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Risks and Opportunities in Early Retirement of CFPP in Indonesia: An Analysis of Environmental, Socio-Economic and Regulatory Implications

Dzikrina Almas Kusumadewi [a]✉, Yuki Mahardhito Adhitya Wardhana[b], Dwi Nowo Martono[c], Zulfahmi[d]

[abc] Graduate School of Sustainable Development, University of Indonesia, Jakarta, Indonesia
[d] Islamic Business School, Universiti Utara Malaysia, Malaysia

✉ Corresponding email: dzikrina.almas@ui.ac.id

Abstract

This study analyzes Indonesia's energy transition initiatives, focusing on the early retirement of Coal-Fired Power Plants (CFPPs) to increase the share of renewable energy in the national energy mix. The analysis shows that Indonesia still faces major regulatory challenges, especially policy uncertainty and the lack of a consistent long-term transition framework. We use mixed-methods, including bibliometric analysis with VOSviewer, to map research trends on early retirement of CFPPs and coal phase-out strategies. Successful coal retirement requires a comprehensive policy strategy covering environmental impacts, legal and policy standing, financial and fiscal aspects, and regional support and compensation. Furthermore, implementing a gradual coal phase-out strategy creates opportunities to accelerate renewable energy development, mitigate environmental impacts, and reinforce global climate commitments while addressing the just transition aspect. This study underscores the urgent need for an integrated policy framework to guide Indonesia's energy transition toward an environmentally sustainable, socially inclusive, and affordable energy system.

KEYWORDS *Coal phase-out, early retirement CFPP, ETM, just transition, sustainability*

Introduction

Global electricity demand remains dominated by coal-fired power plants. In Europe, domestic coal is primarily consumed in three sectors: power generation, industry, and heating. In alignment with global commitments to achieve the 1.5°C target, Germany has reinforced its coal phase-out agenda through the Coal Exit Plan. This plan was formulated in response to recommendations from the Commission on Growth, Structural Transformation, and Employment, which was established in 2018. As part of this strategy, Germany set a goal in 2020 to completely shut down coal-fired power plants (CFPPs) by 2038, with the possibility of accelerating the phase-out to 2030 contingent on progress in developing renewable energy sources. In 2023, approximately 52% of Germany's gross electricity consumption derived from mixed renewable sources, including solar, wind, and hydropower.[1]

A comparable trend occurred in China and parts of Southeast Asia, where emissions increased steadily from 2014 to 2020, reaching a peak of 9.80 Gt in 2019.[2] The COVID-19 pandemic and associated lockdowns did not offset China's annual rise in CO_2 emissions. In 2019, coal was the primary driver of China's emissions, accounting for approximately 75.4% of CO_2 from fuel combustion. Oil contributed 13.3%, natural gas 4.4%, and

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[1] ZSW and BDEW, "Renewable Energies Covered More than Half of Electricity Consumption for the First Time in 2023," 2023, https://www.bdew.de/presse/erneuerbare-energien-deckten-2023-erstmals-mehr-als-die-haelfte-des-stromverbrauchs/.

[2] Yuru Guan et al., "Assessment to China's Recent Emission Pattern Shifts," *Earth's Future* 9, no. 11 (2021): 1–13, https://doi.org/10.1029/2021EF002241.

cement production approximately 7.0% of total emissions. China's continued reliance on coal is largely due to its substantial reserves and the relatively low cost of coal mining compared to alternative energy sources. Coal consumption in China peaked in 2013, prompting the government to implement a series of policies, particularly in the eastern provinces, aimed at reducing coal use and promoting the development of new energy technologies to accelerate the transition away from oil and gas. In 2019, non-fossil energy sources represented 15.3% of total energy consumption.[3] China has announced plans to significantly expand its renewable energy capacity by 2030. An innovation-driven industrial system is anticipated to gradually develop, supporting the broader objective of achieving net-zero emissions.[4]

To support the global objective of limiting temperature rise to 1.5 degrees Celsius, Indonesia has committed to reducing emissions by 31.89% through unconditional measures and by 43.20% through conditional measures, as outlined in Indonesia's Enhanced Nationally Determined Contribution (NDC) document.[5] In the energy sector, greenhouse gas emissions are projected to decrease by 358 million tons of CO_2 equivalent ($MtCO_2e$) under the unconditional mitigation scenario and by 446 million tons of CO_2 equivalent under the conditional mitigation scenario. Indonesia has also developed a long-term strategy for achieving a low-carbon economy by 2050, as detailed in the LTS-LCCR document.[6] The NDC targets were further

3 Ye Qi et al., "China's Post-Coal Growth," *Nature Geoscience* 9, no. 8 (2016): 564–66, https://doi.org/10.1038/ngeo2777.

4 Guan et al., "Assessment to China's Recent Emission Pattern Shifts."

5 KLHK, "Enhanced Nationally Determined Contribution Republic of Indonesia 2022" (Jakarta, 2022).

6 KLHK, "Indonesia Long-Term Strategy for Low Carbon and Climate Resilience 2050 (Indonesia LTS-LCCR 2050)" (Jakarta, 2021).

First Nationally Determined Contribution (NDC) was submitted in 2016, was update the Enhanced NDC (ENDC) in 2022, reflecting increased emission-reduction ambition. The continuous Second NDC (SNDC) submitted in 2025, demonstrates a continuous strengthening of national policy frameworks toward achieving long-term climate and energy transition targets.

updated in the Second NDC, which was submitted in 2025.[7] The emissions accounting in the Second Nationally Determined Contribution (NDC) adopts 2019 as the baseline year, consistent with the Global Stocktake Decision to update global commitments based on the latest national circumstances. This methodology allows Indonesia to refine its climate commitments through 2035 by using emissions projects. The SNDC further emphasizes that emission reduction trajectories must consider national economic development. It incorporates several economic growth scenarios, including the Current Policy Scenario (CPOS) and two Low Carbon Compatible Pathways (LCCP_L and LCCP_H). These pathways provide alternative projections for Indonesia's economic growth in the coming years. The scenarios are used to model changes across key sectors, including industry, waste, energy, agriculture, forestry, and other land use (FOLU), resulting in emissions estimates that better reflect Indonesia's development needs and mitigation capabilities. This approach aims to ensure that the emission targets outlined in the SNDC are consistent with global mitigation ambitions and aligned in Indonesia's economic growth objectives, specified in the National Medium-Term Development Plan (RPJMN).

Mitigating emissions within the energy sector is essential for Indonesia to achieve its climate targets. To facilitate the country's long-term energy transition, the Government of Indonesia established the National Energy General Plan (RUEN) in 2017, grounded in the National Energy Policy (KEN). The RUEN provides a strategic framework to decrease reliance on fossil fuels, particularly coal, while emphasizing the expansion of renewable energy sources. It sets specific targets to increase the share of new and renewable energy to at least 23% by 2025 and 31% by 2050. Although the plan does not require an immediate coal phase-out, it anticipates a more balanced energy mix with progressively larger contributions from renewable sources such as wind, solar, geothermal, and biomass over the coming decades. Indonesia has initiated measures to reduce coal dependence, as demonstrated by Presidential Decree No. 112 of 2022, which aims to accelerate the phase-out of CFPPs to operate

[7] KLH, "Second Nationally Determined Contribution Republic of Indonesia" (Jakarta, 2025).

until at least 2050. The regulation supports Indonesia's commitment to achieving net zero emissions (NZE) by 2060 or earlier and encourages the early retirement of CFPP as part of a structured energy transition. It also enables Indonesia to access international financing through mechanisms such as carbon pricing and green financing. This policy framework is reinforced by PMK No. 103/2023 on the Provision of Fiscal Support for Accelerating the Energy Transition in the Electricity Sector.[8] A central element of this policy is the Energy Transition Mechanism (ETM), which seeks to mobilize both public and private investment to facilitate the phased retirement of CFPP. In collaboration with the Asian Development Bank (ADB) and various global climate funds, the ETM provides financial incentives for the early retirement of CFPPs and supports the replacement of coal-based generation with renewable energy projects. This mechanism advances Indonesia toward a cleaner, more sustainable, and low-carbon energy system.[9] The Electricity Sector Energy Transition Roadmap No. 10 of 2025 further strengthens this commitment by establishing clear targets for power-sector emissions reductions through 2060.[10] According to this roadmap, Indonesia plans to achieve a total generation capacity of 443 gigawatts, with 41.5% derived from variable renewable energy sources such as wind (PLTB), ocean energy (PLTAL), and solar (PLTS), all equipped with storage systems, and 58.5% from dispatchable renewable energy sources.

Although Indonesia has established technical and financial regulations for the early retirement CFPP, significant gaps persist in explicit provisions for a just transition, particularly concerning affected local communities. Current policies do not comprehensively address worker protection frameworks or

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8 Kementerian Keuangan, "Peraturan Menteri Keuangan Nomor 103 Tahun 2023 Tentang Pemberian Dukungan Fiskal Melalui Kerangkan Pendanaan Dan Pembiayaan Dalam Rangka Percepatan Transisi Energi Di Sektor Ketenagalistrikan," *Kementerian Keuangan* (Jakarta, 2023).

