identify, synthesize, and evaluate global green energy policies, and to formulate their policy and socio-economic implications for Indonesia's road and railway sectors. A Systematic Literature Review (SLR) methodology, based on the PRISMA 2020 protocol and CASP quality appraisal, was applied to 35 relevant studies published between 2015 and 2025. Thematic analysis identified three primary policy pillars: (1) economic incentives, (2) regulatory mandates, and (3) infrastructure development. This review concludes that effective transition management requires an adaptive hybrid policy framework. The novelty of this research is an evidence-based synthesis that recommends a a multi-modal approach considering socio-economic impacts, prioritizing electrification for light-duty and urban transport while utilizing biofuels for heavy-duty freight and long-haul logistics.

Keywords: Energy Transition, Policy, Road and Railway Transportation, Systematic Review

INTRODUCTION

The global commitment to climate change mitigation, solidified by the Paris Agreement, mandates that nations decarbonize key economic sectors. For Indonesia, achieving its Net Zero Emissions (NZE) target by 2060 places a strategic imperative upon transforming the transportation sector, which contributes approximately 27% of the nation's total energy-related CO_2 emissions (Republic of Indonesia, 2021). Within this, the land transport subsector—encompassing both road and railway transportation—is the largest contributor, making its

transition to a sustainable, low-carbon system a critical managerial and policy challenge (Bakker et al., 2017).

A brief review of existing literature shows that nations worldwide have implemented a range of policies to promote green energy adoption, including fiscal incentives, regulatory mandates, and infrastructure investments (Gallo & Marinelli, 2020). However, most research is heavily skewed toward developed nations, whose market conditions and socio-economic structures differ substantially from those in developing countries like Indonesia (Emodi et al., 2022). This geographical skew creates a significant knowledge gap: while many individual case studies exist, a comprehensive synthesis that systematically translates the global policy spectrum into actionable, socio-economically relevant implications for Indonesia is lacking.

The primary reason for this research is to bridge this identified gap by providing an evidence-based roadmap for policymakers and managers in Indonesia. The study's novelty lies in its use of a rigorous Systematic Literature Review to connect global best practices with the nation's unique socio-economic context. To achieve this, the research is guided by three primary research questions: (1) What are the dominant typologies of green energy policies implemented globally in the road and railway sectors? (2) What are the key socio-economic and managerial factors influencing their success? (3) What are the most relevant policy implications for managing an equitable and effective energy transition in Indonesia's land transport sector? To analyze the complex dynamics inherent in these questions, this study is theoretically informed by the field of sustainability transitions research, which provides a framework for understanding the multi-level interactions between technological innovations, existing policy regimes, and the broader socio-economic landscape (Köhler et al., 2019).

METHOD

This research adopts A Systematic Literature Review (SLR) methodology to ensure a rigorous, transparent, and replicable synthesis of existing knowledge. This approach was chosen to comprehensively identify, critically evaluate, and integrate all relevant research evidence, thereby enabling the formulation of robust, evidence-based conclusions that are free from selection bias.

Review Protocol and Timeframe

The entire review process was strictly guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 framework (Page et al., 2021). All stages of this desk-based study, from the initial literature search to the final data analysis, were conducted in October 2025. The study's timeframe for included literature (2015–2025) is strongly justified, commencing from the year of the Paris Agreement, which served as a primary catalyst for global decarbonization policies.

Data Sources and Search Strategy

To ensure comprehensive literature coverage, a systematic search was performed across three major academic databases: Scopus, ScienceDirect, and Google Scholar. The search strategy utilized a Boolean-based query string designed to maximize both sensitivity and specificity. The core search query was structured as follows and adapted to the syntax of each database:

("green energy" OR "renewable energy" OR "electric vehicle*" OR "biofuel*") AND ("transport* policy" OR "decarbonization strategy" OR "low-carbon transition") AND ("road transport" OR "railway*" OR "land transport")

Study Selection Criteria

The article screening process was guided by a set of specific and *a priori* inclusion and exclusion criteria. These criteria, detailed in Table 1, were structured thematically to ensure each selection dimension was clearly defined and consistently applied.

Table 1. Study Selection Criteria Framework and Justification

Criteria Dimension	Specific Criteria Applied	Rationale / Justification
Publication Boundaries	• **Period:** Published between **January 1, 2015, and December 31, 2025**.	• **Period:** To capture relevant literature published after the Paris Agreement, which marked a key inflection point for global decarbonization policy.
	• **Type:** Peer-reviewed journal articles or high-reputation technical reports (e.g., IEA, IRENA).	• **Type:** To ensure the validity, reliability, and quality of the synthesized evidence base.
	• **Language:** Written in English or Indonesian.	• **Language:** To align with the linguistic capabilities of the research team.
Thematic Scope	• **Intervention:** The study must explicitly focus on green energy **policies, strategies, or implementation** (e.g., EVs, biofuels, hydrogen).	• To ensure all included studies are directly relevant to the established research questions and to maintain a well-defined and manageable scope.
	• **Context:** The study must be centered on the **land transport sector** (road and/or railway). Studies focused on maritime/aviation transport or purely technical engineering aspects without policy analysis were excluded.	
Outcome Focus	• **Content:** The study must present an **analysis of the policy's outcomes**, such as its impacts, challenges, success factors, or effectiveness. Purely descriptive articles without a clear analytical component were excluded.	• To ensure that the synthesis is based on empirical or analytical evidence, thereby enabling the formulation of strong, evidence-based implications.

Source: Author's elaboration (2025)

Study Selection and Data Extraction

The study selection process followed the four-stage PRISMA protocol, as detailed in Figure 1. The initial search yielded 1,286 records, which were imported into Mendeley reference management software for deduplication, leaving 998 records for screening. A two-stage screening process was then independently conducted by two researchers to mitigate subjectivity. In the first stage, 928 records were excluded based on title and abstract screening, primarily for not meeting the thematic relevance criterion (IC2). This left 70 articles for full-text review. In the second stage, the full texts were assessed for eligibility, resulting in the exclusion of a further 35 articles for reasons such as irrelevant context (EC2; n=15) or a non-analytical scope (EC3; n=12). This rigorous process yielded a final sample of 35 studies. Data from each included study were then extracted into a standardized form, capturing: study identity, geographical focus, study design, policy instruments, key findings, and novelty contribution

