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Early Retirement Policy of Power Plant In Pelabuhan Ratu: A Multi-Level Governance Analysis To Support The Energy Transition In Indonesia

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early retirement, multi-level governance, energy transition, PLTU pelabuhan ratu, decarbonization

ABSTRACT
The early retirement policy of the Pelabuhan Ratu Steam Power Plant (PLTU) with a capacity of 3x350 MW is one of the strategic steps in supporting Indonesia's energy transition towards a low-carbon energy system. This research uses a multi-level governance framework to analyze the roles of various actors, levels of government, and relationships between stakeholders in the formulation of this policy. With a qualitative method approach, this research combines bibliometric analysis to map the development of global literature related to early retirement PLTU and comparative case studies of similar policies in other countries. The results identify key challenges, such as regulation, financing, and governance transparency, as well as key success factors, including community engagement and international support. The study also examines the impact of policy implementation on power sector decarbonization, air quality, and greenhouse gas emission reduction. The research findings provide recommendations to improve the effectiveness of energy transition policies in Indonesia, while contributing to the achievement of Nationally Determined Contributions (NDC) targets and transformation towards a sustainable energy system. This research is expected to be a practical reference for the government, PT PLN, investors, and international organizations in promoting a more inclusive and integrated energy transition.

Introduction

Coal-fired power plants have long been the backbone of Indonesia's electricity sector. According to data from the Ministry of Energy and Mineral Resources (MEMR, 2022), coal-fired power plants account for around 60% of the total national electricity generation capacity. However, the high dependence on coal-fired power plants has caused

various problems, especially environmental aspects. Coal-fired power plants are one of the main contributors to greenhouse gas emissions in Indonesia. A study conducted by Pertamina Energy Institute (2022) shows that the energy sector, especially coal-fired power plants, contributes around 65% of total national CO2 emissions. In addition, the operation of coal-fired power plants also has an impact on air quality and public health around the plant (Sanchez & Luan, 2018).

Responding to the global challenge of climate change, Indonesia has committed to reduce its greenhouse gas emissions by 29% by 2030 through its own efforts, or up to 41% with international support (Indonesia's NDC, 2022). To achieve this target, the Indonesian government has announced plans to build no new coal-fired power plants after 2023 and to target net zero emissions by 2060 or sooner (RUPTL PLN 2021-2030; Efendi, 2023). On the other hand, the declining cost of renewable energy technologies has the potential to change the landscape of the power sector. A report by the International Renewable Energy Agency (IRENA, 2023) indicates that the cost of generating electricity from renewable energy sources, such as solar and wind power, is now more competitive than new coal-fired power plants in many countries, including Indonesia (Marzouk, 2024).

Thus, efforts to decarbonize the electricity sector and energy transition in Indonesia are not only an imperative in the context of mitigating global climate change, but also a potential catalyst for transformation towards a more sustainable, efficient and competitive energy system in the future (IRENA, 2023). Currently, there are various alternative decarbonization and energy transition options that are developing, including operational management efficiency (IEA, 2021), development of renewable resources (ESDM, 2022), and early retirement of PLTU (ADB, 2022).

In this context, the concept of early retirement has emerged as a potential strategy to accelerate the energy transition. Early retirement involves the closure of a coal-fired power plant before the end of its planned operational life, usually accompanied by financial compensation to the plant owner (Nacke, 2020). This approach has been implemented in several countries, such as Germany and the UK, as part of the power sector decarbonization strategy (Bang et al., 2022). In Indonesia, the discourse of early retirement of PLTU has begun to receive serious attention from stakeholders. In 2021, the Indonesian government together with the Asian Development Bank (ADB) announced the Energy Transition Mechanism (ETM) program, one of the components of which is a financing scheme for the early retirement of PLTU (Ministry of Finance, 2021). However, the implementation of this policy faces various challenges, including specific technical, economic and legal certainty aspects (Resosudarmo et al., 2023).

Another important aspect is the compatibility of PLTU's early retirement policy with Indonesia's international commitments. Indonesia's updated Nationally Determined Contribution (NDC) in 2021 emphasizes the role of the energy transition in achieving emissions reduction targets. However, a study by Climate Transparency (2022) indicates that without accelerated retirements, Indonesia risks not achieving its NDC targets. Furthermore, issues of governance and transparency in the decision-making process are crucial. Experiences from power sector restructuring programs in various countries, as reported by the World Bank (2023), show that stakeholder engagement and strong oversight mechanisms are essential to avoid conflicts of interest and ensure accountability in policy implementation.

Despite the growing trend of research on power plant early retirement (Firdaus & Mori, 2023; Muchiri et al., 2022) and multi-level governance in energy transition

(Goldthau, 2014), there is still a gap in the understanding of the application of these concepts in the Indonesian context (Maamoun et al., 2020; Park et al., 2023). This research aims to fill this gap by focusing on the case study of PLTU Pelabuhan Ratu, analyzing the dynamics of multi-level governance, and comparing it with the design and formulation of early retirement policies in other countries, especially in developing countries. The results of this research are expected to contribute significantly to the understanding of PLTU early retirement policy design in the context of multi-level governance, as well as provide practical recommendations for the development of an effective energy transition strategy in Indonesia. The objectives of this research include:

1. Identify and analyze the performance of multi-level governance and key factors that influence the formulation process and policy design of early retirement of PLTU Pelabuhan Ratu 3x350 MW in the context of energy transition in Indonesia.
2. Conduct a comparative analysis between the draft early retirement policy of PLTU Pelabuhan Ratu and policies in other PLTUs globally, and examine the development of research trends related to this policy reflected in the Indonesian context.