9 Budy P. Resosudarmo, Jahen F. Rezki, and Yuventus Effendi, "Prospects of Energy Transition in Indonesia," *Bulletin of Indonesian Economic Studies* 59, no. 2 (2023): 149–77.

10 Kementerian ESDM, "Peraturan Menteri ESDM Nomor 10 Tahun 2025 Tentang Peta Jalan (Road Map) Transisi Energi Sektor Ketenagalistrikan" (Jakarta, 2025).

regional economic transition strategies. In contrast, Germany implemented a more comprehensive legal framework through the 2020 Coal Exit Strategy, which incorporates compensation mechanisms for power plant operators and provides social and economic protection for affected workers and coal-dependent regions. The German Federal Government allocated more than EUR 40 billion to support regional transformation, renewable energy development, and sustainable economic growth throughout the coal phase-out process.[11]

A comprehensive understanding of energy transition strategies is essential for developing countries, where the goals of ensuring energy access, promoting economic development, and addressing environmental challenges intersect. Research in this field is vital to ensure that energy transition regulations are technically and economically viable, as well as socially inclusive and acceptable to affected communities. In Indonesia, establishing a robust policy framework is particularly important due to the nation's significant reliance on coal-fired power plants. Implementing evidence-based and participatory approaches is fundamental to reducing climate risks and supporting long-term sustainable development. In the absence of a clear, adaptable framework, the early retirement of CFPPs may lead to regulatory uncertainty, employment disruption, and regional economic instability. This study, therefore, investigates the multifaceted implications of early CFPP retirement as a critical strategy for Indonesia's efforts to mitigate climate change and contribute to global initiatives.

A mixed-methods approach is utilized, integrating quantitative and qualitative methodologies through two primary techniques: bibliometric analysis and systematic literature review (SLR). Bibliometric analysis measures and examines scientific publications, identifying trends, patterns, and contributions within the relevant literature. The synthesis process is supported by VOSviewer software, which visualizes relationships among keywords, bibliographic information, article titles, and abstracts within the defined time frame. Initial

[11] Pao Yu Oei, Hanna Brauers, and Philipp Herpich, "Lessons from Germany's Hard Coal Mining Phase-out: Policies and Transition from 1950 to 2018," *Climate Policy* 20, no. 8 (September 13, 2020): 963–79, https://doi.org/10.1080/14693062.2019.1688636.

data are collected using Publish or Perish (PoP) software and the Scopus database to determine citation counts, publication years, and research collaborations. The SLR focuses on the topic of energy transition, with particular emphasis on Coal Phase-Out policies implemented by various countries over the past few decades. This method provides a comprehensive, in-depth analysis of key findings from the selected literature.

Google Scholar, Scopus, and Crossref served as the primary databases for literature retrieval. A targeted search was conducted using the keywords "early retirement CFPP" and "coal phase-out" across the title, abstract, and keyword fields for publications from 2015 to 2025. Recent literature on energy transition, with a particular focus on the just energy transition framework, was analyzed using bibliometric methods. The Systematic Literature Review (SLR) method provides a structured approach to identifying, evaluating, and synthesizing studies relevant to a specific research question. This approach enhances the reliability of the review process by adhering to predefined criteria. SLR is especially valuable in qualitative research, as it provides a comprehensive overview of the current scientific literature and research landscape. Additionally, SLR facilitates the identification of research gaps and future research directions, thereby establishing a robust foundation for subsequent investigations.[12] The SLR process involves a critical evaluation of existing literature through systematic procedures, typically conducted manually by researchers through content

[12] Vincenzo Del Duca et al., "Towards Economic, Environmental, and Societal Sustainable World: Reviewing the Interplay of Methodologies, Variables, and Impacts in Energy Transition Models," *Journal of Cleaner Production* 479 (2024): 1–16, https://doi.org/10.1016/j.jclepro.2024.144074.

and thematic analyses.[13 14 15]

SLR, similar to bibliometric analysis, enables rigorous evaluation through several structured stages guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Protocol. Article selection for qualitative analysis followed three primary criteria: (1) high citation frequency, reflecting substantial influence and contribution to the field; (2) inclusion of relevant keywords representing dominant themes identified via bibliometric mapping, such as keyword co-occurrence or co-citation analysis, to provide deeper thematic insights; and (3) restriction to literature published within the past ten years.

Inclusion and exclusion criteria were established to ensure a focused and rigorous review process. The review adhered to PRISMA protocol, which comprises four stages: identification, screening, eligibility, and inclusion, based on predefined data criteria. The inclusion criteria specify the characteristics required for studies to be considered, such as alignment with research objectives and publication within a designated time frame. Exclusion criteria were applied to remove studies that did not fit the research scope, including those lacking peer review, falling outside the target domain, or published in non-academic sources. These criteria ensured an objective and consistent data-selection process, as illustrated in the

TABLE 1. Research Criteria

Criteria	Inclusion	Exclusion

13 Naveen Donthu et al., "How to Conduct a Bibliometric Analysis: An Overview and Guidelines," *Journal of Business Research* 133 (2021): 285–96, https://doi.org/10.1016/j.jbusres.2021.04.070.

14 Weng Marc Lim, Sheau Fen Yap, and Marian Makkar, "Home Sharing in Marketing and Tourism at a Tipping Point: What Do We Know, How Do We Know, and Where Should We Be Heading?," *Journal of Business Research* 122 (2021): 534–66, https://doi.org/10.1016/j.jbusres.2020.08.051.

15 Robert W. Palmatier, Mark B. Houston, and John Hulland, "Review Articles: Purpose, Process, and Structure," *Journal of the Academy of Marketing Science* 46, no. 1 (2018): 1–5, https://doi.org/10.1007/s11747-017-0563-4.

Theme	Renewable Energy Transition: Early Retirement of Coal-Fired Power Plants and Coal Phase-Out	Research Unrelated to the Energy Transition
Publication type	Open-access international journals and proceedings	Limited access to international journals and proceedings
Year of publication	2015 - 2025	2015 – 2025
Language	English	Not in English

Sources: Analysis Result, 2026

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram improves the reproducibility and transparency of the review process by documenting the number of records included or excluded at each stage, and providing reasons for exclusion. In this study, 2,634 publications were selected for bibliometric analysis, from three major databases: Google Scholar (n = 400), Scopus (n = 234), and Crossref (n = 2,000). During the identification phase, studies were sourced from both journals and conference proceedings, using predefined inclusion criteria, focusing on the last 10 years (2015–2025). Following the screening process, 55 articles were deemed relevant and suitable for analysis. The SLR process using the PRISMA protocol is illustrated in Figure 1.

