Analysis of Solar Renewable Energy Development in Energy Perspective in Indonesia: Prisma (Preferred Reporting Items for Systematic Review and Meta-Analysis)

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Abstract. This study aims to review of the development of solar renewable energy in Indonesia, identify key factors influencing its adoption, and analyze policies and strategies. Using the PRISMA method, this study conducted a systematic review of the literature published in the last 10 years. Data are extracted and analyzed using narrative synthesis and meta-analysis. This review identifies key in solar energy research in Indonesia, including technological developments, government policy impacts, implementation challenges, and economic and environmental benefits. The analysis shows a significant increase in the adoption of solar energy, but there is still a gap between potential and realization. Factors such as incentive policies, network infrastructure, and public awareness were found have a crucial role in solar energy development. Although Indonesia has great potential for solar energy, its implementation still faces various challenges. This research highlights the importance of technical, economic, policy, and social aspects in the development solar energy.

Keywords: Renewable energy, Solar energy, PRISMA, Energy policy

1.   Introduction

Indonesia, as the largest archipelagic country in the world, faces significant challenges in meeting its increasing energy needs (Daniarta & Farasi, 2015; Prawitasari et al., 2024). Dependence on fossil fuels not only poses environmental problems but also long-term energy security. Renewable energy, especially solar energy, offers a potential solution considering Indonesia's geographical location on the equator(Afrane et al., 2021; Wassie & Adaramola, 2019). Previous studies have explored various aspects of solar energy development in Indonesia. Some studies focus on technical aspects such as the efficiency of solar panels in tropical climate conditions, while others discuss government policies and incentives to encourage the adoption of solar energy(Aktaş et al., 2019; Gibson, 2015). There is also a study that analyzes the socio-

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economic impact of solar energy projects in various regions of Indonesia(Lim, 2022; Sthepani & Sunitiyoso, 2022; Vries, 2023). However, most of these studies tend to focus on certain aspects and have not provided a holistic picture of the development of solar energy in Indonesia.

Although a lot of research has been done, several gaps need to be filled. First, there has not been a comprehensive systematic review of the development of solar energy in Indonesia using the PRISMA method. Second, most previous studies did not consider the complex interaction between technical, economic, social, and policy factors in the adoption of solar energy. Third, comparative analysis between various regions in Indonesia in terms of potential and challenges in the development of solar energy is still limited. Finally, long-term projections about the role of solar energy in Indonesia's energy transition have not been explored in depth.

This research has crucial significance in the context of Indonesia's energy transition and global efforts to overcome climate change. The novelty of this study lies in the use of the PRISMA method to conduct a comprehensive systematic review of solar energy development in Indonesia, an approach that has never been applied before in this context (Gómez et al., 2024; Puspita et al., 2024). This analysis will not only integrate findings from previous studies, but will also identify trends, gaps, and opportunities that have not been revealed in the existing literature. By combining technical, economic, social, and policy perspectives, this research will provide a much-needed holistic understanding of the solar energy landscape in Indonesia(Bhusal et al., 2020; Chaurasia et al., 2021; Missoum & Loukarfi, 2021). The results of this study are expected to be an important reference for policymakers in designing more effective and sustainable renewable energy development strategies, as well as providing direction for future research in this field.

The main objective of this study is to conduct a systematic and comprehensive analysis of the development of solar renewable energy in Indonesia using the PRISMA method. Specifically, this study aims Identify and analyze the latest research trends in solar energy development in Indonesia context of Indonesia's energy transition(Dirie et al., 2023; *Renewable Energy Tariffs and and Incentives in Indonesia:*, 2020; Tarihoran[1] et al., 2023). Through the achievement of these goals, research is expected to make a significant contribution to the understanding and development of renewable energy in Indonesia.

2. Literature Review

According to a study conducted by (Lee & Rao, 2018) the potential of solar energy in Indonesia is very large with an average solar radiation of 4.8 kWh/m²/day. This study uses satellite data and field measurements to map the potential of solar energy throughout the Indonesian archipelago, showing that the eastern region of Indonesia has a higher potential than the western region (Asikin et al., 2015; Gad & Gad, 2015; Vries, 2023). A policy analysis published by (Jamal et al., 2021; Rahmanta et al., 2023) reveals that the implementation of the feed-in tariff policy for solar energy in Indonesia has increased private sector investment by 30% in the last three years. However, the study also identifies several regulatory hurdles that still need to be overcome to accelerate the adoption of solar energy.