According to Nacke (2020), early retirement of coal-fired power plants is a crucial strategy to support the transition to renewable energy and decarbonize the power sector, as it helps reduce emissions and improve air quality. Nacke highlights that the policy faces several challenges, including the high costs of early retirement and the need for adequate financing mechanisms. Similarly, Goldthau (2014) emphasizes that multi-level governance plays a pivotal role in shaping energy transition policies, as it facilitates collaboration between various levels of government, private sector, and international organizations to achieve sustainable energy solutions.

The urgency of this research arises from Indonesia's commitment to reducing greenhouse gas emissions and transitioning towards renewable energy, which necessitates the early retirement of coal-fired power plants. The Pelabuhan Ratu PLTU is a critical case study as it faces challenges related to financing, governance, and the socio-economic impacts of such a transition. Understanding how multi-level governance can support the successful implementation of early retirement policies is vital for accelerating Indonesia's energy transition while ensuring a just and sustainable transformation.

While the global discourse on energy transition and early retirement policies has gained traction, there is limited research on the application of multi-level governance in the context of Indonesia's energy transition, particularly regarding the early retirement of coal-fired power plants. Most studies focus on the theoretical aspects of energy transition, without adequately addressing the practical challenges of policy implementation and coordination among different governance levels. This study aims to fill this gap by exploring the dynamics of multi-level governance in the formulation of early retirement policies for Pelabuhan Ratu PLTU.

This study is novel in its use of the multi-level governance framework to analyze the early retirement policy of Pelabuhan Ratu PLTU, combining global perspectives with Indonesia's unique context. The research examines how coordination between local, national, and international actors influences the policy's design and implementation, offering new insights into the role of governance structures in supporting energy transitions in developing countries. By comparing the Pelabuhan Ratu case with policies in other countries, this study contributes fresh perspectives on the challenges and successes of early retirement policies.

The primary objective of this research is to analyze the role of multi-level governance in the formulation and implementation of the early retirement policy for

Pelabuhan Ratu PLTU. The study seeks to identify key factors influencing the policy's success and compare Indonesia's approach with those of other countries. The benefits of this research include providing actionable recommendations for policymakers to improve the design and execution of energy transition policies in Indonesia, promoting a more inclusive and efficient approach to decarbonization. Additionally, the findings will contribute to global knowledge on energy transitions and governance, offering valuable lessons for other nations facing similar challenges.

Literature Review

Concept and Urgency of the Global Energy Transition

According to the IPCC (2022), the energy transition represents a long-term shift from a fossil fuel-based energy system to one based on low- or zero-carbon energy sources. A similar concept is also put forward by IRENA (2023), which explains the energy transition as the transformation of the energy sector towards a more sustainable, secure and low-carbon future. Meanwhile, the World Bank (2023) explains the energy transition as the process of shifting the global energy system from fossil fuel consumption to low-carbon technologies, to support the international goal of limiting climate change.

Based on the ideas above, the concept of energy transition is the concept of a gradual energy system transformation process and its context to meet the changing demands of global climate adaptation, long-term and low-carbon processes. The energy transition aims to create a more sustainable energy system, reduce dependence on fossil fuels, and increase the use of renewable energy (Silviana, 2020). The ultimate goal is to decarbonize the energy sector to achieve the greenhouse gas emission reduction targets under the 2015 Paris Agreement.

The power sector is one of the major contributors to global greenhouse gas (GHG) emissions, accounting for about 35% of the world's total GHG emissions by 2023 (Bruckner et al., 2014). In Indonesia, the situation is even more significant, where the sector accounts for about 41% of total national emissions (Global Carbon Budget, 2023). Therefore, decarbonization of the power sector is key to climate change mitigation efforts, both at the global and national levels. The urgency of decarbonization is further emphasized by Indonesia's commitment in the Paris Agreement to reduce GHG emissions by 29% by its own efforts or up to 41% with international support by 2030 (Government of Indonesia, 2016). In this context, transforming the power sector to be cleaner and more sustainable is not only important for achieving climate targets, but also has the potential to provide co-benefits such as improved air quality, green job creation, and strengthened national energy security (IRENA, 2023).

However, decarbonizing the power sector in Indonesia faces complex challenges. These include a high reliance on existing coal-based infrastructure, large investment requirements to transition to renewable energy, as well as technical issues such as intermittency and grid stability (ADB, 2022). Nonetheless, various initiatives have been launched to promote this transition, including policies to accelerate renewable energy development, early retirement plans for coal-fired power plants, and innovative schemes such as the Energy Transition Mechanism (ETM) supported by the Asian Development Bank (Perpres No. 112 Year 2022, 2022).

Early retirement of power plants is an option that is currently in the process of policy implementation. This strategy involves retiring fossil fuel, mainly coal, power plants before the end of their planned operational life. According to analysis by Carbon Tracker (2020), up to 45% of global coal plants are no longer economical compared to renewable energy. In Indonesia, the ADB-supported Energy Transition Mechanism

(ETM) program aims to facilitate early retirement of coal power plants and accelerate the transition to clean energy (ADB, 2022). Integrated implementation of these strategies is necessary to achieve an effective energy transition. However, challenges such as large investment requirements, technical constraints, and resistance from certain stakeholders need to be overcome through coherent policies, technological innovation, and international cooperation.