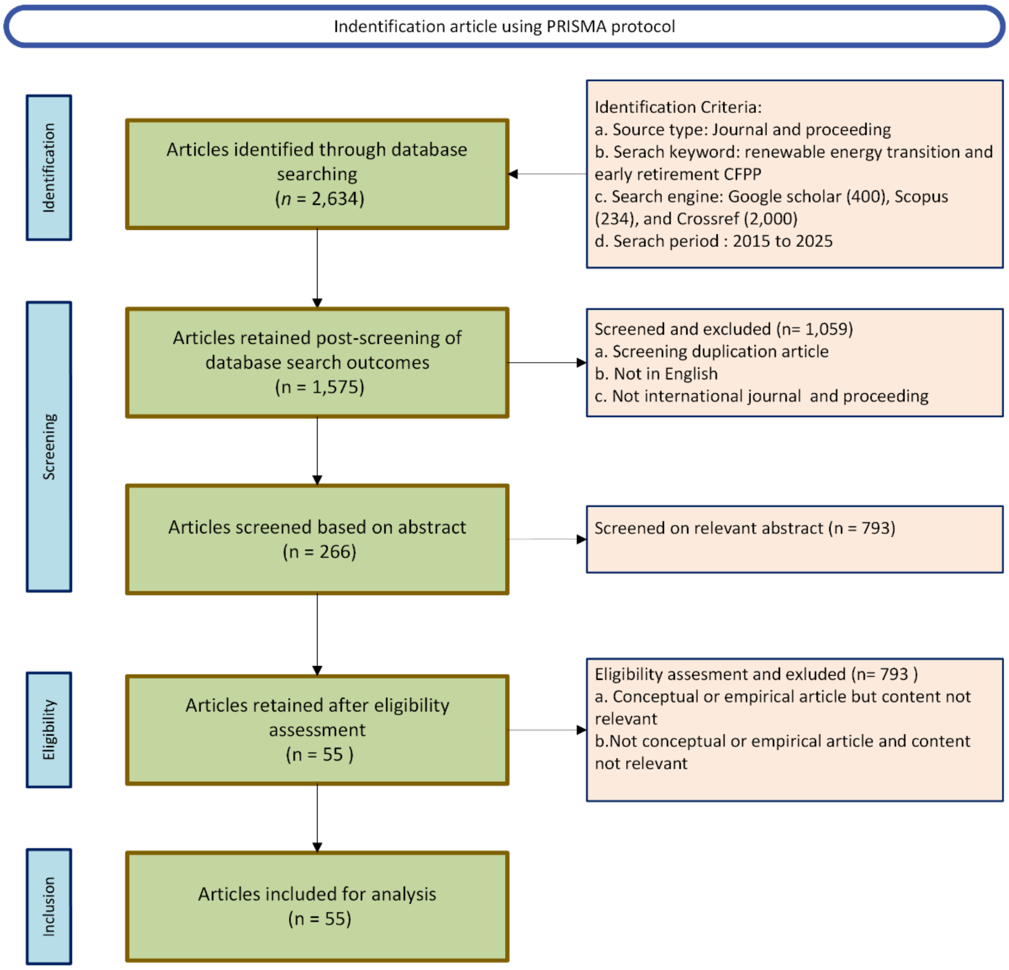

Figure 1. Flowchart study using PRISMA Protocol

Result & Discussion

Figure 2 presents a bibliometric analysis using VOSviewer, which visualizes keyword co-occurrence in the scientific literature. This mapping identifies the frequency with which key expressions co-occur, thereby elucidating relationships among concepts in energy transition research, particularly regarding early retirement, CFPPs, and the coal phase-out. The analysis identifies several clusters, each representing a distinct thematic focus within the literature. These clusters reflect a range of perspectives on energy transition pathways, including regulatory approaches, financing strategies, environmental impacts, and just transition considerations. Furthermore, the clusters demonstrate the evolution of academic discourse and highlight areas where research has been most concentrated.

Figure 2 illustrates a balanced and hierarchical research landscape. Topics related to the energy transition and coal phase-out are predominant, with empirical analyses of coal impacts and environmental outcomes also receiving significant attention. These studies offer essential insights for future research, which, while expanding, remains limited in scope. This distribution suggests that the literature has moved beyond debating the necessity of the energy transition and is increasingly addressing strategies for implementing it in an equitable, effective, and sustainable manner, particularly within coal-dependent energy systems.

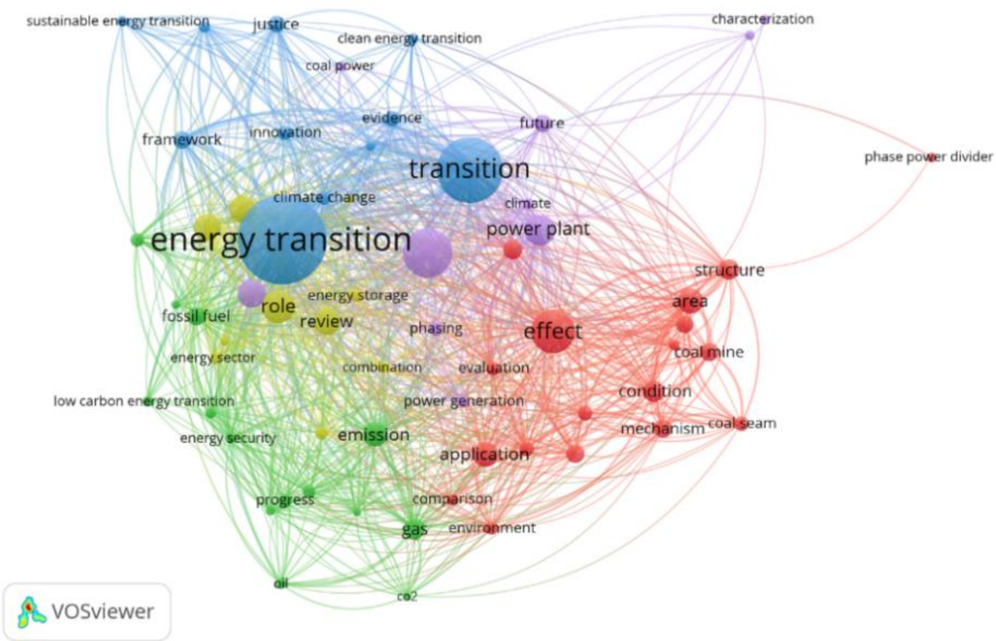

Figure 2. Bibliometrik visualisation by keyword

The thematic distribution of keywords, identified using VOSviewer, reveals several key clusters. The blue cluster contains the most keywords, indicating that the current literature is primarily focused on conceptual frameworks, policy perspectives, and just energy transition narratives. The red and green clusters also demonstrate substantial keyword presence, reflecting a significant research emphasis on the technical and environmental impacts of coal phase-out, particularly regarding emissions reduction, environmental impact, and energy security. The yellow cluster highlights research on energy systems and transition pathways, including coal reduction strategies and technologies such as energy storage. In contrast, the purple cluster contains the fewest keywords. As shown in Figure 2, these clusters illustrate strong linkages–among policy, technology, environment, and socio-economics aspects within energy transition research. The relative weight of each cluster reflects prevailing scholarly priorities and identifies areas requiring further investigation. Notably, research gaps persist within the Future and Climate Challenges theme of the purple cluster, as depicted in Figure 3, which is less explored than other themes. This underscores the need for additional research on long-term implications and future strategies.

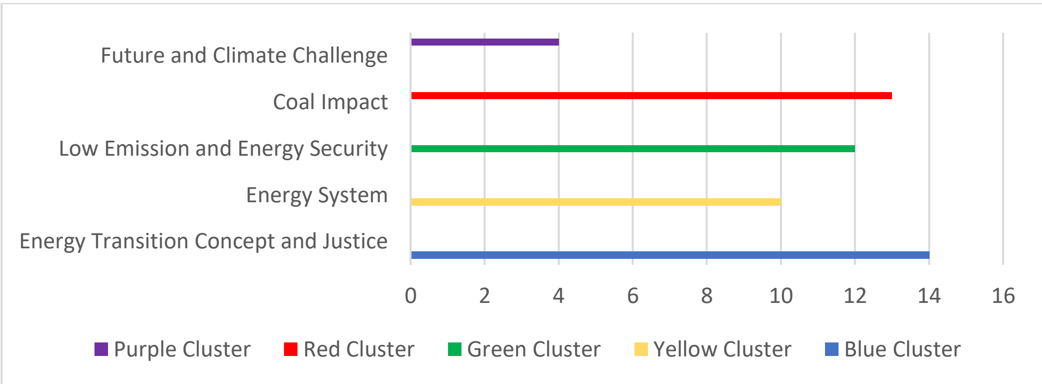

Figure 3. Visualization by clusters

A. Overlay Visualization and Trends in the Literature

The overlay visualization of keyword co-occurrence displays node size by frequency, while color indicates the average year of publication. This method improves cluster differentiation and enables direct mapping of temporal trends onto the network. Figure 4 presents the research distribution by publication year. In this co-occurrence network overlay, node size corresponds to frequency, link thickness represents association strength, and color denotes the average publication year.

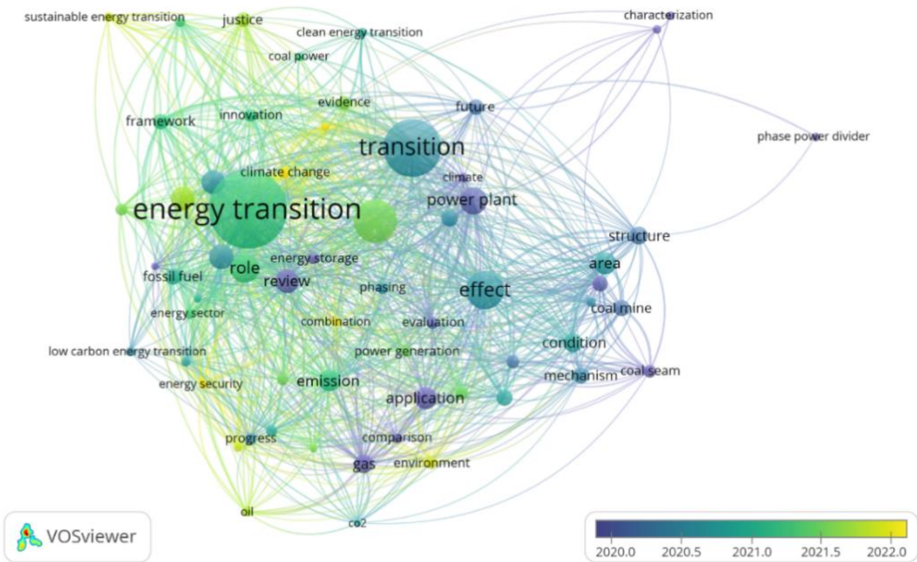

Figure 4. Overlay visualization of co-occurrence by the year

The visualization, indicated by brighter colors for the period 2020–2025, demonstrates a peak in awareness and publication growth regarding the early retirement of CFPPs and the coal phase-out around 2020. This is followed by fluctuating publication trends throughout 2025. Figure 4 indicates that research in this field requires ongoing updates to enrich the literature, expand knowledge, and foster innovation, thereby strengthening strategies for a sustainable energy transition.[16] The findings also reveal that the number of studies on energy development and renewable energy has increased significantly between 2019 and 2025, as illustrated in Figure 5.

