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Risk Management in the Energy Sector in Indonesia: A Review

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Abstract

Indonesia's energy sector is crucial for economic growth but faces complex risks such as technical, financial, environmental, regulatory, and socio-political that hinder its transition to sustainable and greener systems. Existing research on risk management in this sector is fragmented, covering different levels of analysis, energy sources, and types of risk. A systematic review and categorization of the literature are needed to map current knowledge, identify gaps, and guide future research and policy development. Harzing's Publish or Perish software is used to search, filter, and evaluate academic articles from multiple databases using appropriate keywords that allows to systematically identify the most relevant, credible, and influential literature. This article investigates recent literature on risk management in Indonesia's energy sector. Thirty-three articles from Google Scholar discuss various issues related to risk management inquiry in the energy sector. After careful reading and reviewing, three categories are naturally developed, i.e., level of study, type of energy source, and type of risk, and function as a map in comprehending the literature. The analysis shows that risk management in Indonesia has been researched using various methods and for multiple purposes. With different levels of study and energy sources, the risks identified in this research provide a clear picture of how and why the energy sector has difficulties transitioning to a more sustainable and greener system. The article also offers a future agenda for research in the area of risk management in the energy sector.

Keywords: Energy Sector, Indonesia, Literature Review, Risk Management, Transition Risk

1. Introduction

Indonesia's energy sector is increasingly vital [1]. With the commitment of the new president to have an economic growth of 8%, the energy needed to support the development needs to be secured [2]. As one of the most populous countries in the world, Indonesia has substantial energy needs and consumes a significant proportion of global energy production. After becoming a net energy importer, Indonesia's concern with energy security takes a new elevation since it cannot depend only on domestic output but also needs to source globally from the international market [3].

Besides energy security, Indonesia must also tackle environmental concerns as global warming becomes mainstream in energy policy and planning [4]. The effects of extreme weather, floods, and drought are already present in the country. Moreover, Indonesia has committed itself to the Paris agreement to voluntarily reduce greenhouse gas emissions by 2060 with the help of world assistance. This climate concern will define the strategy for building a future energy system [5]. Another problem in Indonesia is the issue of energy poverty [6]. Not all people have access to their energy needs. After nearly 80 years of independence, some six thousand villages and some 1.3 million households have yet to have electricity in 2024 [7].

Therefore, energy sector challenges are burdensome and require serious effort to devise and build an energy system that can overcome the trilemma of energy security, environmental sustainability, and energy poverty [8]. Indonesia needs an energy transition process that is manageable, achievable, and sustainable in the long term [9]. In this respect, risk management as a body of knowledge and research can humbly contribute. By systematically identifying various risks in the form of barriers and obstacles, the risk management discipline can guide and shed light on constructing a smooth shift towards a desirable energy future [10].

Prior research on risk management in the energy sector has been conducted by Gorzeń-Mitka & Wieczorek-Kosmala [11] with a bibliometric approach. To the author's knowledge, there is no article on this topic in an Indonesian context. Unlike previous methods, this research will use content analysis, and the result will be illustrated in a mind map scheme [12]. This article contributes in three novel ways. The first is to report on recent research on risk management in the energy sector in Indonesia. Secondly, it will identify various risks related to energy sector development in Indonesia and classify them into macro and micro risks. Lastly, it will suggest future research on this topic.

2. Research Method

The relevant articles are identified using Harzing's Publish or Perish software. The software searches the Google Scholar database with three keywords: risk, management, and energy. The title of the articles should include the word Indonesia, with publication periods from 2021 to 2025. This is conducted deliberately to narrow down the intended articles of the most recent publication [13].

Initially, the articles' quantity was limited to 100 to ensure the manageability of the reading, and the focus was on the most highly cited ones. After examining the abstracts, the articles end up being 33 in number [14]. A simple content analysis of the articles is conducted, and several categories and themes emerge from the readings described in the result section [15]. The mind map concept is employed in the result, neatly organizing the themes using Vensim Software that is freely available [16].

3. Results and Discussion

After reading and interacting with text in the collected articles, three emergent categories can structure this review of how risk management has been previously researched in the energy sector in Indonesia [17]. The first category is the level of study. There are three levels identified, i.e., company level, market level, and economy level. The following category is the type of energy source. Various energy sources have been the subject of research, including fossil-based fuels such as coal, gas, nuclear, and solid waste.