The Role of Early Retirement PLTU in Decarbonizing Electricity

According to a study by Climate Analytics (2019), to meet the Paris Agreement target of limiting global warming to below 1.5°C, OECD countries and the European Union must phase out coal by 2031, while other countries including Indonesia must do so by 2037. This shows the importance of PLTU's early retirement strategy in a global context.

Many countries have adopted policies and regulations that support the energy transition. For example, the European Union through the European Green Deal is committed to achieving carbon neutrality by 2050 (European Commission, 2019). In Asia, Japan and South Korea have announced net-zero emissions targets by 2050, while China has a similar target by 2060 (Climate Action Tracker, 2021). In Indonesia, ADB (2022) has launched an ETM pilot project with a value of US$250-300 million to facilitate the early retirement of one PLTU unit. The project is expected to reduce CO2 emissions by 30 million tons over 15 years. These policies create pressure to accelerate the decommissioning of fossil fuel power plants.

The implementation of early retirement PLTU in decarbonization not only affects the electricity sector, but also has significant economic and environmental impacts, including:

1. Early retirement of power plants can result in stranded assets, which according to the Carbon Tracker Initiative (2018) could reach $638 billion globally by 2030. In Indonesia, the potential financial loss from early retirement is estimated at $35 billion (IEEFA, 2020).
2. The transition to renewable energy requires large investments. IRENA (2021) estimates that global annual investment in the energy transition will need to reach $4.4 trillion by 2050. For Indonesia, investment needs in renewable energy development are projected to reach $167.4 billion by 2050 (National Energy Council, 2019).
3. The energy transition will change the employment landscape. The ILO (2018) projects that the transition to a low-carbon economy could create 24 million new jobs globally by 2030. However, it also has the potential to eliminate around 6 million jobs in the fossil energy sector.
4. Early retirement of power plants can contribute significantly to emissions reductions. A study by Climate Analytics (2019) shows that global retirements by 2040 could reduce CO2 emissions by 12.5 Gt per year.
5. Reductions in coal-fired power plant operations correlate with improvements in air quality. Research in China shows that a reduction of 86 GW of coal power capacity between 2014-2017 reduced PM2.5 concentrations by 11% (Tong et al., 2018).
6. Reduction of negative impacts on ecosystems due to power plant operations. Coal-fired power plants negatively impact ecosystems through water, soil and air pollution. A study by Greenpeace (2017) revealed that coal-fired power plants in Indonesia have polluted water sources and surrounding agricultural land.

Concept and Theory of Multi-Level Governance

Multi-level governance (MLG) is a concept that describes the complexity of decision-making processes involving different levels of government and non-governmental actors. The theory was first introduced by Gary Marks (1993) in the context of EU policy, but has since been widely applied in various policy areas, including energy transition.

MLG recognizes that power and authority are no longer exclusively concentrated in the central government, but are dispersed among different levels of government (supranational, national, regional, and local) as well as non-governmental actors such as civil society organizations and the private sector (Hooghe & Marks, 2003). In the context of energy transition, MLG emphasizes the importance of coordination and interaction between various stakeholders in formulating and implementing policies (Pratiwi et al., 2018).

In the context of energy policy, MLG has proven to be a valuable analytical framework. Research by Goldthau (2014) shows that energy transitions require an MLG approach due to the complexity and cross-sectoral nature of the challenges faced. MLG allows for a more comprehensive analysis of how energy policies are shaped and implemented through interactions between different levels of government and non-governmental actors.

Case studies in various countries demonstrate the importance of MLG in energy policy. For example, in Germany, the success of the Energiewende (energy transition) is largely attributed to the MLG approach that enables active participation from the federal government, states, municipalities and communities (Schreurs, 2016). While MLG offers a powerful framework for understanding and managing the complexities of the energy transition, it also presents significant challenges. Coordination between levels of government is often complicated by different priorities, capacities and resources. Research by Sovacool (2011) identified several key challenges in energy transition MLG, including jurisdictional conflicts, policy misalignment and implementation gaps.

However, MLG also offers important opportunities. It enables policy innovation at the local level that can inspire change at the national level. In addition, MLG can increase policy legitimacy through broader participation of various stakeholders (Bache et al., 2016). In the Indonesian context, the application of MLG in energy transition policy, particularly regarding the early retirement of PLTU, requires an in-depth understanding of the dynamics of relationships between levels of government and the role of non-governmental actors such as PLN, the private sector, and civil society.

Research Methods

This research will use a systematic review (SR) approach in collecting data from literature in the form of research journals, official documents related to energy and electricity policies and regulations. Further analysis follows the method of combining data from the criteria test results in SR to produce comparative case study information on policies related to early retirement or phase-out of PLTU. The results of the comparative case study will be compared and validated by source triangulation and peer review using a questionnaire. Based on the results of this validation, this research is expected to provide a more complete and valid picture of the early retirement policy of the Pelabuhan Ratu PLTU in Indonesia and the results of its comparison with policies related to early retirement and financing mechanisms enacted in other countries. The contextuality of the policy is then linked to research trends that have developed over the past decade, so that

it can provide an understanding of policy design and its relationship with developing issues in the international world, as well as policy developments that can be recommended.