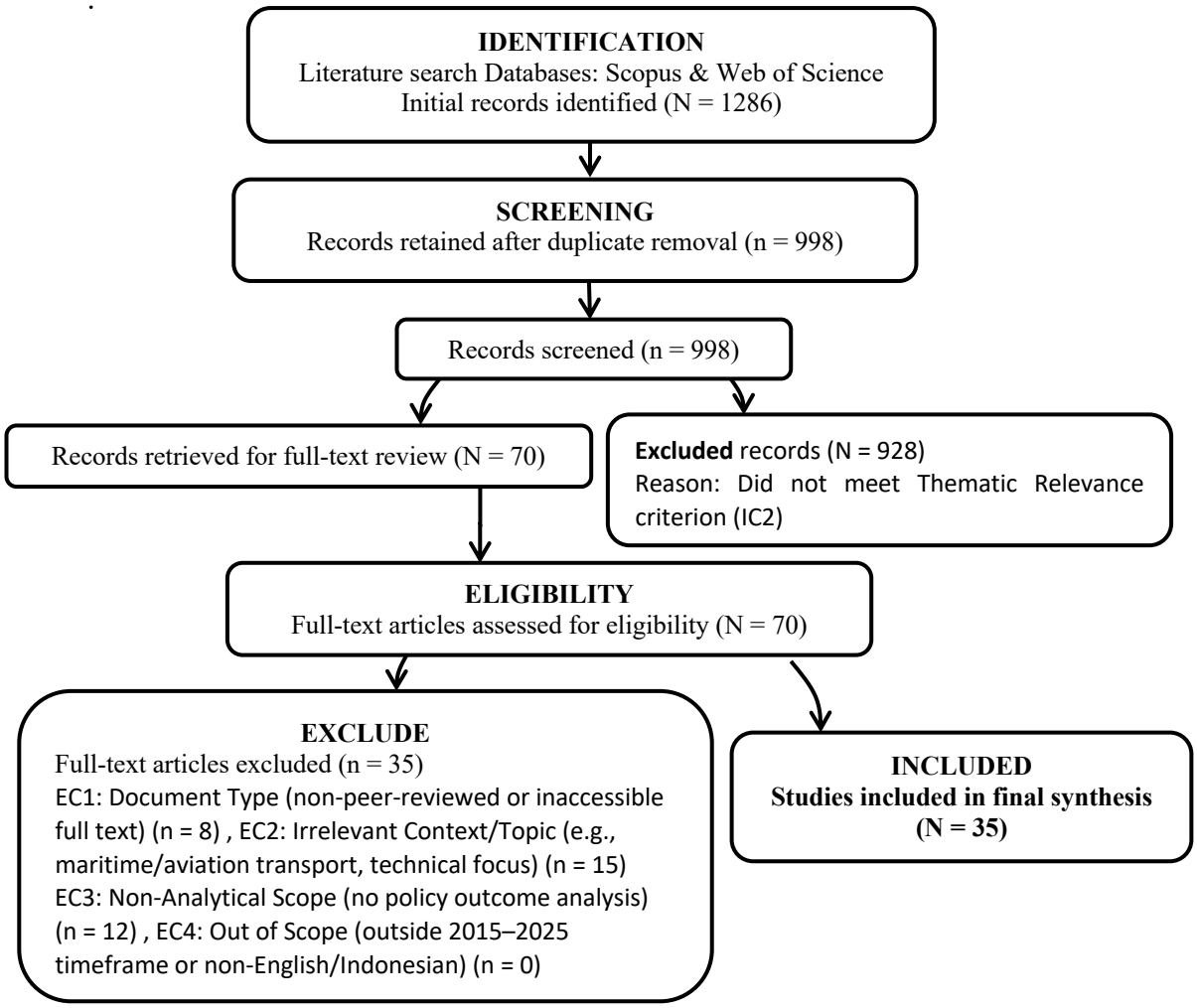
Data Analysis: Quality Appraisal and Thematic Synthesis.

The data analysis was conducted in two interconnected phases. The first phase consisted of a critical appraisal of each of the 35 included studies using the CASP Systematic Review Checklist (CASP, 2018) to formally evaluate its methodological validity and risk of bias. The second phase involved a thematic synthesis, which rigorously followed the six-phase

procedural framework outlined by Braun & Clarke (2006). During this synthesis, findings from the various studies—contextualized by their quality appraisal scores—were systematically coded and grouped into recurrent themes. These themes were then narratively synthesized to construct policy typologies, identify key determinant factors, and formulate actionable implications that directly answer the study's research questions.

RESULTS AND DISCUSSION

The systematic literature selection process, guided by the PRISMA 2020 protocol, culminated in a final sample of 35 studies deemed eligible for in-depth analysis. This comprehensive filtering procedure, which began with an initial pool of 1,286 records, is visually detailed in the flow diagram presented in Figure 1.

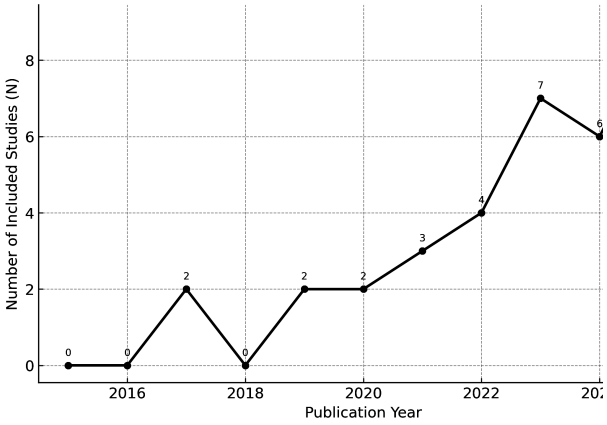


Source: Adapted from Page et al. (2021)

Figure 1. PRISMA 2020 Flow Diagram for Study Selection

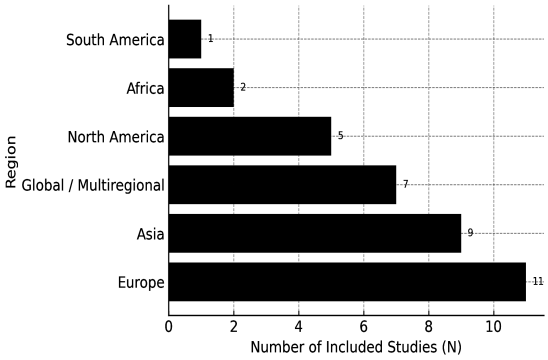
Characteristics and Quality of Included Studies

The temporal distribution of the 35 included studies, shown in Figure 2, indicates a marked increase in research attention on this topic, particularly in the years following 2020, which aligns with the global acceleration of climate commitments. Furthermore, the geographical distribution, illustrated in Figure 3, reveals a significant scholarly focus on Europe and Asia. In contrast, research explicitly centered on developing countries, especially in regions like Africa and South America, remains limited, thereby reinforcing the relevance and necessity of this study's focus on Indonesia.