In contrast, renewable energy sources encompass biomass, solar, and geothermal. Another type that is not necessarily fit to the energy source but related to this category is energy efficiency. The last category is the type of risk. There are two general types of risk, i.e., macro and micro. Macro risk relates to obstacles and barriers to the energy transition to a cleaner and greener system based on renewable energy. In comparison, micro risks are concerned with specific aspects of risk in the energy sector, i.e., technical, economic, financial, operational and human risk, strategic, project, policy, and perception risk. Overall, all three categories are depicted in Figure 1 below.

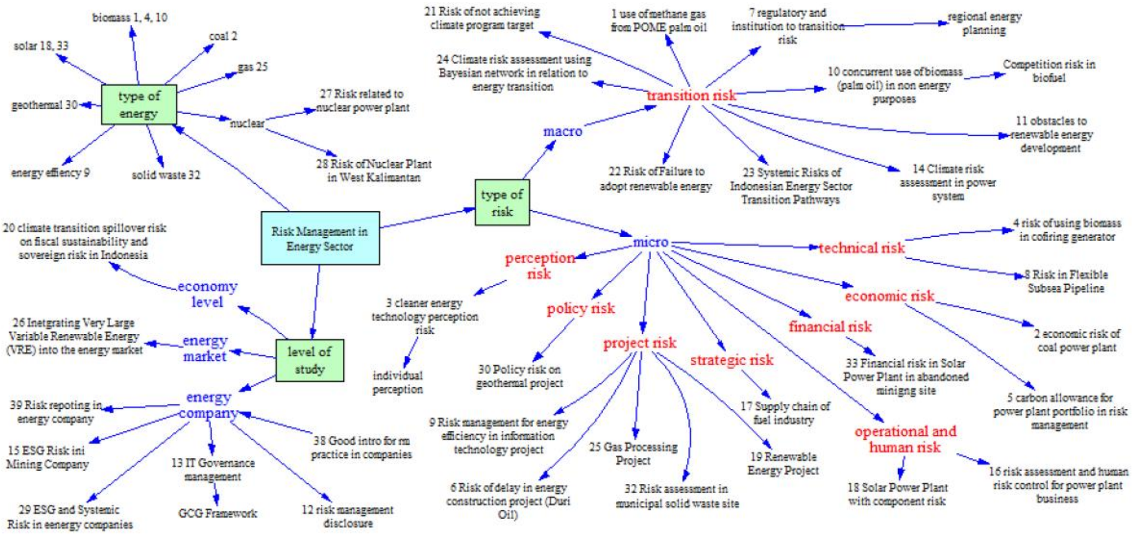

Figure 1. The Mind Map Scheme of the Collected Articles
Source: Data analysis by the author

3.1. Level of Study

The three levels of company, market, and economy have been identified in the collected articles, with an explanation as follows.

3.1.1. Company Level

Five articles deal with energy companies. Implementing risk management in running companies has improved efficiency and investment activity [18]. For companies in the energy sector, disclosure on risk management practice in risks of strategic and information technology processing has contributed to firm value in the stock market [19]. In the case of the national state oil company, risk governance integrated with IT implementation also helps to achieve the corporate goal [20]. Social disclosure in the ESG framework can also reduce systematic risk in nine energy companies [21]. In the mining sector, positively, wide-ranging ESG risk management applications can increase resilience, compliance, and trust from business stakeholders [22]. Risk management can also be enhanced with risk reporting, as in energy and palm oil companies [23].

3.1.2. Market Level

Only one article discusses the electricity market as a whole, where only one state company dominates in three divisions, i.e., generation, transmission, distribution, and retail. Introducing a considerable scale of renewable energy into the system generates techno-economic risks, necessitating the development of supporting elements such as technology, financing, and infrastructure. To be successful, all stakeholders, including government, industry players, and the community as users, need to be integrated to participate synergistically [24].

3.1.3. Economy Level

One article by Gourdel et al. [25] discusses the spillover risk caused by foreign countries when they implement decarbonization policies for energy commodities they import. As an exporting trading partner, this measure impacts Indonesia by decreasing its sovereign and fiscal sustainability, resulting in a declining balance of payment and affecting its revenue and public finance stability and sustainability. A country should prepare cautiously for how its trading counterpart can impose on it.

3.2. Type of Energy

The articles discuss risk management issues relating to energy systems that depend on various sources to generate power, namely fossil-based non-renewable and renewable energy. Regarding energy conservation, efficiency also plays an important part in supporting the system and maintaining sustainability.