Research by (Han et al., 2022; Yao et al., 2019) evaluates the efficiency of solar panels in Indonesia's tropical climate. They found that solar panels with bifacial technology showed up to a 15% increase in efficiency compared to conventional panels, especially in areas with high albedo such as white roofs or beach areas. A comparative study conducted by (Dusonchet & Telaretti, 2015; Jarzebski et al., 2024) compares the adoption of solar energy in Indonesia with

other ASEAN countries. A socio-economic analysis (Duran & Sahinyazan, 2021; Mehmood et al., 2023) shows that the implementation of community-scale solar energy projects in remote areas of Indonesia has increased access to electricity by 40% and created local jobs. However, challenges in long-term maintenance and knowledge transfer still need to be overcome(Dubey & Saravanan, 2022; Nguyen et al., 2015; Vries, 2023).

A techno-economic study published by (Chaurasia et al., 2021; Yin et al., 2020) analyzes the feasibility of a solar-diesel hybrid system for the electrification of remote islands in Indonesia. The study shows that hybrid systems can reduce diesel fuel consumption by up to 60% and have a payback period of less than 5 years in most scenarios(Missoum & Loukarfi, 2021; Narayanan, 2017). Research by (Vries, 2023)explores the potential for the integration of solar photovoltaic systems with smart grid networks in urban Indonesia. They found that the implementation of this technology can reduce the peak load of the power grid by up to 25% and improve the stability of the electricity supply.

Environmental impact study (Nengsih Titin Agustin, Muhamad Abduh, Urwawuska Ladini, 2023; Sotnyk et al., 2023; Wassie & Adaramola, 2019)evaluates the life cycle of large-scale solar farm projects in Indonesia. They found that despite the initial impact of land clearing, the project could reduce carbon emissions by up to 70% compared to fossil fuel power plants in the long run(Jumah et al., 2021). Policy analysis conducted by (Sloot & Scheibehenne, 2022) examines the effectiveness of fiscal incentives for the adoption of solar energy in Indonesia's industrial sector. The study reveals that tax cuts and initial capital subsidies have increased the adoption of solar energy in the manufacturing sector by 45% in the last two years (Rahmanta et al., 2023). Interdisciplinary research (Ante et al., 2021; Jafar et al., 2022)analyzes the potential use of blockchain technology for solar energy management and trading in Indonesia. They found that the implementation of this system can increase energy distribution efficiency by up to 30% and open up new opportunities for solar energy prosumers.

3. Methodology

This study adopts the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method to conduct a systematic review of the literature related to the development of solar renewable energy in Indonesia (Jafar et al., 2022; Syivarulli et al., 2024; Tetteh et al., 2024). The stages of research implementation include: (1) Formulation of research questions and inclusion/exclusion criteria, (2) Systematic search using Publish or Perish, (3) Screening and selection of studies based on predetermined criteria, (4) Data extraction from selected studies, (5) Assessment of study quality using appropriate instruments. Each stage will be documented in detail to ensure transparency and replication of the research(Fauzi, 2023; Torres et al., 2019; Yuniarti et al., 2024).

The research procedure begins by defining specific research questions related to the development of solar energy in Indonesia (Adhikari et al., 2024; Dubey & Saravanan, 2022; Tırmıkçı, 2021). The research team then developed a comprehensive search strategy, including keyword determination and inclusion/exclusion criteria. Literature searches are conducted using Publish or Perish, which will access various databases such as Google Scholar, Scopus, and Web of Science (Candra, 2022). According research by (Nazir, 2021) the search results will go through a gradual filtering process, starting from the title and abstract check, followed by a full-text review. Data from the selected studies will be extracted using a standard pre-designed form. The quality of each study will be assessed using appropriate instruments. Inclusion criteria

include: (1) Studies that focus on solar energy in Indonesia, (2) Published in the last 10 years, (3) Is a substantial primary or secondary study. Exclusion criteria include: (1) Non-academic technical reports or policy documents, (2) Studies that do not provide empirical data or substantial analysis. The selection process will be carried out independently by two researchers, with discussions or third-party consultations to resolve disagreements. The use of Publish or Perish will help in identifying the most relevant and influential studies based on citation metrics.

Data collection will be carried out using Publish or Perish, a software that allows a comprehensive search of academic literature (Adhikari et al., 2024; Candra, 2022). Publish or Perish will be used to access various academic databases, including Google Scholar, Scopus, and Web of Science. The search strategy will use a combination of relevant keywords such as "solar energy", "renewable energy development", and "Indonesia". Publish or Perish will help in identifying the most relevant articles based on metrics such as the number of citations, h-index, and year of publication. Bibliographic data and metrics from search results will be exported and saved for further analysis (Al-Qadami et al., 2022). In addition, full text of articles that meet the inclusion criteria will be downloaded for more in-depth data extraction.