Source: Author's analysis (2025)

Figure 2. Publication Trend of Included Studies by Year (2015–2025)



Source: Author's analysis (2025)

Figure 3. Geographical Distribution of the Reviewed Studies (N=35)

The methodological, focal, and novelty characteristics of each study are detailed in **Table 2**. The analysis highlights a rich diversity in study designs, from broad systematic reviews (e.g., Emodi et al., 2022) to focused empirical case studies (e.g., Hasibuan & Mulyani, 2022) providing a multi-faceted evidence base for the subsequent thematic synthesis.

Table 2. Methodological, Focal, and Novelty Characteristics of Reviewed Studies (N=35)

No.	Study (Author & Year)	Research Method, Geographical Focus & Scope	Primary Focus	Novelty Contribution
1	(Ammenberg & Dahlgren, 2021)	Method Development (Europe: Sweden) Scope: Methodological Framework	Multi-criteria sustainability assessment for various bus technologies.	Developed a new Multi-Criteria Analysis (MCA) method for sustainable public bus procurement.
2	(Bakker et al., 2017)	Comparative Case Study (Asia: ASEAN) Scope: N=4 cases (Nations)	Low-carbon transport policies in Indonesia, Philippines, Thailand, and Vietnam.	Direct comparison of policy approaches across four key ASEAN nations.
3	(Emodi et al., 2022)	Systematic Literature Review (Global South) Scope: N=62 studies reviewed	Decarbonization strategies for the transport sector, including challenges and cost-effective options.	The first comprehensive synthesis on transport decarbonization specifically for the Global South.
4	(Gallo & Marinelli, 2020)	Narrative Review (Global/Multiregional) Scope: ~100+ sources cited	Classification and review of actions and policies for sustainable mobility.	A holistic framework categorizing policies into environmental, socio-economic, and technological pillars.
5	(Halder et al., 2024)	Critical Review (Global/Multiregional) Scope: N=85 sources reviewed	Performance, emissions, and economic feasibility analysis of hydrogen fuel cell vehicles.	Integration of lifecycle cost and impact analysis with a technical performance review.
6	(Hasibuan & Mulyani, 2022)	Case Study (Asia: Indonesia) Scope: N=1 case (Longitudinal, 8 years)	Transit-Oriented Development (TOD) implementation and commuter behavior	A longitudinal study comparing land use and travel behavior changes over an eight-year period.

			around urban rail stations.	
7	Hidayat & Choocharukul (2023)	Comparative Case Study (Asia: Thailand & Indonesia) Scope: N=2 cases (Cities)	Analysis of public transport usage intentions during the COVID-19 pandemic.	Direct comparison of psychological and service-related factors in two major ASEAN cities.
8	(Huu & Ngoc, 2021)	Analytical Study (Asia: Vietnam) Scope: National-level data analysis	Review of the urban transportation status and the potential transition to electric motorcycles.	Analysis of mobility transition within the context of a motorcycle-dominant society.
9	(Ibrahim et al., 2023)	Systematic Literature Review (Developing Countries) Scope: N=78 studies reviewed	Analysis of sustainable power source mixes for developing economies.	Focuses on the dilemma between inadequate power supply and fossil fuel dependency.
10	(Jannesar Niri et al., 2024)	Literature Review (Global/Multiregional) Scope: N=110+ sources reviewed	Analysis of sustainability challenges across the entire electric vehicle battery value chain.	A holistic review from mineral extraction to end-of-life battery recycling.
11	(Kamran et al., 2023)	Systematic Literature Review (Global) Scope: N=55 studies reviewed	Identification of critical elements required for a successful energy transition.	Focuses on the supply risk of critical raw materials (minerals, metals) for clean energy tech.
12	(Kenworthy, 2017)	Comparative Data Analysis (7 Cities) Scope: N=7 cases (Cities, 20-year data)	Investigates whether automobile dependence is an inevitable trend in emerging cities.	Empirical evidence showing physical limits to mass motorization over a 20-year period.
13	(Leuthold et al., 2025)	Systematic Literature Review (Global) Scope: N=153 publications reviewed	Identification of implementation factors for green hydrogen projects (including for rail).	Synthesis of techno-economic, socio-political, and site-specific resource factors.
14	(Liu et al., 2025)	Systematic Literature Review (Global) Scope: N=60+ LCA studies reviewed	Lifecycle assessment (LCA) analysis of hydrogen mobility and identification of research gaps.	Proposes a novel "surface-level" LCA framework for hydrogen systems.
15	(Mamat et al., 2025)	Multi-Dimensional Review (Global) Scope: N=100+ sources reviewed	A strategic framework for overcoming barriers in the renewable energy transition.	Proposes an integrated framework connecting innovation, governance, and equity.
16	(Mhana et al., 2024)	Literature Review (Global) Scope: N=85 studies evaluated	The use of remote sensing and satellite data for sustainable urban road planning.	Synthesis of modern geospatial applications in transportation infrastructure planning.
17	(Moeen et al., 2025)	Systematic Literature Review (Global & Pakistan) Scope: PRISMA-based review	A review of global practices in integrated energy planning for energy security and the Paris Agreement.	Identifies gaps in Pakistan's energy planning related to its climate targets.

18	(Momodu et al., 2022)	Systematic Literature Review (Sub-Saharan Africa) Scope: N=21 studies reviewed	Analyzes the decarbonization process in the electricity sector as a form of climate action.	Focuses on the technological and political economy aspects of decarbonization in an African context.
19	(Nassary et al., 2025)	Systematic Literature Review (Developing Countries) Scope: SPAR-4-SLR methodology	Analysis of opportunities and challenges in the clean energy transition for developing countries.	Utilizes a specific SLR protocol (SPAR-4-SLR) to analyze technological, financial, and governance aspects.
20	(Nevzorova & Kutcherov, 2019)	State-of-the-Art Review (Global) Scope: Multi-database review	Identification of barriers to the implementation of biogas as an energy source.	Systematic classification of barriers into six distinct categories (technical, economic, etc.).
21	(Nikulina et al., 2019)	Systematic Literature Review (Global) Scope: N=90+ documents analyzed	Context-adapted urban planning for the transition of personal mobility.	Integration of three literature fields: mobility, urban planning, and transitions.
22	(Riera et al., 2023)	Review (Global) Scope: N/A (Modeling focus)	Modeling and optimization of hydrogen production and supply chains.	Identifies future research topics in hydrogen system modeling.
23	(Riyadi et al., 2023)	Review (Global) Scope: Experimental & numerical studies	Analysis of the prospects and challenges of using biodiesel for HCCI engines (including locomotives).	Specific focus on the synergy between biofuels (biodiesel) and HCCI engine technology.
24	(Rizki et al., 2021)	Case Study (Asia: Indonesia) Scope: N=400+ survey respondents	Analysis of tourist preferences for electric vehicles and estimation of CO_2 reduction.	Use of a stated choice experiment to target the tourist segment for EV adoption.
25	(Samarasinghe et al., 2025)	Systematic Review (Global) Scope: N=30 modeling tools analyzed	A review of modeling tools for net-zero emission energy systems.	A comprehensive technical review and comparison of 30 existing energy modeling tools.
26	(Sandaka & Kumar, 2023)	Critical Review (Global) Scope: Comparative analysis	Analysis of challenges in using electricity, hydrogen, and biofuels as vehicular fuels.	A direct, side-by-side comparison of challenges across three major alternative fuel pathways.
27	(Sarda et al., 2024)	Comprehensive Review (Global) Scope: Multi-thematic review	Analysis of EV charging technology, its impact on the grid, and associated policies.	Integration of the technical aspects of charging with policy consequences and grid management.
28	(Satpathy et al., 2025)	Multi-Dimensional Review (Global) Scope: Structured comparative methods	Technological innovations and sustainable strategies for EV performance and market integration.	Use of structured comparative methods (SWOT, maturity mapping) to assess EV technologies.
29	(Sunanda et al., 2025)	SLR & Bibliometric Analysis (Asia: Indonesia)	Analysis of the carbon pricing framework in Indonesia.	The first multi-dimensional mapping of carbon pricing