3.2.1. Fossil-based Energy

Before proceeding with the reviewed articles, it is appropriate to depicts the existing situation in the energy mix in Indonesia. The current condition of energy system remains overwhelmingly reliant on fossil fuels, that in 2023, coal accounted for approximately 39–43 % of primary energy consumption, followed by oil at 29–31 % and natural gas at 16–17 %, while renewables contributed only 8–12 % [57]. This is in contrast with the intention of the previous National Energy Policy (Kebijakan Energi Nasional, KEN; Presidential Regulation No. 79/2014) and the National Energy General Plan (RUEN; Presidential Regulation No. 22/2017) that states the country aims to reduce the use of fossil fuel and in 2025 achieve the uses of oil, coal and gas in energy mix 25%, 30% and 22% consecutively [58].

This dominance of fossil fuel is inline with the content of the reviewed articles. Coal is mainly used in the energy system today in a significant proportion. However, Kang et.al. [26] finds that coal power plants have an increasingly economic risk since more investment projects will squeeze profit margins, so there is little interest in building more coal plants, as shown in Java, Bali, and Kalimantan. This is more pronounced with the tendency for the coal price to rise. However, for Sulawesi and Papua, there is room for investment opportunity [26]. In the gas segment, Hermawan et al. [27] investigate various risks that affect the gas processing facility project, including contractor financial condition and the COVID pandemic becoming the main risks, along with other risks such as construction and procurement activities.

3.2.2. New Energy

Within the framework of Indonesia’s national energy legislation, as stipulated in Law No. 30 of 2007 on Energy and further elaborated in the Draft Bill on New and Renewable Energy (RUU EBET), new energy refers to energy produced through innovative technologies derived from either non-renewable or renewable sources, which have not yet been widely utilized and remain in the developmental stage. This category includes nuclear energy, hydrogen, coal bed methane (CBM), liquefied and gasified coal, as well as energy from ocean currents and waves. Unlike renewable energy, which originates from naturally sustainable processes such as solar, wind, hydro, and biomass, new energy emphasizes technological innovation to optimize unconventional resources. The classification reflects Indonesia’s strategic approach to energy transition, aiming not only for sustainability but also for technological diversification and enhanced national energy resilience [69] [70].

Nuclear power is also the subject of research in risk management, such as that of Josia [28], which looks at the feasibility of building a nuclear plant and overcoming several obstacles. Nuclear power is perceived as an alternative, cleaner, and more reliable energy source in the face of global emissions. However, investment in nuclear energy needs assurance in terms of benefits and prudent waste disposal management. West Kalimantan was also chosen for the site study to identify risks related to human health and safety [29]. Investigating hazard risk, its scale, and consequences is part of risk management precautions to prevent the negative impact of the nuclear plant.

3.2.3. Renewable Energy

The current energy mix show that renewable energy contributes around 14.1% in early 2025 [59]. Whereas target stipulated in National Energy Policy [58] renewable energy should have a minimum share of renewable energy (RE) in the primary energy mix of 23% by 2025 and 31% by 2050, alongside restrictions on the share of oil, coal, and gas. However, recently there was revision in the drafting of a KEN revision proposing a downward adjustment of the 2025 RE target to around 17–19%, although this revision has not been finalized. The latest electricity supply plan (RUPTL 2025–2034) sets a more ambitious expansion of RE capacity, yet structural barriers such as project execution delays, grid integration issues, and new market reform needs still exist [60].

Renewable energy is increasingly perceived as an essential part of a sustainable energy system [31], and studies of its risk management become significant. Three articles touch upon biomass, such as that of Rishanty et al. [32], which looks at the role of captured methane gas in the palm oil industry to see whether it can reduce carbon emissions by utilizing it as an energy source and therefore mitigating energy transition risk. In other applications, biomass is also used to co-fire with coal in power plants. Kesuma et al. [33] find that the prominent risks are sustainable supply and quality content of the biomass, along with other risks such as efficiency, reliability, cost, and environmental impact. Another risk studied in biomass is competition risk since food and energy are common elements in biomass production [34].

Risk management research also investigates the feasibility of solar power plant development in the new capital city (IKN), with identified risks including module component failure, control system, and sunrays intensity level effect, with the end goal is to build a resilient plant that is economically viable [35]. With numerous lands available in the post-mining area, there is a proposal for building solar power plants on the lands for productive energy generation. Risks identified in such a plant comprise technical and financial feasibility and environmental impact [36]. In the geothermal energy sector, risk management research investigates how policy and stakeholder decision-making participation impact and become a risk to its development performance and promotion of its vast potential size [37].