Object and Type of Research

The object of research to be carried out is the early retirement policy of Pelabuhan Ratu PLTU located in Sukabumi, West Java, Indonesia. This PLTU has a capacity of 1,050 MW and is one of the pilot projects for early retirement policies for coal-fired power plants in Indonesia. This research will be conducted in July-September 2024.

The research to be conducted is descriptive research using a mixed-methods approach that combines qualitative and quantitative methods. This approach was chosen to provide a comprehensive and in-depth understanding of the research problem (Creswell, 2021). Quantitative methods are applied through bibliometric analysis to identify trends and patterns in the scientific literature related to early retirement of coal-fired power plants and energy transition. Meanwhile, qualitative methods are used in systematic reviews and comparative case studies to deeply analyze early retirement policies and implementation in various countries, including Indonesia.

Research Framework

The framework of this research is based on three main concepts, namely Multi-Level Governance Theory, the concept of sustainable energy transition, and the early retirement policy analysis model of coal-fired power plants. The research will examine the relationship between the design and formulation of PLTU early retirement policies with national energy transition efforts with energy governance at various levels, by considering legal, technical, economic, social, and environmental aspects.

The data input in this research consists of policies that oversee the early retirement process of Pelabuhan Ratu PLTU, scientific literature and research publications related to energy transition policies and issues in Indonesia and the world collected through the rapid evidence assessment review (REA) method in the systematic review method, as well as cases of early retirement in other PLTUs that are relevant to current political and economic conditions. The data processing process of this research is carried out through bibliometric analysis to obtain information about research trends on the topic of early retirement of PLTU. Systematic review is expected to provide evidence-based information on the process and dynamics of making and formulating PLTU early retirement or phase-out policies, thus providing comparative information on policies taken by governments in other countries. MLG analysis is expected to produce identification of influential factors in the design and formulation of policies from various stakeholders involved and interested in the early retirement policy of Pelabuhan Ratu PLTU. Based on information from the results of bibliometric analysis, systematic review, and MLG analysis, it is expected to produce recommendations for the development or improvement of the formulation and design of the early retirement policy of PLTU Pelabuhan Ratu.

Data Type and Source

The data to be used in the research are primary and secondary data. The data needed in this study are presented in Table 1.

Table 1. Research Methods and Research Data

Data Type	Data Source
Primary Data	a. Scientific publications related to early retirement of PLTU and energy transition from b. Results of questionnaire responses (text attached) with expert respondents from stakeholders as part of comparative case studies (where possible)
Secondary Data	1) Indonesian government policy documents 2) National and international energy industry reports 3) Comparative case studies from other countries regarding phase-out and early retirement policies in other countries. 4) International organization report on energy transition

Data Analysis Technique

Data analysis in this study was carried out in several ways including regulatory mapping, content analysis, thematic analysis, comparative policy analysis, actor and interest mapping, and descriptive statistical analysis. The analysis techniques are explained as follows:

1. **Regulatory Mapping**, a systematic process of identifying, analyzing, and documenting the various regulations that apply in a particular field or sector . The main objective is to comprehensively understand the legal framework governing a particular activity or industry and ensure compliance with all relevant legal requirements (Vosselman, 2012).
2. **Content** is used to analyze the content of policy documents and reports related to early retirement PLTU. Content analysis is an important process in evaluating the information contained in these documents. For example, in the context of PLTU's early retirement policy, content analysis would involve an in-depth understanding of the early retirement age requirements, the benefits available and the procedures to be followed.
3. **Thematic Analysis**, Thematic analysis is used to identify key themes that emerge from comparative case studies. In thematic analysis, the researcher carefully examines the data to find patterns that reveal the dominant themes in a particular context. For example, in a comparative case study on the sustainability of post-PLTU renewable energy implementation in the generation industry, thematic analysis can help identify themes such as environmentally friendly practices, cheap and easy energy accessibility, green technology innovation, and corporate social responsibility.
4. **Comparative Policy Analysis**, Comparative policy analysis comparing PLTU's early retirement policy in Indonesia with other countries shows significant differences in approach and implementation. In Indonesia, PLTU's early retirement policy may be more focused on worker welfare and social adjustment aspects. For example, the early retirement program at PLTU in Indonesia may involve additional financial incentives to encourage older workers to exit the labor market.
5. **Important Actor Mapping, Actor** and interest mapping involves the process of identifying and analyzing the roles played by various stakeholders in the context of multi-level governance. In this context, it is important to understand how these actors interact with each other and how their interests can influence decisions and policies.
6. **Descriptive Statistical Analysis,** Descriptive statistical analysis is used to process quantitative data from bibliometric analysis using VOSviewer. Descriptive statistical analysis is a method used to summarize and describe data systematically. For example, if we take the example of data on the number of published studies related to the post-

Paris Agreement over the past 5 years, descriptive statistical analysis will help us to calculate the average number of publications per year, the time span between publications, and the distribution of the number of publications in various subfields of computer science.

Data Validation Technique

To increase the validity and reliability of the research results, a research data triangulation process will be carried out. Data triangulation is a technique used to increase the validity and reliability of research by combining data from various sources, methods, or theories. In this context, method triangulation and source triangulation will be used. Method triangulation involves using different data collection methods (quantitative and qualitative) to check the consistency of findings. Method triangulation is used in systematic reviews. Meanwhile, for bibliometric analysis, method triangulation is used based on the relevance of the topic in the paper to the issue of early retirement and phase-out of PLTU policies in various countries. Source triangulation involves the use of various data sources (literature, policy documents, and questionnaires) to verify and enrich research findings (Patton, 2015). In this research, source triangulation is described as follows:

1. Triangulation of data sources: Comparing and verifying information from multiple sources to increase the validity of findings.
2. Peer review: Involving experts in the field of energy and policy or involved in the process of formulating public policies related to the early retirement of PLTU Pelabuhan Ratu to review and provide input on the results of the analysis.