		Scope: N=65 studies analyzed		literature in Indonesia.
30	(Tilly et al., 2024)	PRISMA Review (Global) Scope: N=50+ studies reviewed	Identification of externalities (unintended side effects) of electric vehicle adoption.	Focus on negative social side effects (e.g., inequity, job displacement) of EV adoption.
31	(Vakulchuk et al., 2020)	Literature Review (Global) Scope: N=100+ publications analyzed	Analysis of the relationship between renewable energy and geopolitics.	Provides a critique and a theoretical framework for the geopolitical study of renewable energy.
32	(Widiawati et al., 2025)	PRISMA Systematic Review (Global) Scope: Empirical-based literature	Circularity potentials, influencing factors, and policies for the EV supply chain.	Identifies the circularity potential of specific EV components via an optimized waste hierarchy.
33	(Aliyu Yaro et al., 2022)	Systematic & Scientometric Review (Global) Scope: 2009-2022 publications	Circular economy prospects of palm oil waste for the asphalt pavement industry.	Combination of an SLR with VOSviewer analysis to identify specific research gaps.
34	(Zhu et al., 2023)	Bibliometric Analysis (Global) Scope: Web of Science data	Situation and hotspot analysis of rural transport infrastructure.	Use of CiteSpace and VOSviewer to map research trends and intellectual structure.
35	(Zufarihsan et al., 2025)	Comprehensive Review (Asia: Indonesia) Scope: N=1 case (HSR Project)	Recent developments in high-speed rail construction and infrastructure in Indonesia.	The first in-depth technical case study of the Jakarta-Bandung HSR project.

Source: Author's analysis (2025)

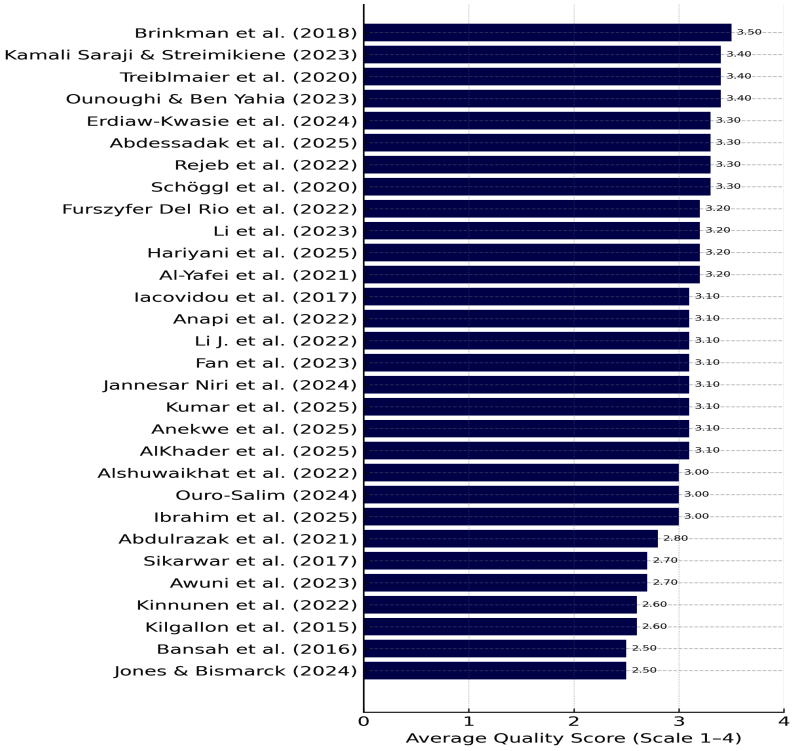
To ensure the reliability of this synthesis, a critical appraisal of each study was conducted using the CASP checklist. The results, summarized in **Table 3**, affirm that the analyzed literature possesses a strong methodological foundation. A significant majority of the studies (28 studies, or 80.0%) were classified as **High** quality. The absence of low-quality studies indicates that the evidence base for this review is robust. The specific quality score distribution for each individual study is further visualized in **Figure 4**.

Table 3. Methodological Quality Analysis of the Reviewed Literature (N=35)

Quality Rating	Score Range	Frequency (N)	Percentage (%)	General Strengths and Weaknesses
High	> 30	28	80.0%	**Strengths:** These studies demonstrate high methodological rigor. They typically feature focused research questions, comprehensive search strategies, and transparent, replicable data synthesis processes. The risk of bias is low, providing a strong and reliable evidence base for synthesis.
Medium	21–30	7	20.0%	**Weaknesses:** While their conclusions remain relevant, these studies exhibit moderate methodological limitations. Common issues include a lack of explicit detail in the search strategy or the absence of a formal critical appraisal of the literature they reviewed,

				introducing potential for selection bias and reducing the overall transparency.
Low	< 21	0	0.0%	No studies in the final sample were found to have significant methodological flaws that would classify them as low quality. This indicates that the foundational evidence for this review is robust.
Total		**35**	**100.0%**	

Source: Author's analysis based on the CASP Systematic Review Checklist (CASP, 2018)



Source: Author's analysis (2025)

Figure 4. Distribution of Average Quality Scores for Each Study (Scale 1-4)

Thematic Synthesis: Policy Pillars and Determinant Factors

The thematic analysis identified three primary policy pillars that consistently emerge as instruments for driving the green energy transition in land transport. The findings strongly indicate that the most successful nations are those that implement a synergistic combination of these pillars rather than relying on them in isolation (Gallo & Marinelli, 2020). A detailed analysis of each pillar is presented in **Table 4**. Building on this, the synthesis also identified a set of overarching determinant factors that consistently influence policy success. These factors are classified as enablers, barriers, and moderating factors, as summarized in **Table 5**.