In a solid waste power plant, a study by Robbani et al. [30] examines the environmental risk, in the form of ash, a byproduct of its power-generating activity. Fortunately, it was found that the risk level was under the maximum level limited by the regulation. The ash can be of economic value when making products for a pedestrian lane.

3.2.4. Energy Efficiency

Energy efficiency is also part of the effort to transition to a more sustainable energy system. Latest technologies in energy efficiencies flourish in many applications such as in building sector where cooling system uses Variable Refrigerant Flow (VRF) systems achieve higher seasonal efficiency than conventional variable-air-volume (VAV) system [61]. In industry application, electrified high-temperature & ultra-high-temperature heat pumps reduces primary energy and on-site losses relative to direct combustion promoting more efficiency [62]. In data center application, latest innovation on liquid & immersion cooling uses less energy by 15–20% and also cutting GHG and water impacts compared with that of air cooling [63]. While in power and grid sector, wide/ultra-wide bandgap and solid-state transformers provide more efficiency than silicon devices and line-frequency transformers [64] [65].

Risk management research investigates the energy efficiency area, as demonstrated by Wahyudi et al. [38] that examines IT project that uses vendor as implementing agency and finds that critical risk factors lie in user requirements, vendor qualification, and projected time frame.

3.3. Type of Risk

Risk management concerns identifying and mitigating various hazards and obstacles that affect the process and activity of the organization in the energy sector. From the scope point of view, this article will classify risks into macro and micro with explanation and elucidation as follows.

3.3.1. Macro Risk

Macro risk concerns system-wide obstacles and barriers affecting the whole system. In this case, if we look at the energy system, there is a general movement toward improving energy sources by shifting to renewable energy to mitigate climate change and global warming. Any inhibition or hindrance to attaining this goal is considered macro risk.

One particular policy related to the macro system is presidential regulation (Perpres) No. 98 of 2021 mandating carbon trading. This regulation establishes Indonesia's legal framework for the implementation of the Carbon Economic Value (Nilai Ekonomi Karbon/NEK) as a market-based and non-market mechanism to achieve the country's Nationally Determined Contribution (NDC) targets and control greenhouse gas (GHG) emissions in line with the Paris Agreement. The regulation replaces Perpres No. 61/2011 and No. 71/2011, and defines NEK as the monetary valuation of each unit of GHG emissions, operationalized through instruments such as carbon trading (cap-and-trade and offsets), result-based payments, and carbon levies. It mandates the integration of NEK into national development planning, establishes governance structures, and requires transparent monitoring, reporting, and verification systems. Subsequent implementing regulations—such as the Ministry of Energy and Mineral Resources Regulation No. 16/2022—translate these provisions into sector-specific schemes, particularly in the energy sector, while ongoing policy debates address challenges related to market integrity, social inclusion, and alignment with constitutional principles on natural resource management [66].

Energy transition utilizes all available renewable potential to succeed in transforming the energy system. Using biomass is one option, but this comes with risks such as land clearing expansion [32] and food production rivalry [34]. Various risks of not developing renewable energy have also been identified in research by Adrian et al. [35], which suggests that the optimization of fossil fuel consumption is contrary to the transition. High dependence on fossil fuel, policy and regulatory impediment in central government [40] and also in regional government when devising energy plan development [41], leading to systemic risk that inhibits the smooth transition to a greener system [42].

Efforts to mitigate climate change, in turn, also face difficulty. Devinadiar & Anityasari [43] assess explicitly climate risk in the energy system, including policy aspect, system disruption and consumer demand, which affect energy system performance and consumer satisfaction. In a more technical paper, Harun et al. [43] use a test scenario with a Bayesian network to see how climate risk affects the economy and financial system that influence the pace of energy transition. With the current target, existing policy, and contemporary action, Indonesia is at risk of underachieving its climate change target and greener energy transition [40].

Identifying macro should lead to formulating mitigation efforts so that the intended resolution to tackle the climate change problem can be realized. This can chart and facilitate a progressive road map for a fruitful endeavour.

3.3.2. Micro Risk

Micro risk concerns a particular aspect of hindrance that works on the energy system. The classification of micro risk is found in literature such as in the business domain [45], in firm organization [46], and also in a more general classification across multiple disciplines [47]. The identification of micro risk in this paper relates to the exact term used in the reviewed articles collected in this research. All various micro risks are explained below.