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[16] Abdul Hayy Haziq Mohamad and Rossazana Ab-Rahim, "Mapping the Research Landscape of Energy Market and Renewable Energy: A Bibliometric Analysis," *International Journal of Renewable Energy Development* 14, no. 4 (2025): 703–16, https://doi.org/10.61435/ijred.2025.61058.

Figure 5. Trends Publication article related Early Retirement CFPP and coal phase-out by year

Recent research on energy transition has expanded significantly over the past four years, increasingly integrating new technologies, governance mechanisms, policy instruments, and digitalization as primary drivers.[17] Bibliometric analyses in Sub-Saharan Africa have identified emerging themes in sustainable energy transition and climate action through 2024, addressing existing gaps by offering a comprehensive overview of research developments in the region.[18] Additionally, studies on renewable energy and coal phase-out have identified the latest technological trends and innovations, such as advancements in solar, wind, biofuels, and geothermal systems, using bibliometric methods. These studies also emphasize future challenges, including integrating energy storage systems, ensuring grid connectivity, and achieving cost competitiveness. The bibliometric findings offer both academic insights and

[17] Xu Tian et al., "Nudging Sustainable Development: Reviewing Energy Transition and Economic Development," *Sustainability (Switzerland)* 16, no. 8 (2024): 2–15, https://doi.org/10.3390/su16083101.

[18] Enoch I. Obanor et al., "Bibliometric Analysis of Sustainable Energy Transition and Climate Action in Sub-Saharan Africa with a Focus on Nigeria," *Discover Energy* 5, no. 1 (2025): 2–19, https://doi.org/10.1007/s43937-025-00084-6.

practical strategies for guiding future directions in energy transition research.[19]

B. Trends Study by Countries

The distribution of the top ten publications across countries, as illustrated in Figure 6, demonstrates that research on energy transition and coal phase-out is primarily shaped by national energy challenges and policy objectives. China accounts for the largest share of publications, highlighting its efforts to balance rapid economic growth with commitments to carbon neutrality and coal reduction.[20] Germany ranks second, supported by the *Energiewende* framework, which has fostered sustained academic interest in coal retirement and the integration of renewable energy systems.[21]

India, the European Union, Poland, and the United Kingdom contribute moderately to the body of publications. South Africa's involvement underscores the growing importance of coal transition in coal-dependent developing economies.[22] Indonesia and Japan-demonstrate increasing research activity, particularly in response to emerging policies on early coal retirement and renewable energy. [23] Slovakia, a Central European country, accelerated its coal phase-out, moving the original target from

19 Dickson Boateng, "When Energy Transitions Are Unjust: Examining Actor Strategies and Household Engagement in Ghana's Clean Energy Shift," *Energy Reports* 14 (2025): 3390–3402, https://doi.org/10.1016/j.egyr.2025.10.009; Okeke Gerald Ndubuisi, Cynthia Amaka OBIORAH, and Theopillus Aku Ugah, "Renewable Energy and Sustainability: Emerging Trends and Technology," *International Journal of Innovative Human Ecology & Nature Studies* 13, no. 3 (2025): 15–24, https://doi.org/10.5281/zenodo.16094402.

20 Renzo Seminario-Córdova and Raúl Rojas-Ortega, "Renewable Energy Sources and Energy Production: A Bibliometric Analysis of the Last Five Years," *Sustainability* 15, no. 13 (2023): 4–20, https://doi.org/10.3390/su151310499.

21 Katja Heinisch, Oliver Holtemöller, and Christoph Schult, "Power Generation and Structural Change: Quantifying Economic Effects of the Coal Phase-out in Germany," *Energy Economics* 95 (March 1, 2021), https://doi.org/10.1016/j.eneco.2020.105008.

22 Tian et al., "Nudging Sustainable Development: Reviewing Energy Transition and Economic Development."

23 Tian et al.

2030 to 2024. The Nováky CFPP was closed in December 2023, followed by the Vojany plant in March 2024, effectively ending coal-based power generation in the national electricity system by 2024.[24] Also demonstrate that publication intensity correlates with national exposure to coal-related risks and transition opportunities. The literature is gradually shifting from technology-centric studies to more comprehensive analyses that incorporate governance, regulatory frameworks, social equity, and long-term sustainability. This trend indicates significant opportunities for further research, particularly regarding the early retirement of CFPPs and coal phase-out strategies in other countries.

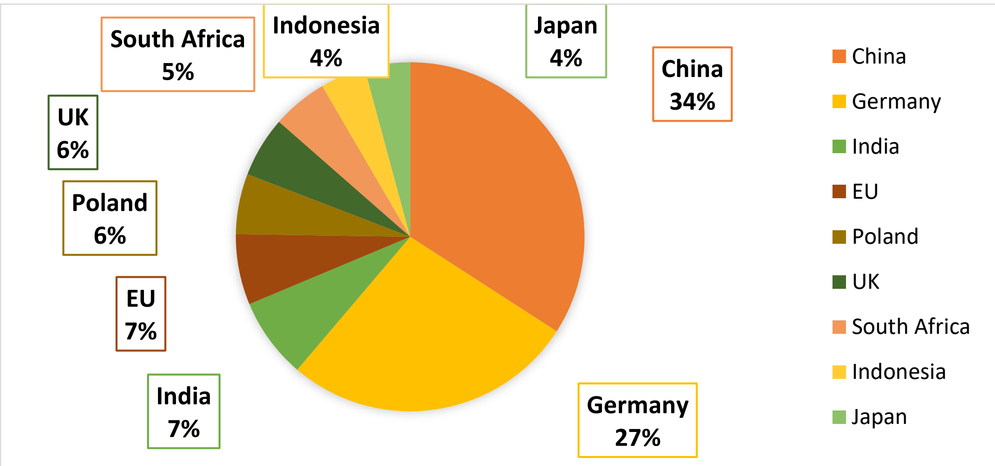

Figure 6. Publication article distribution based on countries

C. Energy transition concept framework

The energy transition is a key focus in recent publications, as many countries commit to reducing emissions in their energy sectors. Growing concerns about the negative impacts of fossil fuels, such as air pollution, climate change, and resource depletion, are accelerating the shift toward sustainability and clean energy. Notably, several countries have advanced the transition by phasing out coal, aligning these efforts with the broader framework concept.

The development illustrated in

24 IEA, "Energy Policy Review," 2024, www.iea.org.

Figure 7 has prompted numerous studies aimed at promoting the adoption of renewable energy to address primary energy consumption. An effective energy transition framework must integrate four interrelated dimensions:

1. Environmental impacts must be systematically assessed to ensure the effectiveness of decarbonization strategies.[25]
2. Robust legal foundations and coherent policy instruments are essential to guide implementation and provide regulatory certainty for stakeholders.[26]
3. Financial and fiscal mechanisms are critical, as the transition from fossil fuel systems requires long-term investment, effective management of transitional risk, and targeted incentives. These mechanisms include innovative financing instruments and green funding schemes.[27]
4. Regional support and compensation measures are essential to protect workers and communities affected by coal phase-out and structural socio-economic changes, including job losses. These components underscore that the energy transition is not solely a technological shift but also a socio-economic and institutional transformation that requires coordinated planning across environmental, regulatory, financial, and social dimensions.[28]

25 Darren McCauley and Raphael Heffron, "Just Transition: Integrating Climate, Energy and Environmental Justice," *International Energy Law* 119 (2018): 1–7, https://doi.org/10.1016/j.enpol.2018.04.014.

26 Francesca Diluiso et al., "Coal Transitions - Part 1: A Systematic Map and Review of Case Study Learnings from Regional, National, and Local Coal Phase-out Experiences," *Environmental Research Letters* 16, no. 11 (2021): 2–27.

27 Dr Paul Upham, Prof Benjamin Sovacool, and Dr Bipashyee Ghosh, "Just Transitions for Industrial Decarbonisation: A Framework for Innovation, Participation, and Justice," *Renewable and Sustainable Energy Reviews* 167 (2022), https://doi.org/10.1016/j.rser.2022.112699.

28 Karoline S. Rogge and Kristin Reichardt, "Policy Mixes for Sustainability Transitions: An Extended Concept and Framework for Analysis," *Research Policy* 45, no. 8 (2016): 1620–35, https://doi.org/10.1016/j.respol.2016.04.004.