Table 4. Analysis of Green Energy Policy Typologies by Objective and Mechanism

Policy Category	Primary Objective	Core Mechanism	Key Examples from Literature	Common Limitations Identified
Demand-Side Policies	To stimulate consumer and fleet operator adoption of clean technologies.	**Reducing the total cost of ownership (TCO)** and upfront purchase price of green vehicles.	• Direct purchase subsidies for Electric Vehicles (EVs) (Emodi et al., 2022; Tilly et al., 2024)	• High fiscal burden on national budgets (Sandaka & Kumar, 2023).
			• Tax incentives (e.g., VAT, income tax) (Bakker et al., 2017).	• Risk of abrupt policy termination due to budget constraints, creating

				market uncertainty (Jannesar Niri et al., 2024).
			• Reduced tolls and parking fees (Gallo & Marinelli, 2020).	
Supply-Side Policies	To compel or incentivize the industry to produce and sell clean technologies.	**Establishing mandatory standards** and imposing penalties for non-compliance.	• Stringent vehicle CO_2 emission standards (Gallo & Marinelli, 2020).	• Requires strong regulatory capacity for monitoring and enforcement (Bakker et al., 2017).
			• Biofuel blending mandates (e.g., B30) (Riyadi et al., 2023).	• Can face significant lobbying and resistance from incumbent industries (Kenworthy, 2017).
			• Zero-Emission Vehicle (ZEV) sales quotas (Tilly et al., 2024).	
Ecosystem-Building Policies	To remove practical and structural barriers to the widespread use of clean technologies.	**Providing enabling physical infrastructure** and fostering long-term technological innovation.	• Public investment in national charging station networks (SPKLU) (Sarda et al., 2024).	• Requires massive, long-term capital investment (Emodi et al., 2022).
			• Electrification of railway infrastructure for passenger and freight (Zufarihsan et al., 2025).	• Prone to inter-agency coordination challenges and a lack of technical standardization (Satpathy et al., 2025).
			• R&D grants for battery and hydrogen technologies (Leuthold et al., 2025).	

Source: Author's synthesis (2025).

Table 5. Key Determinants of Green Energy Policy Implementation Success

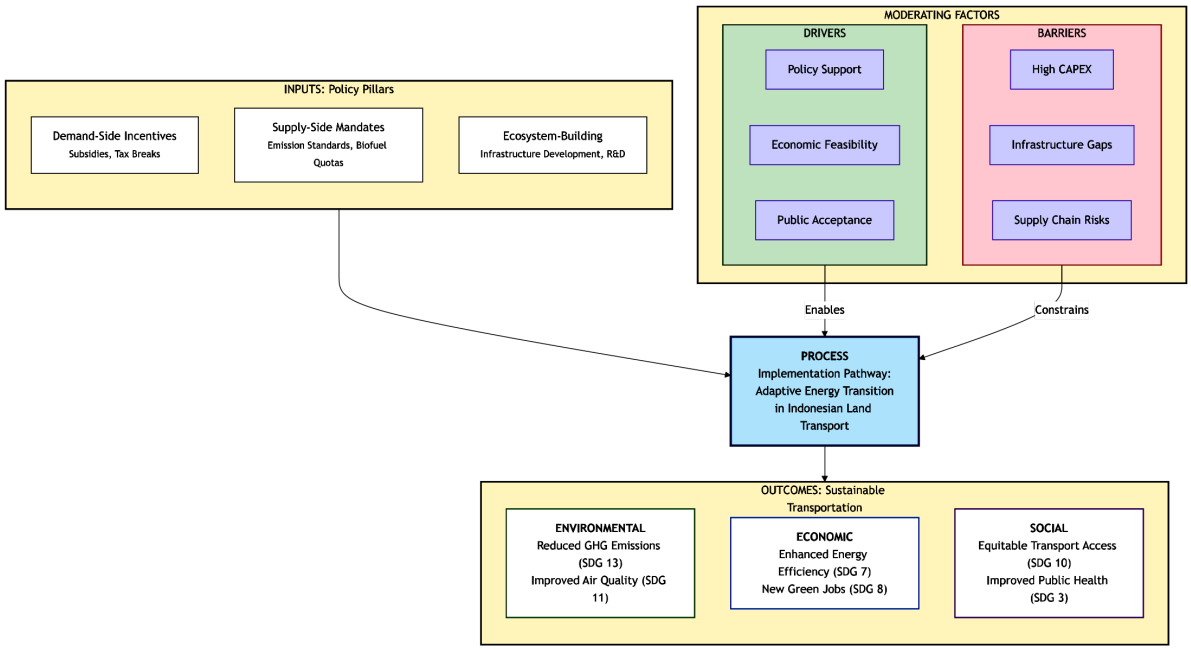
Determinant Factor	Indicators	Key Finding & Impact from Literature	Key References
		ENABLERS	
Government Policy & Regulatory Support	•Fiscal subsidies (tax credits, grants)	**Strongly Positive.** Strong, stable, and long-term government policy is consistently identified as the most critical prerequisite for attracting investment and driving market adoption.	(Bakker et al., 2017; Gallo & Marinelli, 2020)
	•Emission standards & biofuel mandates		
	•National energy transition roadmaps		
Economic Feasibility & User Benefits	•Reduced operational expenditures (OPEX)	**Positive / Context-Dependent.** The potential for cost savings is a powerful driver for consumers and fleet operators, but its viability is highly contingent on the scale of initial incentives and local energy prices.	(Emodi et al., 2022; Sandaka & Kumar, 2023)
	•Competitive Total Cost of Ownership (TCO)		
	•Energy price stability		
Environmental Awareness &	•Public perception of air pollution	**Positive.** High public awareness of environmental issues can create both the	(Kenworthy, 2017; Tilly et al., 2024)

Public Acceptance	•Market demand for green products •Community support and engagement	political pressure and market demand necessary to accelerate policy implementation.	
BARRIERS			
High Initial Capital Expenditure (CAPEX)	•High purchase price of Electric Vehicles (EVs) •Cost of infrastructure development (charging stations, rail electrification)	**Strongly Negative.** High CAPEX remains the most dominant economic barrier, particularly in developing countries, hindering mass adoption without robust financial schemes.	(Emodi et al., 2022; Jannesar Niri et al., 2024)
Infrastructure Readiness and Availability	•Lack of public charging networks •Grid instability and capacity issues •Limited biofuel supply chains	**Strongly Negative.** The absence of adequate and reliable infrastructure is the most significant practical barrier, creating "range anxiety" and impeding widespread deployment.	(Nevzorova & Kutcherov, 2019; Sarda et al., 2024)
Supply Chain & Geopolitical Challenges	•Dependency on critical minerals (lithium, cobalt) •Land-use competition for biofuels •Geopolitical risks and trade tensions	**Increasing Long-Term Risk.** The sustainability of the energy transition is heavily dependent on the security of upstream supply chains, which are vulnerable to price volatility and geopolitical tensions.	(Jannesar Niri et al., 2024; Kamran et al., 2023)
MODERATING FACTORS			
Technological Maturity & Innovation	•Increased battery energy density •Efficiency of hydrogen fuel cells •Development of advanced biofuels	**High Potential with Uncertainty.** Technological innovation can drastically reduce costs and improve performance, but the pace and scalability of its adoption remain a key moderating factor.	(Halder et al., 2024; Satpathy et al., 2025)

Source: Author's synthesis (2025).