Technical risk is the probability of failure and malfunction in engineering and production specifications in an energy plant. For example, in a biomass energy plant with co-firing implementation, low quality of biomass input can deter the intention to reduce carbon emission, production efficiency, and reliability [33]. This technical risk also occurs in energy infrastructure when building a large module involving a flexible subsea pipeline [48].

Economic risk is the barrier to commercial feasibility when an energy project is designed and constructed. Currently pervasive in our energy system, coal power plants suffer economic risk to some extent. At least in the case of Indonesia, it is found that in populated islands such as Java and Bali, the coal power plant project is increasingly considered economically unviable [26]. With the world increasingly embracing greener energy, fossil-based energy commodities must include mitigation efforts such as introducing carbon allowance to stay economically viable in their business [49].

Financial risk concerns the possibility of loss when the energy project is in operation. Not all businesses can be predicted in advance, especially in a complex system like the energy business. This clever idea is to build a solar power plant on land previously used for mining. As Ronyastra et al. [50] show in their research, such an idea can face financial risks related to interest and tax rate, the feed-in tariff, and operating and structure costs. This risk can also occur with economic transactions involving energy commodities with trading counterparties [25].

Operational and human risks are two interrelated risks that manifest in the same event. One definition of operational risk is a potential adverse event that results from inadequate internal processes, individuals, systems, or external causes. From this, we understand that the human element is built into the meaning. In the power plant business, operational and human risks exist in daily activities, generating energy for its users and customers [50]. Mitigating these risks will ensure the business's continuity in fulfilling power needs and sustainability expectations. New improvements in novel technology in a renewable energy plant, such as solar energy, necessitate the precaution against working practices of how the plant generates power. Module inspection routine, monitoring activity, firmware update, and regular maintenance procedures can minimize the effect of these risks [35].

Strategic risk is the probability of loss from unfitting corporate decision-making and its related dynamic market response. The case in point is in the fuel industry, where an interrelated network of business entities transacts with each other. The key to mitigating strategic risk in this industry is identifying main stakeholders, incorporating integrated planning, and collaborating in synergistic business dealings [51]. The internal management in mitigating this risk can also benefit from implementing good corporate governance (GCG) practice where alignment of people's interests in the company is possible [20].

Project risk concerns the possibility of failure in project completion, with time delay, cost overrun, and under-spec product. This risk happens in both fossil-based and renewable energy power plants alike. For example, in a gas processing project, various problems during the project construction include contractor capability in executing the project and engineering, procurement, construction, and commissioning (EPCC) related risk factors [27]. Stochastic techniques can be used to simulate the anticipated project risk to mitigate and design correct response to avoid delay and procurement mistake such as in a gas construction project in Duri [52]. Project risk is especially pervasive in the first new development, such as a waste-to-energy incineration pilot plant [30], since there are always factors that are not expected. Even in relatively established efforts such as energy efficiency, project risks manifest when a new IT implementation vendor is involved [38]. The case of renewable energy projects also shows similar risks, such as those found in research conducted by Arwadi et al. [53] that finds critical success factor in new projects including participants' teamwork and monitoring activity, and other primary factors such as inadequate preparation, suboptimal communication, and impractical budget and time planned target.

Policy risk encompasses possible negative consequences of regulation changes, rules, and political dynamics. Policy risks for riskier and complex energy projects, such as plants that use geothermal sources, come from wider scope in business decisions and regulations external to management [37]. Energy companies should have proper preparation in risk management to mitigate this policy risk since the sources of this risk come from outside the business domain, and the management does not control them.

Lastly, perception risk refers to the possibility of negative effect that comes from individual and group of people due to factors such as differences in cognitive domain, psychological and cultural norms, and social life. Interesting research on public and expert perception by Ho et al. [54] reveals that in conceiving new renewable energy technologies, both have similar perceptions regarding energy need fulfilment, global impact on the environment, and their safety aspect. However, they differ in how they use cognitive sources. Ordinary people use contextual factors such as culture and values, while the experts use scientific evidence and professional judgement.

All these micro risks identified in the collected articles provide practical menus for finding mitigation strategies suitable for successfully completing any energy project and building a more sustainable future energy system.