The systematic step of PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) analysis is used to evaluate and compile the results of the research(Nagendrababu et al., 2019). PRISMA has four important stages, namely identification, screening, eligibility, and included. The identification stage shows the number of records identified using database searches and other sources (Selcuk, 2019). The screening stage displays the number of records after duplicates have been deleted, the number of records filtered, and the number of records excluded (Nazir, 2021). The eligibility stage shows the number of full-text articles assessed for eligibility and the number of full-text articles excluded with reason. Finally, the included stage displays the number of studies included in the qualitative. Each stage is connected by an arrow that shows the flow of the selection process from identification to included, and in each box will be listed the number of relevant studies for each stage. PRISMA analysis provides a clear and systematic way of evaluating and compiling research results to produce accurate and reliable conclusions.

4.   Results And Discussion

This study uses the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) method to analyze the development of solar renewable energy in Indonesia from an energy perspective. The data collection process was conducted using the Publish or Perish program, which is an effective tool for collecting scientific articles. The search focused on articles published in the last 10 years, providing a comprehensive overview of recent developments in this field. The keywords used in the search were "development economy and policy of Renewable energy solar panels in Indonesia". The use of these keywords yielded 1000 articles from various publishers, including journals, proceedings, and book chapters. This diversity of sources demonstrates the broad scope of research in the field of solar renewable energy in Indonesia, covering both economic and policy aspects.
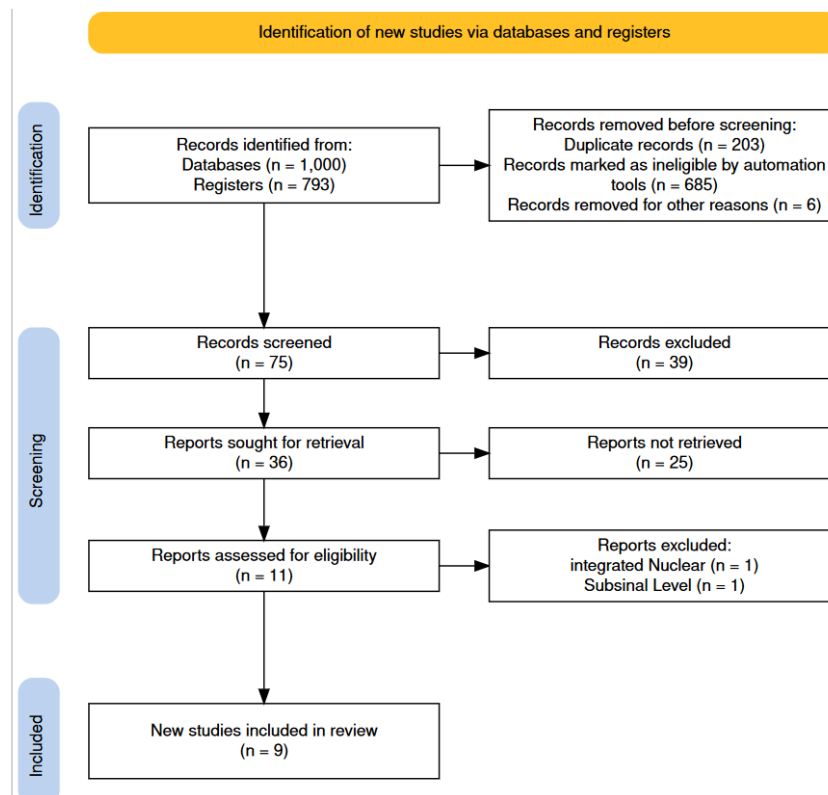
Figure 1 Prisma Filter Identification

Figure 1 From the 1000 articles collected, the initial screening process identified 203 duplicate articles. This indicates a high level of overlap in publications in this field, which may be due to multiple publications or repeated indexing by various databases. This duplicate removal process is important to ensure the accuracy of the analysis and avoid bias in data interpretation. Furthermore, 685 articles were excluded for not having an abstract. This number is quite significant and demonstrates the importance of abstracts in the screening process of scientific literature. The abstract is a key component in determining the relevance of the article to the research topic, and its absence may indicate insufficient quality or completeness of the publication. Six additional articles were excluded for not having a clear publisher. This emphasizes the importance of source credibility in scientific research. Articles without a clear publisher may be less reliable or difficult to verify, making them unsuitable for inclusion in a systematic analysis.