Proposing the Adaptive Transport Energy Transition (ATET) Framework

Building upon the synthesis of policy pillars and determinant factors, this research proposes the Adaptive Transport Energy Transition (ATET) Framework as its primary conceptual contribution (illustrated in Figure 5). This framework is designed as a strategic tool for policymakers, particularly in developing nations, to navigate the complexities of the energy transition. Theoretically, the ATET framework contributes to the sustainability transitions literature by offering a granular, policy-focused perspective within the broader Multi-Level Perspective (MLP) (Köhler et al., 2019). The 'adaptive' nature of the framework emphasizes that the strategic weight of each policy pillar should evolve over time in response to changing market maturity and technological advancements.



Source: Author's synthesis (2025)

Figure 5. The Adaptive Transport Energy Transition (ATET) Conceptual Framework

Literature Gaps and Future Research Directions

Despite the richness of the data, this review also surfaced critical limitations within the existing literature. A significant geographical bias toward developed nations was evident, limiting the direct generalizability of findings to contexts like Indonesia (Emodi et al., 2022). This gap directly informs the proposed research agenda presented in Table 6, which is tailored to address these knowledge gaps with a specific focus on Indonesia's research needs.

Table 6. A Research Agenda for Accelerating the Energy Transition in Indonesia's Transport Sector

No.	Research Theme	Key Research Questions / Directions	Rationale and Potential Impact	Relevant SDGs
1	**Contextual Economic Viability & Business Models**	•What are the realistic Total Cost of Ownership (TCO) models for electric motorcycles and buses across different Indonesian urban typologies (e.g., metropolitan, medium, small cities)? •How can business models like Battery-as-a-Service (BaaS) or battery swapping effectively reduce upfront CAPEX for consumers and SMEs?	**Rationale:** High initial cost is the primary adoption barrier in Indonesia. **Impact:** Context-specific studies will inform the design of viable incentive schemes and business models, attracting private investment and accelerating adoption, a need highlighted by Emodi et al. (2022).	SDG 8, 9, 11
2	**Infrastructure Integration & Spatial Planning**	•What are the optimal network designs for charging/swapping stations (SPKLU/SPBKLU) to accommodate the dominance of two-wheelers? •How can Transit-Oriented Development (TOD) policies around MRT/LRT/Commuter stations be integrated with green energy infrastructure planning (Hasibuan & Mulyani, 2022)?	**Rationale:** Infrastructure readiness is a critical bottleneck. **Impact:** This research will inform smarter urban and regional planning, ensuring efficient integration between transportation and energy systems, a challenge emphasized by (Sarda et al., 2024).	SDG 7, 9, 11

3	**Multi-Level Governance, Policy, & Regulation**	•What adaptive regulatory frameworks are needed to establish national standards for charging interoperability? •How can the role of sub-national (provincial and municipal) governments be optimized in implementing national green energy policies?	**Rationale:** Regulatory uncertainty stifles investment. **Impact:** This research is essential for creating policy stability, de-risking private investment, and ensuring effective coordination between central and local governments.	SDG 9, 11, 16
4	**Socio-Technical Factors & a Just Transition**	•What are the long-term impacts of transport electrification on the labor market (e.g., drivers, mechanics)? What constitutes a "just transition" framework for these workers? •What are the key behavioral and cultural drivers of, and barriers to, EV and biofuel adoption among Indonesian consumers?	**Rationale:** Social acceptance is a major uncertainty. **Impact:** This research is crucial for designing an equitable transition, managing social impacts, and building public trust, addressing concerns raised by (Tilly et al., 2024).	SDG 8, 10, 11
5	**Lifecycle Sustainability & the Circular Economy**	•What is the full lifecycle environmental impact (LCA) of EV batteries in Indonesia, from nickel mining to end-of-life recycling? •How can Extended Producer Responsibility (EPR) policies be effectively designed and implemented for the battery and biofuel supply chains?	**Rationale:** To avoid problem-shifting (e.g., from tailpipe emissions to battery waste). **Impact:** LCA and circular economy research are necessary to ensure holistic, long-term sustainability, a theme raised by Widiawati et al. (2025).	SDG 12, 13

Source: Author's analysis of identified research gaps.

Actionable Recommendations for Indonesian Stakeholders

As the culmination of this analysis, the practical implications are formulated into a set of actionable recommendations for key stakeholders in Indonesia's transport sector. Presented in **Table 7**, these recommendations are designed to translate the global findings and the proposed ATET framework into concrete, context-specific steps to accelerate a just and effective energy transition.

Table 7. Actionable Recommendations for Key Stakeholders in Indonesia

No.	Target Stakeholder	Actionable Recommendation	Key References Supporting Recommendation
1	**Central Government** (e.g., Ministry of Transportation, Ministry of Energy, Ministry of Finance)	**Develop an Integrated and Adaptive Hybrid Policy Roadmap.** Combine short-term fiscal incentives (e.g., subsidies, tax breaks) with clear, long-term regulatory mandates (e.g., stringent emission standards, biofuel blending targets) to provide market certainty and guide investment.	(Bakker et al., 2017; Gallo & Marinelli, 2020)
2	**Sub-National Governments** (Provincial & Municipal)	**Integrate Green Energy into Urban and Regional Spatial Planning.** Proactively zone and plan for the deployment of charging infrastructure (SPKLU/SPBKLU), dedicated lanes, and Low	(Hasibuan & Mulyani, 2022; Nikulina et al., 2019)

		Emission Zones (LEZs), particularly around transit hubs (MRT/LRT/Commuter stations).	
3	**State-Owned Enterprises (SOEs) & Private Sector** (e.g., PLN, Pertamina, KAI)	**Invest in Open and Interoperable Infrastructure.** Build a public charging network accessible to all vehicle brands and platforms. Simultaneously, invest in grid capacity upgrades and modernize electric rail depots to support increased electricity demand.	(Leuthold et al., 2025; Sarda et al., 2024)
4	**Automotive Industry & Transport Operators**	**Prioritize Electrification of Two-Wheelers and Public Transit.** Focus on developing and marketing affordable electric motorcycle models. Accelerate the electrification of urban bus fleets and other public transport modes (e.g., paratransit, rail-based systems).	(Ammenberg & Dahlgren, 2021; Huu & Ngoc, 2021)
5	**Financial Institutions & Investors**	**Create Innovative Green Financing Mechanisms.** Develop attractive credit and leasing products for individual and SME purchases of EVs. Establish dedicated funds or green bonds to finance large-scale renewable energy and charging infrastructure projects.	(Emodi et al., 2022; Gandhi et al., 2022)
6	**Academic & Vocational Institutions**	**Develop Curricula for the "Green Workforce."** Partner with industry to create forward-looking training programs and certifications for emerging roles, such as EV mechanics, battery technicians, and modern railway systems specialists.	(Ibrahim et al., 2023; Tilly et al., 2024)

Source: Author's synthesis (2025).