Using this methodology, the research aims to provide a comprehensive analysis of the early retirement policy of PLTU Pelabuhan Ratu 3x350 MW in the context of multi-level governance of sustainable energy transition in Indonesia.

Results and Discussions

Data Analysis

This section describes the results of data analysis related to the research topic in which the results will be described based on research questions. Before presenting the research results, it is necessary to review the relevant literature which will be the main material in presenting the research results. Relevant literature needs to be traced by looking at existing gaps or gaps. This gap review needs to be done to ensure that this literature review will produce findings that have novelty. In reviewing this gap, the researcher utilized the VOSviewer software, the following are the results:

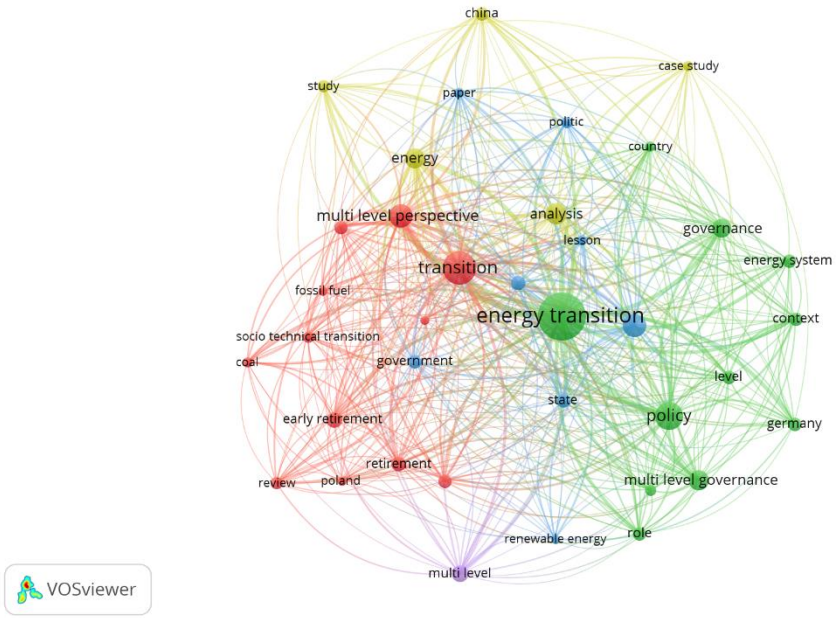

Figure 1. Visualization of VOSViewer

Based on 200 literature processed using VOSviewer, using search keywords such as Early retirement policy; Multi-Level Governance Analysis; and Energy Transition, the VOSviewer results above show that no previous research has been found that directly connects these three concepts (Early retirement policy; Multi-Level Governance Analysis; and Energy Transition). Therefore, this research contributes by bridging the literature gap and providing an in-depth analysis of how multi-level governance plays a role in the early retirement policy formulation process in the coal-based power generation sector, especially at PLTU Pelabuhan Ratu. Furthermore, this research answers two main questions. First, it investigates how multi-level governance influences the formulation and design of PLTU Pelabuhan Ratu's early retirement policy, and identifies key factors in the context of Indonesia's energy transition. Secondly, it compares the design of PLTU Pelabuhan Ratu's policy with global practices , to explore research trends related to PLTU early retirement policies in the context of energy transition. Thus, this research not only provides theoretical contributions but also offers practical insights for policy makers in designing a sustainable energy transition strategy in Indonesia.

Influence of Multi-Level Governance on the Formulation Process and Early Retirement Policy Design of PLTU Pelabuhan

Multi-level governance (MLG) plays an important role in the formulation and design of PLTU early retirement policies, especially in Pelabuhan Ratu 3x350 MW. In the context of Indonesia's energy transition, the PLTU early retirement policy involves coordination between various parties, both at the local, national and international levels. The Indonesian government, through policies such as Perpres 112/2022 and RUPTL, is working with international institutions and state-owned enterprises such as PLN to design this policy in an effort to reduce carbon emissions and support the achievement of Net Zero targets by 2060 (Gundala Project, 2024; Perpres No. 112 Year 2022).

One of the main factors in the formulation of this policy is the coordination between levels of government that involves various parties, ranging from the central government, related ministries, local governments, to PLN as the state-owned energy company. Each level of government has a different role. Local governments focus on

socio-economic impacts and job creation, while the central government focuses more on macro policies and national targets, such as reducing emissions and transitioning to renewable energy (Sarma, 2023; Gundala Project, 2024).

The role of international institutions, such as JETP and ETM, is crucial in providing funding to support the early retirement of power plants. By using blended finance mechanisms, Indonesia can access the international funds needed to accelerate the energy transition to renewable energy sources. This funding includes grants and soft loans that are more accessible to Indonesia, although inter-agency coordination challenges remain (Resosudarmo et al., 2023; Perpres No. 112 Year 2022).