After the initial screening process, 75 articles were left that fit the general discussion. This number indicates that only a small portion of the initial literature was actually relevant to the specific topic of this study. This confirms the importance of a rigorous screening process in systematic reviews to ensure the quality and relevance of the data analyzed. From the 75 articles, further sorting was done based on the suitability to the theme of "development economy and policy of Renewable energy solar panels in Indonesia". This process resulted in 36 articles that were deemed relevant for further analysis. This decrease in the number of articles indicates the

specificity of the research topic and the strictness of the inclusion criteria applied. Of the remaining 36 articles, 25 were excluded after further evaluation. This shows that even after the initial screening, an in-depth evaluation is still required to ensure the articles' suitability to the research focus. This process is important to ensure that only the most relevant and qualified articles are included in the final analysis.

The final evaluation identified 11 articles that fit the research theme. However, two more articles were excluded for discussing irrelevant topics (one on nuclear and one on subsinal levels). This demonstrates the importance of reading and evaluating article content thoroughly, not just based on the title or abstract. this research resulted in 9 articles that were deemed worthy of in-depth study. This number, although small compared to the initial 1000 articles, represents a corpus of literature that is very specific and relevant to the research topic. An in-depth analysis of these 9 articles is expected to provide valuable insights into the economic and policy development of solar panel renewable energy in Indonesia.

Table 1 Development of Solar Sell Energy in Indonesia

No	Authors	Title	Year	Result
1	Dewi Yuliani (Yuliani, 2017)	Is Feed-In-Tariff Policy Effective for Increasing Deployment of Renewable Energy in Indonesia?	2017	Empirical evidence-based energy has great potential to reduce poverty and improve economic performance.
2	Eko Edya Supriyanto (Eko Eddya Supriyanto, 2023)	Green and Renewable Energy Financing Policy in Indonesia	2023	Indonesia has great potential in the use of solar power as a source of clean energy to reduce dependence on fossil fuels and the impact of climate change. However, effective policy implementation requires more than just government intentions.
3	Atmonobudi Soebagio, Bambang Widodo (Soebagio & Widodo, 2019)	Government Policy to Encourage Customers to Support Development of Renewable Energy in Indonesia – A Proposal.	2019	Analysis using the VECM method shows that GDP per unit of energy use has a positive effect on the economy in the long and short term. Carbon emissions also have a positive and significant influence, while non-renewable energy is still moving negatively and significantly.
4	Edmund Ntom Udemba, Lucy Davou Philip (Udemba & Philip, 2022)	Policy Insight from Renewable Energy, Foreign Direct Investment (FDI) and Urbanization towards Climate Goal: Insight from Indonesia	2022	In the context of renewable energy development, research shows that the optimal tariff for the most economical lines ranges from 0.39 to 1.47 cents/kWh over a post-construction 10-year period. The Innovation Diffusion

No	Authors	Title	Year	Result
				Theory-based path proved to be the most cost-effective, with the lowest initial investment and the highest income from the sale of Electricity.
5	H Fajri, Yuliarti, Y Hanoselina, N Wahyuni (Fajri et al., 2023)	Policy Capacity Challenges for Renewable Energy Development in West Sumatra, Indonesia	2023	Overall, an effective energy policy must consider empirical evidence, the potential of renewable resources, economic and environmental impacts, and appropriate implementation strategies to achieve optimal results in the transition to clean and sustainable energy.

Based on Table 1. The Indonesian government's policy on renewable energy has sparked investment interest, although there are still obstacles in its implementation. New Energy and Renewable Energy are seen as important alternatives in the national energy supply, with various policies and programs that support the development of a green economy and low-carbon energy. The implementation of this policy provides benefits, especially for areas that have been connected to the PLN electricity grid, allowing the active participation of consumers in supplying excess energy to the grid. Renewable energy has proven to be a key factor in environmental development in Indonesia, with a significant cause-and-effect relationship to carbon emissions and the use of fossil fuels.

To achieve the goal of sustainable renewable energy development and contribute to global climate change mitigation, it is necessary to strengthen policy capacity and involvement of various sectors. This paper highlights the importance of collaboration between policymakers and industry in realizing ambitious renewable energy targets in the future, while underlining the important role of renewable energy in sustainable development and environmental protection in Indonesia.

Table 2 Renewable Energy Development Policy in Indonesia.