CONCLUSION

This systematic literature review concludes that the transition to sustainable land transportation is a complex socio-technical challenge that cannot be addressed by singular policy instruments. The synthesis of 35 global studies reveals that successful decarbonization consistently relies on a synergistic, hybrid policy framework that integrates three core pillars: demand-side incentives, supply-side mandates, and ecosystem-building infrastructure. The primary contribution of this research is the formulation of the Adaptive Transport Energy Transition (ATET) Framework, a conceptual model designed to guide such an integrated approach in developing nations. For Indonesia, the key implication is the necessity of adopting an adaptive policy mix that strategically prioritizes the electrification of light-duty vehicles and urban transit while leveraging biofuels and hydrogen as transitional solutions for heavy-duty freight and railways. While this review establishes a robust evidence base, it also underscores significant geographical and technological biases in the existing literature. Consequently, future research, as outlined in our proposed agenda, should focus on quantitative modeling of policy scenarios and context-specific socio-economic impact assessments to support a just and effective energy transition in Indonesia.

REFERENCE

Aliyu Yaro, N. S., Sutanto, M. H., Habib, N. Z., Napiah, M., Usman, A., Jagaba, A. H., & Al-Sabaeei, A. M. (2022). Application and circular economy prospects of palm oil waste for eco-friendly asphalt pavement industry: A review. *Journal of Road Engineering*, *2*(4), 309–331. https://doi.org/https://doi.org/10.1016/j.jreng.2022.10.001

Ammenberg, J., & Dahlgren, S. (2021). Sustainability Assessment of Public Transport, Part I—A Multi-Criteria Assessment Method to Compare Different Bus Technologies. In *Sustainability* (Vol. 13, Issue 2). https://doi.org/10.3390/su13020825

Bakker, S., Dematera Contreras, K., Kappiantari, M., Tuan, N. A., Guillen, M. D., Gunthawong, G., Zuidgeest, M., Liefferink, D., & Van Maarseveen, M. (2017). Low-Carbon

Transport Policy in Four ASEAN Countries: Developments in Indonesia, the Philippines, Thailand and Vietnam. In *Sustainability* (Vol. 9, Issue 7). https://doi.org/10.3390/su9071217

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

CASP, C. A. S. (2018). *CASP Systematic Review Checklist*. CASP Checklists. https://casp-uk.net/casp-tools-checklists/

Emodi, N. V., Okereke, C., Abam, F. I., Diemuodeke, O. E., Owebor, K., & Nnamani, U. A. (2022). Transport sector decarbonisation in the Global South: A systematic literature review. *Energy Strategy Reviews*, *43*, 100925. https://doi.org/https://doi.org/10.1016/j.esr.2022.100925

Gallo, M., & Marinelli, M. (2020). Sustainable Mobility: A Review of Possible Actions and Policies. In *Sustainability* (Vol. 12, Issue 18). https://doi.org/10.3390/su12187499

Gandhi, H. H., Hoex, B., & Hallam, B. J. (2022). Strategic investment risks threatening India's renewable energy ambition. *Energy Strategy Reviews*, *43*, 100921. https://doi.org/https://doi.org/10.1016/j.esr.2022.100921

Halder, P., Babaie, M., Salek, F., Shah, K., Stevanovic, S., Bodisco, T. A., & Zare, A. (2024). Performance, emissions and economic analyses of hydrogen fuel cell vehicles. *Renewable and Sustainable Energy Reviews*, *199*, 114543. https://doi.org/https://doi.org/10.1016/j.rser.2024.114543

Hasibuan, H. S., & Mulyani, M. (2022). Transit-Oriented Development: Towards Achieving Sustainable Transport and Urban Development in Jakarta Metropolitan, Indonesia. *Sustainability*, *14*(9), 5244. https://doi.org/10.3390/su14095244

Huu, D. N., & Ngoc, V. N. (2021). Analysis Study of Current Transportation Status in Vietnam's Urban Traffic and the Transition to Electric Two-Wheelers Mobility. *Sustainability*, *13*(10), 5577. https://doi.org/10.3390/su13105577

Ibrahim, H. A., Ayomoh, M. K., Bansal, R. C., Gitau, M. N., Yadavalli, V. S. S., & Naidoo, R. (2023). Sustainability of power generation for developing economies: A systematic review of power sources mix. *Energy Strategy Reviews*, *47*, 101085. https://doi.org/https://doi.org/10.1016/j.esr.2023.101085

Jannesar Niri, A., Poelzer, G. A., Zhang, S. E., & Rosenkranz, J. (2024). Sustainability challenges throughout the electric vehicle battery value chain. *Renewable and Sustainable Energy Reviews*, *191*, 114176. https://doi.org/10.1016/j.rser.2023.114176

Kamran, M., Raugei, M., & Hutchinson, A. (2023). Critical elements for a successful energy transition: A systematic review. *Renewable and Sustainable Energy Transition*, *4*, 100068. https://doi.org/https://doi.org/10.1016/j.rset.2023.100068

Kenworthy, J. R. (2017). Is Automobile Dependence in Emerging Cities an Irresistible Force? Perspectives from São Paulo, Taipei, Prague, Mumbai, Shanghai, Beijing, and Guangzhou. *Sustainability*, *9*(11), 1953. https://doi.org/10.3390/su9111953

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., … Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions*, *31*, 1–32. https://doi.org/https://doi.org/10.1016/j.eist.2019.01.004

Leuthold, A., Terrapon-Pfaff, J., & Viebahn, P. (2025). Implementation factors for green hydrogen projects: A systematic literature review. *Sustainable Energy Technologies and Assessments*, *82*, 104555. https://doi.org/https://doi.org/10.1016/j.seta.2025.104555

Liu, F., Shafique, M., & Luo, X. (2025). Next leap in the sustainable transport revolution: Identifying gaps and proposing solutions for hydrogen mobility. *Communications in*

Transportation Research, *5*, 100180. https://doi.org/https://doi.org/10.1016/j.commtr.2025.100180