Coordination between institutions, especially in terms of funding, is a key factor in the smooth running of the PLTU early retirement policy. PT Sarana Multi Infrastruktur (PT SMI) acts as a blended finance manager that supports the development of renewable energy. This policy requires large funding to build renewable energy infrastructure and other supporting technologies, such as solar and wind energy, which have a strategic role in replacing PLTU as the main energy source in the future (plnindonesiapower.co.id, 2023; Perpres No. 112 of 2022).

A major challenge faced by Indonesia in the PLTU early retirement policy is the deep dependence on coal, both in economic and social terms. Many regions depend on coal royalties and the presence of coal-fired power plants for their income. This makes the transition to renewable energy challenging, as it requires efforts to mitigate social impacts for communities working in the PLTU sector and related workers. Therefore, this policy must be designed with social and economic aspects in mind (Ordonez et al., 2022).

The design of the early retirement policy for the 3x350 MW Pelabuhan Ratu PLTU reflects a highly structured multi-level governance approach. The central government, PLN, and relevant ministries coordinate this policy through a data-driven decision-making process and in-depth evaluation. The Multi Criteria Decision Making (MCDM) method, which combines AHP and PROMETHEE II, is used to prioritize the plants for early retirement, based on criteria such as age, efficiency, capacity, and CO2 emissions. This ensures that decisions are objective and based on holistic analysis (Sarma, 2024).

In addition to social and economic challenges, Indonesia also faces structural barriers to the energy transition, including corruption and weak law enforcement. This hinders efforts to implement energy transition policies effectively and sustainably. For example, the 35 GW program, which focuses on building coal-based power plants, contradicts long-term emission reduction policies. Therefore, the success of the early retirement policy also depends on the government's ability to overcome these structural barriers (Ordonez et al., 2022).

In supporting the energy transition, the development of renewable energy technologies is non-negotiable. Indonesia needs to develop infrastructure that enables the use of renewable energy sources such as solar, wind, and other existing energy potentials. In addition, carbon capture and storage (CCS) technology is also an important factor in reducing emissions from operating power plants, before early retirement can be carried out as a whole. Cooperation between the government, PLN, and international organizations to fund and develop this technology is needed (Hyun et al., 2023; Kefford et al., 2018).

One of the main objectives of the PLTU early retirement policy is to ensure that the energy transition takes place in a fair and sustainable manner. Therefore, this policy must take into account the socio-economic impacts on communities that depend on the

PLTU sector, by providing training and new job opportunities in the renewable energy sector. Collaboration between different levels of government and the private sector is also essential to create an inclusive policy, which not only prioritizes emission reductions, but also supports economic recovery at the local level (Gundala Project, 2024; Centre for LKFT Studies UGM, 2024).

Multi-level governance plays a very important role in the success of the early retirement policy of PLTU Pelabuhan Ratu 3x350 MW. With good coordination between the central government, PLN, relevant ministries, international institutions, and local communities, Indonesia's energy transition can run smoother and more effectively. Although major challenges remain, particularly in terms of financing, economic dependence on coal, as well as structural barriers, this policy offers an opportunity for Indonesia to reduce carbon emissions and move towards cleaner and more sustainable energy.

Comparison of Early Retirement Policy Design of PLTU Pelabuhan Ratu with Policy Design in Other PLTUs Globally, and its Reflection in the Context

The draft policy of early retirement of the Pelabuhan Ratu power plant in Indonesia reflects the country's efforts to reduce dependence on fossil energy, especially coal, with the aim of achieving carbon emission reduction targets. This policy is in line with global trends in developed countries, such as Germany and the UK, which prioritize the retirement of high-emission power plants to support the energy transition towards Net Zero Emissions (NZE). Nonetheless, Indonesia faces major challenges due to its reliance on coal-fired power plants to meet national electricity demand, which reached 61% in 2021.

Comparison with global policies shows significant differences between the approaches of developed and developing countries. Developed countries such as Germany are more focused on shutting down old and inefficient power plants, while developing countries such as Indonesia still rely on new power plants due to the large investments that have been made in recent years (Clark et al., 2020). In countries such as China and India, early retirement policies are more based on age, carbon efficiency, and pollution factors, with the aim of reducing emissions and pollution impacts, while Indonesia tends to focus on coal subsidies and the development of new power plants.

In the Indonesian context, the early retirement policy of PLTU Pelabuhan Ratu must consider different challenges. One is the high costs associated with the energy transition, as well as the economy's dependence on the coal sector, which provides significant barriers to the shift to renewable energy. Large funds are required, most of which must be met through international loans, to fund this energy transition (Resosudarmo et al., 2023). In addition, regulatory and institutional uncertainties also slow down the implementation of such policies, while social impacts related to job and income losses for workers in the coal sector are important issues to be addressed.

The approach used in China, which adopts a carbon emission and pollution-based index to determine which plants should be retired early, could serve as a model for Indonesia. The index takes into account various parameters, including plant age, capacity, operating costs, and air pollution impacts, to provide a more thorough evaluation of plant retirement priorities (Maamoun et al., 2022). However, implementing a similar model in Indonesia faces major challenges, especially due to the high dependence on coal-fired power plants in the electricity system.

One proposed solution to this challenge is to adapt a policy model similar to that of Germany, which plans to completely shut down its power plants by 2038 and decouple

related business units to support the energy transition (Gundala Project, 2024; Bang et al., 2022). Indonesia could adopt a similar approach by separating unproductive power plant assets to support renewable energy investment. However, the implementation of this policy requires close coordination between central and local governments, as well as the restructuring of entities such as PLN to ensure the sustainability of the green energy transition policy.