3.4. Policy Implication of the Findings

Based on the review findings, policy implications for Indonesia's energy sector should prioritize an integrated, multi-level risk management framework that addresses macro- and micro-level risks across company, market, and economy scales, while aligning with the national energy transition agenda. Policymakers need to strengthen governance, regulatory certainty, and stakeholder collaboration to accelerate renewable energy adoption and energy efficiency programs, while mitigating systemic risks such as policy inconsistency, infrastructure gaps, and market concentration. Incentive schemes, fiscal safeguards, and targeted investments should be designed to reduce economic and financial risks in both fossil-based and renewable projects, particularly in underdeveloped regions [67]. Moreover, risk mitigation strategies should embed environmental, social, and governance (ESG) principles to enhance public trust and market confidence, supported by transparent reporting, adaptive regulation, and cross-sector partnerships that balance technological innovation with sustainable development goals [68].

3.5. Discussion

From the result above, it is clear that the collected articles have various scopes and focuses when investigating risk management in the energy sector. From the study level and energy type, enough variability is found, and numerous interests from the research community are represented, as well as a plurality of exploration. From the type of risks identified here, there is this profound understanding that the energy sector is complex and has a multilevel perspective that needs multidisciplinary scientific inquiry. This is more so since the energy sector has become the main area for human progress into the future to have a prosperous life. Prominence in risk type is transition risk, which emphasizes attention to the energy transition issue. Risk management can help guide understanding how to overcome the barriers and obstacles in the transition process from realizing our dream future [55]. Regarding the energy trilemma, most articles reviewed here concern energy security and the environmental impact of global warming. Almost none relate to the problem of energy poverty. This will, of course, call attention to all the researchers in the energy field and provide room for a future agenda.

The case of Indonesia above shows a similar pattern in ASEAN Countries in that they share many of Indonesia's challenges in balancing the energy trilemma of security, affordability, and sustainability, but with significant diversity in capacity and policy maturity across member states. Research focuses on power-sector decarbonization modelling, regional grid integration, and renewable expansion, though attention to energy poverty and just transition remains limited. Financing constraints are widespread due to high perceived risks, underdeveloped capital markets, and regulatory uncertainty, leading to heavy reliance on multilateral and blended finance. Climate vulnerability is high, requiring investment in resilient infrastructure. Regional cooperation through the ASEAN Power Grid is gaining traction as a strategy to improve energy security and facilitate renewable integration [71] [72]. While in EU, the literature suggests that the energy transition as an integrated governance, market, and social-policy problem, embedding climate goals within strong supranational frameworks like the EU ETS and the Green Deal. Academic and policy attention is well distributed across transition risk, energy poverty, and physical resilience, with carbon pricing and regulatory mandates serving as core tools. The EU benefits from deep capital markets, established green finance instruments, and relatively high policy certainty, though internal coordination challenges and distributional tensions persist. Infrastructure resilience and adaptation to climate extremes are well integrated into planning, and the social dimension is addressed through targeted subsidies, legal protections, and just-transition funds. [73] [74]. Whereas in the USA, they approach to the energy transition emphasizes private-sector finance, market incentives, and technological innovation, driven in part by large-scale federal incentives like the Inflation Reduction Act. Academic literature focuses on transition risk in financial markets, grid resilience, and long-term investment structures such as extended PPAs. Regulatory fragmentation between federal and state levels creates policy uncertainty, and permitting bottlenecks slow infrastructure buildout. While energy poverty is recognized, it is often addressed through separate social-assistance programs rather than embedded in energy policy. The US faces acute physical risks from extreme weather events, which have already exposed significant grid vulnerabilities, prompting a push for modernization and climate-adapted planning [75] [76].

4. Conclusion

This research surveys recent articles on the energy sector, including the case of Indonesia, from a risk management perspective. The intention is to report the academic effort in identifying various issues concerning risk management in the energy sector in the country. The article delineates various risk management issues in the energy sector from a broader scope of transition risk and narrower micro risks. This map of risks will hopefully provide a more complete chart on how to create and envision our future clean energy with the earth still sustainably liveable, complete with a more equitable community [56].

Limitations are apparent in this research since only one Google Scholar database is used and only the period from 2021 to 2025 is covered. More years and other proper databases are welcome in the forthcoming research. The following research agenda can include wider areas for complementing existing studies and promote more risk management research in the energy sector. A special highlight is the area of energy poverty, which ensures democratic and equitable access to energy for Indonesia. With the country's more pressing need for energy security and tackling the environmental impact of global warming and energy poverty, this research cannot be overemphasized.

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