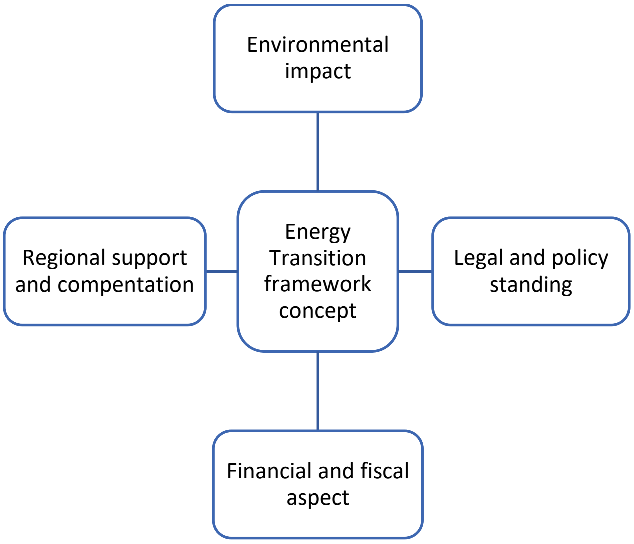

Figure 7. Energy transition concept framework

The case study examines the energy transition framework in developed countries, including Slovakia, Germany, and China, as presented in Table 2. The analysis addresses funding mechanisms, socio-economic impacts, and technological advancements.[29] Transitioning from fossil fuel to renewable energy has positive effects by supporting infrastructure development, advancing local and regional scientific research, and aligning with regional development priorities. In Slovakia, this transition is projected to reduce CO_2 emissions by 34% compared to scenarios reliant on fossil fuels. Despite these benefits, implementing the energy transition encounters challenges, particularly in securing sustainable funding due to the high investment costs associated with renewable energy plant projects. The transition also presents significant socio-economic implications for local communities, especially regarding employment. Companies are required to adapt their business strategies and value chains to mitigate these impacts and align with the ongoing shift.[30]

Climate policy has become increasingly significant in Germany. In line with its commitment to global emissions

29 IEA, "Energy Policy Review."

30 Hana Gerbelová, Amanda Spisto, and Sergio Giaccaria, "Regional Energy Transition: An Analytical Approach Applied to the Slovakian Coal Region," *Energies* 14, no. 1 (January 1, 2021), https://doi.org/10.3390/en14010110.

reduction, Germany established the Integrated Energy and Climate Programme (*Integrierte Energie-und Klimaprogramm*) in 2007, marking the inception of comprehensive climate policy by setting a target of 40% reduction in emissions in reductions by 2020.[31] From a long-term perspective, policy analysis considers the trajectory of coal use in relation to the Carbon Capture and Storage (CCS) scheme. Recent policy developments demonstrate a pronounced shift from CFPPs toward renewable energy sources such as wind and solar. This transition has substantial implications for coal-producing regions, where approximately 600,000 workers—face the risk of job and livelihood loss.[32] In response, the German Federal Government implemented labor compensation measures, particularly targeting lignite power plant operators and affected workers.[33]

China, which comprises 18% of the world's population and accounts for 26% of global primary energy use, is also implementing a coal phase-out scheme. The energy transition in China is a critical component of the country's commitment to achieving global emission-reduction targets.[34] Policy priorities are evident in a series of regulations aimed at reducing greenhouse gas (GHG) emissions by replacing coal with renewable energy sources. Under the 14th Five-Year Plan, China targets a 65% reduction in emissions by 2030 and seeks to achieve carbon neutrality by 2060.[35] The policy framework includes financial incentives supported by both national resources and international contributions, with G7 countries pledging up to 600 billion USD by 2027 through the Just Energy Transition Partnership (JETP) scheme. To mitigate the socio-economic impacts of the energy transition, the Chinese

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31 BMU, "Eckpunkte Für Ein IntegriertesEnergie-UndKlimaprogramm" (Berlin,Germany, 2007).

32 Oei, Brauers, and Herpich, "Lessons from Germany's Hard Coal Mining Phase-out: Policies and Transition from 1950 to 2018."

33 European Commission, "State Aid: Commission Opens in-Depth Investigation into Compensation for Early Closure of Lignite-Fired Power Plants in Germany," 2021, https://ec.europa.eu/commission/presscorner/detail/en/ip_21_972.

34 DNV, "Energy Transition Outlook 2024" (Hovik, 2024).

35 RMI, "Toward Net Zero: Decarbonization Roadmap for China's Cement Industry," 2022, https://rmi.org/insight/net-zero-decarbonization-in-chinas-cement-industry/.

government is focused on generating green jobs, providing re-skilling opportunities for affected workers through education and training, and improving infrastructure in regions previously dependent on coal mining. [36] [37] A comparative analysis of the frameworks in three countries is presented in Table 2.

Table 2 . Implementation of the energy transition framework in developed countries

Framework Concept: Environmental Impact	
Slovakia	A 34% reduction in carbon dioxide emissions from the national target has been achieved.[38]
German	Greenhouse gas emissions are targeted for reduction by 2020 and by 55% by 2050 relative to the national target.[39]
China	A 65% reduction in greenhouse gas emissions is targeted for 2030.[40]
Framework Concept: Legal and Policy Standing	
Slovakia	a. The Just Transition Mechanism (JTM) has been adopted as part of the European Green Deal.[41] b. National Energy and Climate Plans (NECP) set

[36] Weila Gong and Joanna I. Lewis, "The Politics of China's Just Transition and the Shift Away from Coal," *Energy Research and Social Science* 115 (September 1, 2024), https://doi.org/10.1016/j.erss.2024.103643.

[37] Niu Niu et al., "Ripple Effects of Coal Phaseout on Employment in China: From Mining to Coal Consumption Sectors," *Resources Policy* 97 (October 1, 2024), https://doi.org/10.1016/j.resourpol.2024.105290.

[38] Gerbelová, Spisto, and Giaccaria, "Regional Energy Transition: An Analytical Approach Applied to the Slovakian Coal Region."

[39] Katja Heinisch, Oliver Holtemöller, and Christoph Schult, "Power Generation and Structural Change: Quantifying Economic Effects of the Coal Phase-out in Germany," *Energy Economics* 95 (2021): 2–29, https://doi.org/10.1016/j.eneco.2020.105008.

[40] DNV, "Energy Transition Outlook 2024"; RMI, "Toward Net Zero: Decarbonization Roadmap for China's Cement Industry."

[41] Gerbelová, Spisto, and Giaccaria, "Regional Energy Transition: An Analytical Approach Applied to the Slovakian Coal Region."

	a national target reaching 19,2% by 2030 with the potential to accelerate to 20% through energy alternatives, and aim to achieve carbon neutrality by 2050.[42] [43] c. The Solvak Low Carbon Strategy outlines a comprehensive 30-year plan to facilitate the transition to a low-carbon economy.
German	a. The German Coal Exit Plan aims to decommission CFPP by 2038, with the potential to expedite this process by 2030.[44] b. Renewable Energy Sources Act (*EEG – Erneuerbare-Energien-Gesetz*) establishes an expansion target of at least 30% renewable energy in the electricity sector by 2030 and up to 80% by 2050.[45] c. Germany's international energy transition policy promotes multi-actor partnerships focused on global cooperation, technological innovation, and climate finance.[46]
China	a. A target has been set to reduce greenhouse gas emissions by 65% by 2030.[47] b. China's 14th Five-Year Plan outlines ambitious climate action key milestones set

42 Hedvika Koďousková and Dominik Bořuta, "Energy Poverty in Slovakia: Officially Defined, but Misrepresented in Major Policies," *Energy Policy* 168 (September 1, 2022), https://doi.org/10.1016/j.enpol.2022.113095.
43 Solvak Ministry of Economy, "Integrated National Energy and Climate Plan for 2021 to 2030" (Bratislava, 2019).
44 Heinisch, Holtemöller, and Schult, "Power Generation and Structural Change: Quantifying Economic Effects of the Coal Phase-out in Germany," 2021.
45 Wolfgang Gründinger, "The Renewable Energy Sources Act (EEG)," in *Drivers of Energy Transition* (Berlin: Springer Fachmedien Wiesbaden, 2017), 257–419, https://doi.org/10.1007/978-3-658-17691-4_6.
46 Karoline Steinbacher and Sybille Röhrkasten, "An Outlook on Germany's International Energy Transition Policy in the Years to Come: Solid Foundations and New Challenges," *Energy Research and Social Science* (Elsevier Ltd, March 1, 2019), https://doi.org/10.1016/j.erss.2018.10.013.
47 DNV, "Energy Transition Outlook 2024"; RMI, "Toward Net Zero: Decarbonization Roadmap for China's Cement Industry."

	for 2020, 2025, and 2030.[48] [49] c. China has committed, through its Nationally Determined Contribution (NDCs), to achieving peak carbon emission before 2030.[50] d. China has articulated a long-term vision to achieve carbon neutrality by 2060.[51]
Framework Concept: Financial and Fiscal Aspect	
Slovakia	a. Advocate for fiscal policies that reduce value-added tax (VAT) on heating and cooling services generated from renewable energy sources.[52] b. Implement a financial support mechanism from 2021 to 2030 to advance national priority projects focused on clean energy transition and the development of a low-carbon economy.[53] c. Allocate 459 million euros in Just Transition funding to facilitate the Upper Nitra region's shift toward a sustainable economic model.[54] [55]

48 Cameron Hepburn et al., "Towards Carbon Neutrality and China's 14th Five-Year Plan: Clean Energy Transition, Sustainable Urban Development, and Investment Priorities," *Environmental Science and Ecotechnology* (Editorial Board, Research of Environmental Sciences, October 1, 2021), https://doi.org/10.1016/j.ese.2021.100130.

49 Zhang and Chen, "Assessing the Energy Transition in China towards Carbon Neutrality with a Probabilistic Framework."

50 Hepburn et al., "Towards Carbon Neutrality and China's 14th Five-Year Plan: Clean Energy Transition, Sustainable Urban Development, and Investment Priorities."