While the early retirement of PLTU Pelabuhan Ratu is an important step in Indonesia's energy transition, major challenges remain, particularly in terms of financing. Indonesia faces very high early retirement costs of PLTU, with the risk of stranded assets that could affect the country's economic and energy stability. This is a major concern in research related to this policy, where the importance of international funding schemes, such as JETP (Just Energy Transition Partnership), and social impact mitigation are highlighted (Sarma, 2023).

Comparison with China

China uses a multidimensional index-based approach to determine which plants should be retired early. The index includes the parameters of age, capacity, operational efficiency, air pollution impact, and population exposure to emissions. This approach provides a more comprehensive evaluation in the prioritization of PLTU retirement than the age or capacity-based method alone (Maamoun et al., 2022). While in Indonesia, the early retirement policy still focuses on the closure of high-emission power plants, but limited funding and dependence on coal are slowing down its implementation.

China has managed to retire 400 GW of power plant capacity in recent years, supported by substantial funding from the central government and the private sector. On the other hand, Indonesia is still heavily reliant on coal, which supplied 61% of its electricity needs in 2021. Indonesia does not yet have a comprehensive assessment index like in China, which could help prioritize retirements in a more targeted way (Clark et al., 2020).

Funding is a major obstacle for Indonesia in accelerating the energy transition. China utilizes incentive schemes and subsidies to accelerate renewable energy development, while Indonesia still maintains coal subsidies to keep electricity prices affordable. International financing schemes, such as the Just Energy Transition Partnership (JETP), are starting to be implemented in Indonesia but have not yet reached the scale of those in China (Resosudarmo et al., 2023).

Social impacts are also a concern in both countries. However, China's approach is more systematic with worker retraining programs and redeployment to the renewable energy sector. Indonesia still faces challenges in addressing the social impacts of early retirement of PLTU, such as loss of employment for coal workers and surrounding communities (Ordonez et al., 2022).

Indonesia can learn from China by adopting an index-based assessment model and strengthening financial incentives for the energy transition. By developing an evidence-based approach, as is done in China, Indonesia can accelerate the process of retiring power plants while reducing the negative impacts on the economy and society.

Comparison with Germany

Germany has set a target to phase out all coal power by 2038 as part of its transition to clean energy. This policy is supported by a strong legal framework and cross-sector coordination, including substantial funding from the government and private sector (Bang et al., 2022; Gundala Project, 2024). In comparison, Indonesia's policy is still in its early

stages, with a focus on retiring high-emission power plants such as PLTU Pelabuhan Ratu, but is limited by regulatory and funding challenges.

The German approach involves spinning off unproductive business units to support renewable energy investments. This model allows for a gradual transition of coal-fired power plant assets without destabilizing the electricity system. In Indonesia, restructuring entities such as PLN remains a major challenge, affecting the speed of the energy transition (Sarma & Dinariyana, 2024).

Germany also compensates affected workers and communities through retraining programs and financial support. This program ensures transitional justice for communities dependent on the coal industry. In contrast, Indonesia still lacks a strong social mitigation program, so the social impact of early retirement of PLTU is potentially greater (Sarma, 2023).

In terms of renewable energy development, Germany has managed to significantly increase its wind and solar capacity, while Indonesia is still in the early stages of clean energy development. The main barriers in Indonesia are dependence on coal and the high cost of renewable energy infrastructure (Resosudarmo et al., 2023).

Indonesia can take lessons from Germany, especially in terms of funding structures and social programs to support the energy transition. By adopting a similar approach, Indonesia can reduce reliance on coal while encouraging renewable energy development in a more planned manner.

Comparison with India

India, like Indonesia, still relies heavily on coal for energy needs. However, India uses an index based on seven parameters, including age, capacity, operating costs, and pollution impact, to determine which plants to retire early. This approach helps India assess the priority of plant retirements more accurately than Indonesia, which does not yet have a similar comprehensive assessment model (Maamoun et al., 2022).

India has implemented incentive schemes to accelerate the transition to renewable energy, although it still faces major challenges in terms of financing and social impacts. In contrast, Indonesia still maintains coal subsidies to keep electricity prices low, thus slowing down renewable energy development (Ordonez et al., 2022).

In terms of financing, India is getting international support through schemes like the Green Climate Fund to develop renewable energy. Indonesia has also begun to explore international financing, but has yet to fully capitalize on the opportunity. Regulatory and institutional challenges in Indonesia are barriers to attracting international investment (Resosudarmo et al., 2023).

India is also more advanced in social impact mitigation through retraining programs and new job creation in the renewable energy sector. Meanwhile, Indonesia needs to strengthen its social strategy to mitigate the negative impacts of power plant retirements on workers and surrounding communities (Sarma, 2023).

Lessons from India suggest that Indonesia needs to develop an index-based assessment model and improve incentives to accelerate the energy transition. International finance and social mitigation support are key elements that can be adopted to address local challenges.

Comparison with South Korea

South Korea faces similar challenges to Indonesia, namely coal dependence and high energy transition costs. However, Korea has identified two main pathways for decarbonization: expansion of renewable energy supported by gas and Carbon Capture and Storage (CCS) technology, and increasing nuclear energy capacity (Hyun et al.,

2023). Indonesia has focused more on renewable energy and CCS due to socio-political limitations to adopt nuclear energy.