Mamat, R., Erdiwansyah, Ghazali, M. F., Rosdi, S. M., Syafrizal, & Bahagia. (2025). Strategic framework for overcoming barriers in renewable energy transition: A multi-dimensional review. *Next Energy*, *9*, 100414. https://doi.org/https://doi.org/10.1016/j.nxener.2025.100414

Mhana, K. H., Norhisham, S. Bin, Katman, H. Y. B., & Yaseen, Z. M. (2024). Road urban planning sustainability based on remote sensing and satellite dataset: A review. *Heliyon*, *10*(21), e39567. https://doi.org/https://doi.org/10.1016/j.heliyon.2024.e39567

Moeen, M. S., Jupesta, J., & Hanaoka, T. (2025). Integrated energy planning: Review of global practices for energy security and Paris Agreement implementation in Pakistan. *Energy Nexus*, *18*, 100413. https://doi.org/https://doi.org/10.1016/j.nexus.2025.100413

Momodu, A. S., Okunade, I. D., & Adepoju, T. D. (2022). Decarbonising the electric power sectors in sub-Saharan Africa as a climate action: A systematic review. *Environmental Challenges*, *7*, 100485. https://doi.org/https://doi.org/10.1016/j.envc.2022.100485

Nassary, E. K., Magubika, A. J., Mwampashi, L. L., Fukah, F. K., Kahangwa, C. A., & Tryphone, G. M. (2025). Transitioning to clean energy and opportunities for developing countries. *Energy Strategy Reviews*, *62*, 101909. https://doi.org/https://doi.org/10.1016/j.esr.2025.101909

Nevzorova, T., & Kutcherov, V. (2019). Barriers to the wider implementation of biogas as a source of energy: A state-of-the-art review. *Energy Strategy Reviews*, *26*, 100414. https://doi.org/https://doi.org/10.1016/j.esr.2019.100414

Nikulina, V., Simon, D., Ny, H., & Baumann, H. (2019). Context-Adapted Urban Planning for Rapid Transitioning of Personal Mobility towards Sustainability: A Systematic Literature Review. *Sustainability*, *11*(4), 1007. https://doi.org/10.3390/su11041007

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *PLoS Medicine*, *18*(3), 1–15. https://doi.org/10.1371/JOURNAL.PMED.1003583

Republic of Indonesia. (2021). Third Biennial Update Report Under the United Nations Framework Convention on Climate Change. *Third Biennial Update Report Under the United Nations Framework Convention on Climate Change*, 1–136.

Riera, J. A., Lima, R. M., & Knio, O. M. (2023). A review of hydrogen production and supply chain modeling and optimization. *International Journal of Hydrogen Energy*, *48*(37), 13731–13755. https://doi.org/https://doi.org/10.1016/j.ijhydene.2022.12.242

Riyadi, T. W. B., Spraggon, M., Herawan, S. G., Idris, M., Paristiawan, P. A., Putra, N. R., R, M. F., Silambarasan, R., & Veza, I. (2023). Biodiesel for HCCI engine: Prospects and challenges of sustainability biodiesel for energy transition. *Results in Engineering*, *17*, 100916. https://doi.org/https://doi.org/10.1016/j.rineng.2023.100916

Rizki, M., Syahputri, J., Belgiawan, P. F., & Irawan, M. Z. (2021). Electrifying Tourist Mobility in Bali, Indonesia: Setting the Target and Estimating the CO2 Reduction Based on Stated Choice Experiment. *Sustainability*, *13*(21), 11656. https://doi.org/10.3390/su132111656

Samarasinghe, S. L., Moghimi, M., & Kaparaju, P. (2025). A review of modelling tools for net-zero emission energy systems, based on model capabilities, modelling criteria and model availability. *Renewable Energy Focus*, *53*, 100659. https://doi.org/https://doi.org/10.1016/j.ref.2024.100659

Sandaka, B. P., & Kumar, J. (2023). Alternative vehicular fuels for environmental decarbonization: A critical review of challenges in using electricity, hydrogen, and

biofuels as a sustainable vehicular fuel. *Chemical Engineering Journal Advances*, *14*, 100442. https://doi.org/https://doi.org/10.1016/j.ceja.2022.100442

Sarda, J., Patel, N., Patel, H., Vaghela, R., Brahma, B., Bhoi, A. K., & Barsocchi, P. (2024). A review of the electric vehicle charging technology, impact on grid integration, policy consequences, challenges and future trends. *Energy Reports*, *12*, 5671–5692. https://doi.org/https://doi.org/10.1016/j.egyr.2024.11.047

Satpathy, P. R., Ramachandaramurthy, V. K., Radha Krishnan, T. R., & Padmanaban, S. (2025). Technological innovations and sustainable strategies for advancing electric vehicle performance and market integration. *Energy Strategy Reviews*, *60*, 101790. https://doi.org/https://doi.org/10.1016/j.esr.2025.101790

Sunanda, W., Setyonegoro, M. I. B., Hadi, S. P., & Sarjiya. (2025). Advancing the carbon pricing framework in Indonesia: A systematic review of policies, challenges, and global lessons. *Results in Engineering*, *28*, 107155. https://doi.org/https://doi.org/10.1016/j.rineng.2025.107155

Tilly, N., Yigitcanlar, T., Degirmenci, K., & Paz, A. (2024). How sustainable is electric vehicle adoption? Insights from a PRISMA review. *Sustainable Cities and Society*, *117*, 105950. https://doi.org/10.1016/j.scs.2024.105950

Vakulchuk, R., Overland, I., & Scholten, D. (2020). Renewable energy and geopolitics: A review. *Renewable and Sustainable Energy Reviews*, *122*, 109547. https://doi.org/https://doi.org/10.1016/j.rser.2019.109547

Widiawati, K., Sopha, B. M., Tjahjono, B., & Rakoto, N. (2025). Circularity potentials, influential factors, modeling approach and policy interventions of circular supply chain for electric vehicles. *Cleaner Engineering and Technology*, *27*, 101013. https://doi.org/https://doi.org/10.1016/j.clet.2025.101013

Zhu, M., Wang, Z., Cui, H., Yang, Y., & Qie, P. (2023). Situation and hotspot analysis on rural transport infrastructure from the perspective of bibliometric analysis. *Journal of Traffic and Transportation Engineering (English Edition)*, *10*(6), 1074–1098. https://doi.org/https://doi.org/10.1016/j.jtte.2023.04.009

Zufarihsan, R., Tambusay, A., Suprobo, P., Suryanto, B., & Laghrouche, O. (2025). Recent developments in high-speed railway in Indonesia: Superstructure construction and track infrastructure. *Transportation Research Interdisciplinary Perspectives*, *31*, 101385. https://doi.org/https://doi.org/10.1016/j.trip.2025.101385