No	Authors	Title	Year	Result
1	Wati Hermawati, Prakoso Bhairawa Putra, Dudi Hidayat, Ishelina Rosaira Poerbosisworo (Hermawati et al., 2016)	Influential Factors of Evidence-Based Energy Policy-making: Government Regulation on Targeting Renewable Energy in Indonesia	2016	Empirical evidence-based energy policies have the potential to reduce poverty and have a greater impact on the economic performance of individuals, communities, and governments. There are various limitations in the process of making energy policies and also in obtaining empirical evidence input from relevant institutions such as universities, research and development institutions (R&D), and

No	Authors	Title	Year	Result
				non-governmental organizations (NGOs).
2	T. Agung Kurniawan, Yanif Dwi Kuntjoro, Purnomo Yoesgiantoro, Habibie Satrio Nugroho (T. Agung Kurniawan et al., 2024)	Impact of Social Movements on Renewable Energy Policy in Indonesia: Study of Solar Power Plants	2024	solar power to reduce dependence on fossil fuels and reduce the impact of climate change. Indonesia has huge solar potential and is preparing to utilize solar power as a clean source of electricity. However, effective policy implementation requires more than just government intentions
3	Heru Wahudi, Ukti Siptwati, Arivina Ratih (Wahyudi et al., 2024)	Planning and Policy Direction for Utilization of Renewable Energy in Sustainable Development in Indonesia	2024	The Vector Error Correction Model (VECM) statistical method shows that in the long-term and short-term economy, the role of GDP per unit of energy use on the economy is urgently needed and has a positive effect, the role of carbon emissions in the short and long term CO2 has a positive and significant direction, non-renewable energy in the long and short term is still moving negatively and significantly.
4	Paramastri Syafina, Gbemi Oluleye (Syafina & Oluleye, 2024)	A comparative assessment of policy induced diffusion pathways for utility scale solar PV: case study of Indonesia	2024	The optimal tariff required ranges from 0.39 to 1.47 cents/kWh for the most economical line over a post-construction 10-year period. Innovation Diffusion Theory-based pathways require the lowest initial investment costs while generating the highest revenue from electricity sales, demonstrating higher cost-effectiveness compared to supply-based and linear pathways.

From table 2, empirical evidence-based energy policies have great potential to reduce poverty and improve economic performance. However, there are various challenges in the process of policy-making and the collection of empirical evidence from relevant institutions. Indonesia has great potential in the use of solar power as a source of clean energy to reduce dependence on fossil fuels and the impact of climate change. However, effective policy implementation requires more than just government intentions.

Analysis using the VECM method shows that GDP per unit of energy use has a positive effect on the economy in the long and short term. Carbon emissions also have a positive and significant influence, while non-renewable energy is still moving negatively and significantly. In the context of renewable energy development, research shows that the optimal tariff for the most economical lines ranges from 0.39 to 1.47 cents/kWh over a post-construction 10-year period.

The Innovation Diffusion Theory-based path proved to be the most cost-effective, with the lowest initial investment and the highest income from electricity sales. Overall, an effective energy policy must consider empirical evidence, the potential of renewable resources, economic and environmental impacts, and appropriate implementation strategies to achieve optimal results in the transition to clean and sustainable energy.

5. Discussion

When combined with the two tables above, it will result in a discussion that Indonesia has shown a strong commitment to the development of renewable energy through various policies and programs that encourage investment and support the green economy. Despite the challenges in implementation, renewable energy has proven to be a key factor in sustainable development and environmental protection in Indonesia. The implementation of renewable energy policies has provided significant benefits, especially in areas connected to PLN's power grid, allowing for the active participation of consumers in supplying excess energy. Economic analysis using the Vector Error Correction Model (VECM) shows the importance of the role of renewable energy in long-term economic growth and carbon emission reduction.

To achieve the goal of sustainable renewable energy development, a comprehensive approach is needed that involves strengthening policy capacity, collaboration between sectors, and the implementation of evidence-based strategies. Studies show that an approach based on Innovation Diffusion Theory can be a cost-effective solution in the development of renewable energy, especially solar power. The transition to clean energy in Indonesia requires close cooperation between the government, the private sector, and research institutions. By optimizing the use of renewable energy resources and implementing effective policies, Indonesia can achieve sustainable development goals, reduce poverty, and contribute to global climate change mitigation.

6. Conclusion

Indonesia's renewable energy policy has increased investment interest and supported the development of a green economy, although there are still implementation challenges. Renewable energy plays an important role in sustainable development and carbon emission reduction. To achieve ambitious renewable energy goals, it is necessary to strengthen evidence-based policies, collaboration between sectors, and optimize the potential of resources, especially solar power. Economic analysis shows the importance of renewable energy for long-term economic growth. Effective implementation, including optimal tariff setting and Innovation Diffusion Theory-based approaches, is necessary for a successful transition to clean energy. Cooperation between the government, industry, and research institutions is essential to achieve sustainable development goals and climate change mitigation in Indonesia

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