South Korea's approach is supported by large investments in research and development of CCS technology, which is considered a long-term solution for carbon emission reduction. In Indonesia, CCS development is still constrained by high costs and lack of supporting infrastructure (Hyun et al., 2023).

Korea has also implemented incentive policies to support the adoption of renewable energy, while Indonesia still relies on coal subsidies that hinder the energy transition. Socio-political and regulatory challenges in Indonesia slow down the implementation of more ambitious policies (Sarma, 2023).

In terms of social mitigation, Korea has started to integrate worker retraining programs and financial compensation to support a just transition. Indonesia needs to learn from this approach to mitigate the negative social impacts of early retirement of power plants, especially for workers in the coal sector (Ordonez et al., 2022). Indonesia can leverage South Korea's experience in developing CCS technology and accelerate the energy transition through stronger incentives and strengthened renewable energy infrastructure. International collaboration and financing support are also needed to address local challenges.

Comparison with the UK

The UK has set a firm policy to phase out coal power as part of its target to achieve Net Zero Emissions (NZE) by 2050. The main focus of policy in the UK is to remove fossil fuel subsidies and heavily incentivize renewable energy. In contrast, Indonesia still maintains coal subsidies to keep electricity prices low, which inhibits the adoption of clean energy (Kefford et al., 2018).

In the UK, the energy transition is supported by a flexible regulatory framework and public-private partnerships, including substantial funding to support renewable energy infrastructure development. Indonesia, through Presidential Regulation No. 112/2022, has started to adjust policies to accelerate the energy transition, but still faces major constraints in terms of funding and frequently changing regulations (Sarma & Dinariyana, 2024).

The UK also has well-planned social mitigation strategies, such as retraining programs for workers and financial support for communities affected by plant retirements. In Indonesia, social mitigation policies are not yet fully integrated, so the risk of social impacts, such as unemployment in PLTU-dependent areas, remains high (Sarma, 2023).

In terms of technological innovation, the UK has aggressively developed and adopted clean energy technologies, including offshore wind and solar panels. Meanwhile, Indonesia is still lagging behind in the development of renewable energy technologies, mainly due to the lack of investment and high costs required for infrastructure development (Ordonez et al., 2022).

Indonesia can learn from the UK by adopting an approach that integrates financial incentives, public-private finance and social mitigation strategies. By strengthening cross-sector collaboration and providing regulatory certainty, Indonesia can accelerate the transition to renewable energy.

Comparison with the United States

The United States (US) has a flexible approach to coal phase-out, focusing on removing fossil fuel subsidies and incentivizing renewable energy. In some states, this policy is supported by federal funds and clean energy development programs. In contrast,

Indonesia still relies heavily on coal subsidies and has not fully transitioned to incentive schemes that promote clean energy (Clark et al., 2020).

The US also prioritizes the development of renewable energy and carbon capture technologies through substantial federal funding. While Indonesia is just starting to implement Carbon Capture and Storage (CCS) technology, the US approach shows that economies of scale and strong regulatory support can accelerate the adoption of this technology (Hyun et al., 2023).

Social mitigation strategies in the US include worker retraining and new job creation programs in the clean energy sector. Indonesia, with limited resources and institutional capacity, needs to learn from the US experience in ensuring transitional justice for communities affected by power plant retirements (Ordonez et al., 2022).

The US also uses a data-driven approach to determine which plants to retire first. This approach is similar to China's, but focuses more on economic efficiency and carbon emissions impacts. Indonesia has not yet adopted a comprehensive data-based assessment method, so the process of stopping PLTU tends to be less targeted (Maamoun et al., 2020).

Indonesia can learn from the US policy framework, especially in terms of using data for decision-making, financial incentives, and technology development. By strengthening institutional and regulatory capacity, Indonesia can be more effective in implementing the phase-out policy.

Conclusion

Research on the early retirement policy of PLTU Pelabuhan Ratu using the Multi-Level Governance (MLG) approach emphasizes the importance of coordination across actors, including central and local governments, the private sector, and international institutions. This approach has proven effective in creating integrated policies that not only target emission reductions, but also consider socio-economic impacts, such as the creation of new jobs. Structural challenges in the energy transition, such as coal dependence, fossil energy subsidies and the risk of stranded assets, are the main obstacles that require innovative policies to accelerate the shift from fossil energy to renewable energy. This is in line with institutional path dependency theory, which suggests the need for external pressures or incentives to overcome the inertia of established systems.

International resource mobilization, including financing through blended finance and support from international institutions such as ETM and JETP, is an important element in Indonesia's energy transition. This global financing helps overcome domestic resource limitations and accelerate the adoption of renewable energy, as per resource mobilization theory. Evidence-based approaches, such as the use of Multi-Criteria Decision Making (MCDM) methods in policy formulation, ensure more objective decision-making, considering technical, economic and environmental criteria holistically. This approach reflects the importance of scientific analysis and data to support optimal and sustainable outcome-oriented policies.

In addition, this policy highlights social justice by ensuring mitigation of impacts on workers and communities dependent on the coal sector through retraining programs and the creation of new jobs in the renewable energy sector, according to the principle of just transition. Indonesia can also learn from the experience of other countries, such as Germany and the UK, in prioritizing old, high-emission power plants, and China, which focuses on reducing emissions from new power plants. An evidence-based approach and in-depth evaluation are key to designing more effective, equitable and sustainable policies in the future.

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