51 Zhang and Chen, "Assessing the Energy Transition in China towards Carbon Neutrality with a Probabilistic Framework."

52 Solvak Ministry of Economy, "Integrated National Energy and Climate Plan for 2021 to 2030."

53 Solvak Ministry of Economy.

54 Callum Coghlan and Geoffrey Ho, "Approaches for Funding Just Transition Fund Projects A Catalogue for Just Transition Regions Approaches for Funding Just Transition Fund Projects," 2023.

55 European Commission, "EU Cohesion Policy: €459 Million for a Just Climate Transition in Slovakia," November 24, 2022, https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7086.

German	a. Investment Law for Coal Regions allocates up to 40 billion euros in support for areas affected by CFPP and lignite mining, with funding available until 2038. b. A feed-in-tariffs mechanism incentivizes electricity generation from renewable energy sources.[56] c. Financial support is provided for creating green jobs, as well as subsidies for sustainable transport and the development of green infrastructure.[57]
China	a. Public and Private investment, facilitated through G7-funded project priorities, is projected to reach 600 billion USD by 2027, in alignment with commitments under the Just Energy Transition Partnership (JETP).[58] [59] b. Market-based economic incentives for the renewable energy sector are implemented through subsidies at both the central and provincial levels.[60]
Framework Concept: Regional support and compensation	
Slovakia	a. The Just Transition Fund (JTF) provides support for the development of labor skills and the creation of new jobs within the green sector. b. The initiative aims to facilitate potential job creation to support the regional sector's transition.

56 Christoph Böhringer et al., "The Impact of the German Feed-in Tariff Scheme on Innovation: Evidence Based on Patent Filings in Renewable Energy Technologies," *Energy Economics* 67 (September 1, 2017): 545–53, https://doi.org/10.1016/j.eneco.2017.09.001.

57 Pao Yu Oei et al., "Coal Phase-out in Germany – Implications and Policies for Affected Regions," *Energy* 196 (April 1, 2020), https://doi.org/10.1016/j.energy.2020.117004.

58 DNV, "Energy Transition Outlook 2024."

59 RMI, "Toward Net Zero: Decarbonization Roadmap for China's Cement Industry."

60 RMI.

	c. Support is provided for the development of new expertise and re-skilling initiatives targeting individuals exposed to unemployment.[61]
German	a. Labour compensation is provided to support workers who become unemployed as a result of coal sector restructuring.[62] b. Training and education programs are implemented to support affected communities. c. Operators of lignite-fired power plants receive compensation totaling 4.35 billion euros. [63]
China	a. Providing significant employment opportunities in the renewable energy sector through vocational and educational training initiatives.[64] b. Facilitating the relocation of mining communities and implementing infrastructure improvements in remote coal mining regions.[65]

Source: Cited by Authors, 2026 (edited)

D. Development of the Energy Transition Mechanism (ETM) in Indonesia

Indonesia has revised its Nationally Determined Contribution (NDC) emission-reduction targets to reflect evolving national

61 Gerbelová, Spisto, and Giaccaria, "Regional Energy Transition: An Analytical Approach Applied to the Slovakian Coal Region."
62 Oei et al., "Coal Phase-out in Germany – Implications and Policies for Affected Regions."
63 European Commission, "State Aid: Commission Opens in-Depth Investigation into Compensation for Early Closure of Lignite-Fired Power Plants in Germany."
64 Niu et al., "Ripple Effects of Coal Phaseout on Employment in China: From Mining to Coal Consumption Sectors."
65 Gong and Lewis, "The Politics of China's Just Transition and the Shift Away from Coal."

and international climate agendas. The government has introduced additional mitigation targets and adaptation priorities, including efforts to strengthen climate resilience and enhance the welfare of vulnerable communities. The GHG emission-reduction target is specified in Indonesia's Enhanced Nationally Determined Contribution (ENDC), which sets a target of 31.89% (an increase from 29%) based on the country's capabilities, and 43.20% (up from 41%) with international support. Consistent with the ENDC, the energy sector plays a pivotal role in achieving national emissions reduction. Indonesia is pursuing this objective through the Coal Early Retirement Initiative, which employs the Energy Transition Mechanism (ETM). This collaborative program transitions to renewable energy by leveraging market-based mechanisms to fund the phase-out of CFPPs and facilitate the development of cleaner energy sources.

ETM forms part of a comprehensive regional strategy to address the impacts of climate change. From a financing perspective, effective implementation of the ETM depends on regulatory consistency and sustained funding. Indonesia, through the National Electricity Supply Business Plan (RUPTL) for 2021–2030, intends to halt the development of new on-grid CFPPs and supports a moratorium on their construction. Presidential Regulation No. 112/2022 further facilitates this transition by accelerating the development of renewable energy power plants, regulating the early retirement of CFPPs, and restricting the development of new CFPPs under specific conditions.

The regulation mandates that CFPPs reduce greenhouse gas (GHG) emissions by at least 35% within 10 years of commencing operations. Additionally, CFPPs must cease operation no later than 2050. The state electricity company, PLN, is responsible for implementing the accelerated early retirement of CFPPs, including those owned by the company and those operating under contractual agreements. The selection process for early retirement considers factors such as plant capacity, age, utilization rate, GHG emission intensity, the availability of domestic and international financing, and access to relevant technologies. As a derivative policy, the Minister of Energy and Mineral Resources Regulation No. 10 of 2025 establishes a technical roadmap to accelerate the energy transition agenda. The regulation requires adequate financial support for CFPP early retirement. Alternative financing mechanisms that do not rely on the state budget enable Indonesia to fund green projects through blended finance schemes. In collaboration with the World Bank Group, Asian Development Bank (ADB), and Islamic Development Bank, Indonesia has introduced a green financing facility with an initial fund of USD 500 million. This initiative aims to attract up to USD 4 billion in soft loans to support early coal plant retirement and promote investment in environmentally friendly electricity generation technologies. This approach enables Indonesia to attract foreign investment while supporting its national sustainability goals.[66] In addition, roadmap 10/2025 regulates the implementation of early CFPP retirement through comprehensive assessments covering technical, legal, commercial, financial, and governance aspects, in line with the framework shown in Figure 7. However, the regulation does not fully address environmental impacts or the protection of local communities affected by the transition. The principles and criteria for a just energy transition are not clearly defined, especially regarding institutional commitments and mechanisms to address the socio-economic impacts of early CFPP retirement.

The adoption of advanced renewable technologies, coupled with the increasing complexity of the transition, introduces uncertainties. The energy transition entails replacing conventional technologies with advanced alternatives, emphasizing sustainable resources to address climate change.[67] The risks inherent in developing and implementing these technologies pose substantial challenges during the transition from fossil fuels to renewable energy sources. For example, Ulrich Beck's concept of social risk and modernization suggests that the linear development model, which assumes continuous techno-scientific progress, has increased levels of uncertainty

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[66] Resosudarmo, Rezki, and Effendi, "Prospects of Energy Transition in Indonesia."

[67] Tadeusz Józef Rudek and Hui Tzu Huang, "Future at Play: Applying Reflexive Public Reason in the Case of Taiwanese Energy Transition," *Energy Research and Social Science* 106 (2023), https://doi.org/10.1016/j.erss.2023.103325.

and risk.[68] Replacing existing technologies requires substantial investment, which is closely linked to financial risks associated with technology development. In Indonesia, Minister of Finance Regulation No. 103/2023 serves as the legal foundation for ETM implementation by appointing PT SMI as the ETM Country Platform Manager, responsible for managing blended finance schemes and fiscal support for energy transition projects. Investment guarantees and risk management mechanisms are administered by the Directorate General of Budget Financing and Risk Management (DJPPR) to enhance investor confidence. Through the Energy Transition Platform facility, the government may also provide guarantees for infrastructure financing obtained through direct loans from international financial institutions and other financing support mechanisms. However, despite the establishment of ETM financing mechanisms in Indonesia, significant gaps persist in investor guarantee schemes, particularly concerning sovereign guarantees, risk-sharing arrangements, and the integration of just transition principles into energy transition financing frameworks.

Financial instruments, including credit and green financing, play a crucial role in mitigating the risks and uncertainties associated with technological innovation and transition.[69] Furthermore, technological advancement is shaped by geopolitical factors. Heightened geopolitical risks, such as the threat of war and political tensions between nations, may impede progress in the energy transition by increasing uncertainty and diminishing the appeal of renewable energy investments. The advancement of new energy technologies, such as solar panels and lithium batteries, depends on raw materials like lithium, cobalt, and nickel, which are either in limited supply or concentrated in a small number of countries.[70] As a result,

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68 Rudek and Huang.

69 Haiying Liu et al., "Transformational Insurance and Green Credit Incentive Policies as Financial Mechanisms for Green Energy Transitions and Low-Carbon Economic Development," *Energy Economics* 126 (October 2023), https://doi.org/10.1016/j.eneco.2023.107016.

70 Qiang Wang, Chen Zhang, and Rongrong Li, "Impact of Different Geopolitical Factors on the Energy Transition: The Role of Geopolitical Threats, Geopolitical Acts, and Geopolitical Risks," *Journal of*

geopolitical dynamics influence national resource dependencies, and supply instability, as well as geopolitically driven market fluctuations, can significantly affect the development of clean technologies.

E. Coal-Phase Out Opportunities and Concept

The coal phase-out concept refers to an environmental policy strategy designed to end coal combustion in coal-fired power plants, thereby advancing the broader objective of eliminating fossil fuel use.[71] The International Energy Agency (IEA) defines coal phase-out as a scenario in which all pathways aligned with climate targets require a rapid reduction in coal consumption. In these scenarios, the energy system systematically eliminates unabated coal and replaces it with cleaner, more efficient low-emission energy sources (IEA, 2021). The concept encompasses two primary aspects: (1) halting the construction of new coal-fired power plants and (2) managing the reduction of emissions from existing facilities. According to IEA projections, unabated coal use is expected to decrease by approximately 5% by 2030 under the Stated Policies Scenario (STEPS) and by nearly 10% under the Announced Pledges Scenario (APS) (IEA, 2021). The coal phase-out framework also emphasizes a managed transition that incorporates economic, social, and institutional factors. Common policy instruments include the early retirement of CFPPs, a moratorium on new coal investments, and the replacement of coal capacity with renewable energy sources and supporting infrastructure.[72]

In several European countries, coal phase-out has emerged as a central strategy for reducing greenhouse gas emissions. This policy approach seeks to eliminate coal use in power generation and other energy sectors in alignment with global climate

Environmental Management 352 (2024), https://doi.org/10.1016/j.jenvman.2023.119962.

[71] Zach Stein, “Coal Phase-Out,” Carbon Collective, 2023, https://www.carboncollective.co/sustainable-investing/coal-phase-out.

[72] Bin Zhang et al., “Assessing the Efforts of Coal Phaseout for Carbon Neutrality in China,” *Applied Energy* 352 (2023): 1–10, https://doi.org/10.1016/j.apenergy.2023.121924.

mitigation commitments.[73] The strategy aims to achieve significant reductions in CO_2 emissions from the electricity sector while simultaneously expanding of renewable energy capacity, enhancing energy system efficiency, and encouraging sustainable investment in clean technologies. Evidence from Germany indicates that socially inclusive transition policies can improve the quality of life.[74] Germany's Coal Exit Strategy provides comprehensive compensation mechanisms for regions and workers affected by the closure of CFPPs. Regions such as North Rhine-Westphalia, Brandenburg, Saxony, and Saxony-Anhalt have historically depended on coal mining for employment and economic activity. To mitigate the socio-economic consequences of this transition, the German Federal Government has allocated more than EUR 40 billion to facilitate the development of new industries, retrain workers, and invest in infrastructure projects that support renewable energy and sustainable economic growth.[75] [76] The implementation of coal phase-out policies can yield substantial public health benefits by reducing air pollution, while also creating employment opportunities in the renewable energy sector and fostering local economic growth through just transition initiatives. Accelerating coal reduction is increasingly seen as essential to long-term climate strategies. However, structural economic factors and institutional interests may slow or limit phaseout efforts.[77] [78]

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73 Ali Kinyar, Keith Bothongo, and Nadia Doytch, "Rebound in Oil and Natural Gas Emissions amid Coal-Phase out: Implications for the UK's Net-Zero Strategy," *Energy* 336 (2025): 17–19, https://doi.org/10.1016/j.energy.2025.138506.

74 Oei, Brauers, and Herpich, "Lessons from Germany's Hard Coal Mining Phase-out: Policies and Transition from 1950 to 2018."

75 Oei et al., "Coal Phase-out in Germany – Implications and Policies for Affected Regions."

76 ZSW and BDEW, "Renewable Energies Covered More than Half of Electricity Consumption for the First Time in 2023."

77 Sugandha Srivastav and Michael Zaehringer, "The Economics of Coal Phaseouts: Auctions as a Novel Policy Instrument for the Energy Transition," *Climate Policy*, 2024, 1–12, https://doi.org/https://doi.org/10.1080/14693062.2024.2358114.

78 Jan Christoph Steckel, Ottmar Edenhofer, and Michael Jakob, "Drivers for the Renaissance of Coal," *Proceedings of the National Academy of Sciences of the United States of America* 112, no. 29 (2015): E3775–81, https://doi.org/10.1073/pnas.1422722112.

Coal phase-out has become a central strategy within global energy transition pathways, aiming to achieve climate mitigation targets and transform national energy systems toward greener alternatives. Although coal has served as a reliable base load energy source, especially in developing countries, it remains the largest contributor to global energy-related CO_2 emissions.[79] Several advanced economies have joined the Powering Past Coal Alliance (PPCA). During COP23, the United Kingdom and Canada advocated for "anti-fossil-fuel norms" (AFFN), presenting fossil fuel dependence as a constraint to be addressed within climate policy.[80] Through domestic mobilization and international diffusion, these norms may become key instruments in global energy transition regulations for the phase-out of coal. For many non-member countries seeking to eliminate coal dependency, this presents a significant policy challenge that must be overcome to achieve net-zero emissions (NZE) by 2050 and mitigate climate change.

The coal phase-out paradigm has led to the development of a complementary approach, wherein limited resources are strategically allocated to integrate energy systems while gradually reducing coal dependence. Numerous countries are adopting a coal phase-down (CPD) pathway, which emphasizes the progressive reduction of coal consumption alongside the expansion of renewable energy capacity.[81] [82] [83] Evidence from China demonstrates that CPD scenarios, driven by cost mechanisms or technological innovation, can accelerate

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[79] Kinyar, Bothongo, and Doytch, "Rebound in Oil and Natural Gas Emissions amid Coal-Phase out: Implications for the UK's Net-Zero Strategy."

[80] Fergus Green, "Anti-Fossil Fuel Norms," *Climatic Change* 150, no. 1–2 (September 1, 2018): 103–16, https://doi.org/10.1007/s10584-017-2134-6.

[81] James R. Mihelcic et al., "Accelerating Environmental Research to Achieve Sustainable Development Goals," *Environmental Science and Technology* 57, no. 45 (2023): 17167–68, https://doi.org/10.1021/acs.est.3c08894.

[82] Yan Nie et al., "Characteristics and Mechanism Analysis of the Clean Evolution of China's Power Generation Structure," *Journal of Cleaner Production* 457 (2024): 1–4.

[83] Zhang et al., "Assessing the Efforts of Coal Phaseout for Carbon Neutrality in China."

emissions reduction and enhance resource efficiency. Previous research has primarily examined CPD within narrow parameters, focusing on GHG reductions, health benefits, and improvements in air quality.[84] [85] In addition to these sector-specific analyses, recent studies suggest that CPD supports progress toward Sustainable Development Goals (SDGs) 7 (Affordable and Clean Energy) and 13 (Climate Action), although certain trade-offs may persist with other development objectives.[86]

Indonesia, a middle-income country, has significant opportunities to advance its transition toward sustainable energy. A primary focus is the adoption of electric vehicles, with national targets set at 2.1 million two-wheeled units and 2,200 four-wheeled units by 2025.[87] To facilitate this objective, the government has implemented reduced taxation on electric vehicles (EVs), which are considered more fuel-efficient than conventional vehicles. In the power generation sector, a transition from CFPPs to new and renewable energy sources is anticipated to support a cleaner energy system. As an archipelagic nation, Indonesia has substantial land and marine resources suitable for renewable energy power generation.[88] By early 2023, the estimated potential for renewable energy development in Indonesia reached 3,687 GW, although only approximately 12,736.6 MW had been newly utilized. Solar energy represents the largest renewable potential at 3,296 GW,

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[84] Sebastian Rauner et al., "Coal-Exit Health and Environmental Damage Reductions Outweigh Economic Impacts," *Nature Climate Change* 10 (2020): 308–12.

[85] Jon Sampedro et al., "Quantifying the Reductions in Mortality from Air-Pollution by Cancelling New Coal Power Plants," *Energy and Climate Change* 2 (December 2021): 1, https://doi.org/10.1016/j.egycc.2020.100023.

[86] Zhang et al., "Assessing the Efforts of Coal Phaseout for Carbon Neutrality in China."

[87] Martha Widhi Dela Utami, Yuniaristanto, and Wahyudi Sutopo, "Adoption Intention Model of Electric Vehicle in Indonesia," *Jurnal Optimasi Sistem Industri* 19, no. 1 (June 1, 2020): 70–81, https://doi.org/10.25077/josi.v19.n1.p70-81.2020.

[88] Jannis Langer, Jaco Quist, and Kornelis Blok, "Review of Renewable Energy Potentials in Indonesia and Their Contribution to a 100% Renewable Electricity System," *Energies* 14, no. 21 (2021): 2–21, https://doi.org/10.3390/en14217033.

followed by wind at 155 GW, hydro-power at 95 GW, and marine energy at 63 GW.[89] The development of renewable energy is contingent upon the availability of natural resources and prevailing conditions. Consequently, replacing fossil fuels necessitates a significantly greater installed capacity to ensure system reliability and address the inherent variability of renewable resources. Currently, Indonesia's new and renewable energy development efforts are primarily concentrated on biogas and waste-to-energy utilization.[90]

The energy sector plays a pivotal role in sustaining economic activity. Investments in clean energy, with multiplier effects within communities, promote green job creation and stimulate innovation, thereby contributing to economic growth.[91] [92] Transitioning to renewable energy provides an opportunity to reduce reliance on coal and advance sustainable development. Nevertheless, the energy transition requires pragmatic policy frameworks that incorporate cross-sectoral considerations. Simultaneously, the coal sector is likely to experience substantial job displacement, necessitating strategies to ensure a just and inclusive transition.[93]

The development of clean energy creates new employment opportunities in the renewable energy sector.[94] A case study conducted in China demonstrates that the renewable energy

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89 Erdiwansyah et al., "Prospects for Renewable Energy Sources from Biomass Waste in Indonesia," *Case Studies in Chemical and Environmental Engineering* 10 (December 1, 2024), https://doi.org/10.1016/j.cscee.2024.100880.

90 David Firnando Silalahi et al., "Indonesia's Vast Solar Energy Potential," *Energies* 14, no. 17 (September 1, 2021), https://doi.org/10.3390/en14175424.

91 IRENA and ILO, "Renewable Energy and Jobs: Annual Review 2023, International Renewable Energy Agency, Abu Dhabi and International Labour Organization" (Geneva, 2023), www.irena.org.

92 Nie et al., "Characteristics and Mechanism Analysis of the Clean Evolution of China's Power Generation Structure."

93 Sandeep Pai et al., "Solar Has Greater Techno-Economic Resource Suitability than Wind for Replacing Coal Mining Jobs," *Environmental Research Letters* 15, no. 3 (2020): 2–7, https://doi.org/10.1088/1748-9326/ab6c6d.

94 Agus Setiawan, "Identification of Green Skills Acquisition in Indonesian TVET Curricula," in *AIP Conference Proceedings*, vol. 1887 (American Institute of Physics Inc., 2017), https://doi.org/10.1063/1.5003557.

sector has the potential to generate approximately 5.5 million jobs across various domains, including geothermal, biomass, hydrogen, wind, hydro, and solar energy. Projections indicate an uneven distribution of these jobs, with approximately 2.76 million in photovoltaic, 0.88 million in hydro-power, and 0.68 million in wind energy.[95]

F. Energy Transition Risk

In accordance with global commitments to mitigate climate change, many countries encounter significant challenges. Developing nations, in particular, may face obstacles in implementing energy transition policies due to limited capacity and resources. Key risks associated with these policies include financial, social, and technological uncertainties.[96] The financial sector is especially vulnerable during the energy transition, as it reflects a country's ability to invest in renewable energy development. Financial sector risks can be categorized into physical and transition risks. Transition risks emerge from policies designed to shift from fossil fuels to green energy. These risks impact the financial and banking sectors, where environmental externalities are recognized as risk factors that may reduce returns. Financial risks encompass market risk, loan risk, production operation risk, and financial recovery risk.[97]

Transition risks can result in a social phenomenon known as "not-in-my-backyard" (NIMBY).[98] This phenomenon often arises from policies related to the adoption of renewable energy, such as the installation of solar panels or wind turbines. Excluding

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95 Tong Zhang, Paul J. Burke, and Qi Wang, "Effectiveness of Electric Vehicle Subsidies in China: A Three-Dimensional Panel Study," *Resource and Energy Economics* 76 (February 1, 2024), https://doi.org/10.1016/j.reseneeco.2023.101424.

96 Laima Eicke and Andreas Goldthau, "Are We at Risk of an Uneven Low-Carbon Transition? Assessing Evidence from a Mixed-Method Elite Study," *Environmental Science and Policy* 124 (2021): 370–74, https://doi.org/10.1016/j.envsci.2021.07.009.

97 Syaiful Habib, "Profil Dan Analisa Risiko Transisi Pada Level Global," *Energy Justice* 1, no. 1 (2024): 1–14, https://doi.org/10.61511/enjust.v1i1.2024.622.

98 Michael Faure, "Energy Transition and Risk Analysis: A Commentary," *Journal of Risk Research* 27, no. 5–6 (2024): 1–4.

local communities from the decision-making process can create communication risks, which may lead to social conflicts and resistance from those who perceive the project as a threat. This underscores the importance of effective communication at the project site to prevent social risks that could significantly delay or derail project implementation.[99] Consequently, involving the community during the pre-assessment phase through mapping, participatory decision-making, and the provision of fair compensation is essential for mitigating these social risks.

The energy transition significantly affects previously prosperous industries, such as coal mining, which now face considerable threats. A decline in coal demand from CFPPs will reduce the market's need for raw materials.[100] This shift presents a substantial risk of job displacement, as individuals employed in these sectors may lose their livelihoods.[101] The resulting job losses in the mining sector are expected to exert socio-economic pressure on affected communities.[102] Conversely, substantial evidence indicates that the renewable energy industry generates numerous opportunities for green jobs. Effective risk mitigation is necessary to address these challenges and ensure that affected communities can adapt without market opportunities. Workers transitioning to new roles often experience lower wages than in their previous positions, resulting in skill and income gaps. Furthermore, replacement jobs may require longer working hours or more demanding conditions.

Conclusion

Indonesia, through the ETM, has initiated key measures to

99 Faure.

100 Sanya Carley and David M. Konisky, "The Justice and Equity Implications of the Clean Energy Transition," *Nature Energy* 5, no. 8 (August 1, 2020): 569–77.

101 Sanya Carley, Tom P. Evans, and David M. Konisky, "Adaptation, Culture, and the Energy Transition in American Coal Country," *Energy Research and Social Science* 37 (2018): 133–39, https://doi.org/10.1016/j.erss.2017.10.007.

102 Lachlan Cameron and Bob Van Der Zwaan, "Employment Factors for Wind and Solar Energy Technologies: A Literature Review," *Renewable and Sustainable Energy Reviews* 45 (2015): 160–72, https://doi.org/10.1016/j.rser.2015.01.001.

accelerate early coal retirement and enhance the renewable energy mix. Despite these advancements, the country's energy transition faces persistent challenges, including a high reliance on coal, restricted access to sustainable financing, and considerable social risks associated with workforce displacement. The following lessons learned and recommendations are derived from relevant case studies:

1) Evidence from developed countries indicates that the effectiveness of early retirement of CFPPs relies on the establishment of a comprehensive policy framework.
2) In addition to pursuing coal phase-out, Indonesia may adopt a coal phase-down approach, which gradually reduces coal use while integrating a renewable energy mix. This strategy promotes long-term environmental sustainability and aligns with national targets.
3) The framework should be consistent with existing legal and regulatory structures, account for fiscal and financial capacities, and address potential adverse social consequences by providing sufficient support and compensation to affected communities. Evidence from developed countries indicates that worker retraining programs, compensation schemes, and the revitalization of former mining regions can substantially reduce social resistance and conflict. Therefore, energy transition policies in Indonesia should prioritize a just transition in policy design to ensure that social protection and livelihoods are comprehensively addressed throughout the transition process.
4) Effective coordination among stakeholders, combined with strong institutional governance, facilitates the accelerated implementation of energy transition policies.
5) In the absence of robust financing frameworks, including blended finance for ETM schemes supported by both domestic and international sources, the early retirement of CFPPs may result in significant financial burdens.

The gradual reduction in coal usage presents Indonesia with strategic opportunities to transform its energy system into a more sustainable model. This transition enables the accelerated deployment of solar, wind, and geothermal energy, supported by stronger grid interconnections and advanced energy storage solutions that can improve long-term reliability. These advantages are further reinforced by reductions in air pollution, which can decrease public health burdens and external costs, while also strengthening national climate commitments. With consistent, inclusive transition policies, Indonesia has the potential to become a successful example of reducing coal dependency and enhancing its position in international climate diplomacy. Furthermore, innovative financing mechanisms, such as blended finance, offer opportunities to accelerate the early retirement of CFPPs without imposing significant fiscal burdens, while simultaneously attracting private investment and advancing the shift toward a cleaner, more resilient energy sector.

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Böhringer, Christoph, Alexander Cuntz, Dietmar Harhoff, and Emmanuel Asane-Otoo. "The Impact of the German Feed-in Tariff Scheme on Innovation: Evidence Based on Patent Filings in Renewable Energy Technologies." *Energy Economics* 67 (September 1, 2017): 545–53. https://doi.org/10.1016/j.eneco.2017.09.001.

Cameron, Lachlan, and Bob Van Der Zwaan. "Employment Factors for Wind and Solar Energy Technologies: A Literature Review." *Renewable and Sustainable Energy Reviews* 45 (2015): 160–72. https://doi.org/10.1016/j.rser.2015.01.001.

Carley, Sanya, Tom P. Evans, and David M. Konisky. "Adaptation, Culture, and the Energy Transition in American Coal Country." *Energy Research and Social Science* 37 (2018): 133–39. https://doi.org/10.1016/j.erss.2017.10.007.

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