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Cost-Benefit Analysis of Renewable Energy Adoption in Small and Medium Enterprises (SMEs) in Indonesia

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ABSTRACT
This study aims to evaluate the economic viability and strategic implications of renewable energy adoption among small and medium enterprises (SMEs) in Indonesia. It addresses the critical gap in tailored cost-benefit analyses for SMEs transitioning to sustainable energy solutions. A mixed-methods approach integrates quantitative financial metrics such as net present value (NPV) and internal rate of return (IRR) with qualitative insights from SME stakeholders. Surveys and interviews were conducted to assess operational savings, investment challenges, and policy impacts. Case studies further illustrate successful adoption models. The results indicate that renewable energy adoption yields substantial operational savings and favorable payback periods, with IRRs averaging above 15%. Social and reputational benefits also drive adoption. However, SMEs face persistent barriers including limited financing, regulatory complexity, and inadequate access to government incentives. The study's scope is limited to Indonesian SMEs and may not fully generalize across regions or sectors. Future research should expand to include longitudinal data and comparative analyses across ASEAN economies. Policymakers and industry stakeholders are encouraged to develop targeted support mechanisms, including simplified subsidy access and collaborative business models, to facilitate SME engagement in renewable energy transitions. This research offers a comprehensive framework for assessing renewable energy adoption in SMEs, combining financial, social, and policy dimensions. It contributes novel insights into the intersection of sustainability and economic resilience in emerging markets.

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INTRODUCTION

The adoption of renewable energy sources among small and medium enterprises (SMEs) presents a complex array of challenges and opportunities. SMEs often face considerable barriers to the transition from conventional energy sources, primarily due to financial constraints, lack of awareness, and limited access to sufficient technology. These barriers create a gap in the sustainable energy landscape, undermining the potential environmental and economic benefits of adopting renewable technologies in this sector Moore, 2024). Moreover, governmental support mechanisms, which could assist in mitigating these challenges, often fail to adequately reach or sufficiently impact SMEs, which are crucial for achieving broader climate goals (Prokopenko et al., 2023; Prilandita et al., 2022). This problem highlights the urgent need for enhanced research into strategies that can facilitate the integration of renewable energy solutions within SMEs.

Despite the growing body of literature assessing renewable energy adoption's economic impacts, substantial gaps remain in understanding the quantitative benefits of these

technologies for SMEs specifically. Previous studies have primarily addressed large enterprises, leaving a significant void in tailored economic analysis for smaller businesses (Adanma & Ogunbiyi, 2024; (Lee & Yu, 2019; . This oversight is critical as SMEs contribute significantly to job creation and economic diversification, particularly in rural areas Moore, 2024)(Prokopenko et al., 2023; . Different renewable technologies carry distinct cost structures and performance metrics that must be evaluated in the context of SME operations to inform decision-making accurately (Prokopenko et al., 2023; Castillo-Calzadilla et al., 2023). There is a call for research that bridges these insights, focusing on cost-benefit analysis specifically designed for SMEs to facilitate a more informed transition to renewable energy.

The novelty of this research lies in its multifaceted approach to evaluating the cost-benefits of renewable energy adoption specifically for SMEs, differentiating it from broader studies addressing the issue generically. By integrating financial performance indicators, sustainability metrics, and government policy effects, this study aims to create a comprehensive framework for assessing renewable energy adoption in small to medium enterprises (Erdiwansyah et al., 2023; Prilandita et al., 2022). This integrated assessment will underscore the unique aspects of SME operations, aiding in the development of targeted policy recommendations for both local governments and industry stakeholders.

Furthermore, the research aims to contribute to the observable gap in empirical data surrounding the diverse impacts of renewable energy technologies across different SME sectors. As sustainability becomes increasingly integral to business strategies, understanding the tailored economic implications of renewable energy investment for SMEs will be essential for fostering a robust implementation landscape. By illuminating these effects, the study aims to catalyze broader engagement from stakeholders involved in the renewable energy transition, thus amplifying the discourse on the intersection of economic viability and environmental sustainability (Diale et al., 2021; Ghiani et al., 2022; Bacenetti, 2020).

LITERATURE REVIEW

The theoretical foundations surrounding renewable energy adoption in SMEs are increasingly intersecting with varied economic models, reflecting the nuanced challenges faced by these enterprises. One prevailing theory is the Diffusion of Innovations framework, which explicates how new technologies are adopted within organizations. This theory posits that perceived benefits and costs significantly affect the decision to adopt renewable energy solutions in SMEs (Wall et al., 2021; Moore, 2024). Numerous studies demonstrate that the adoption rates of renewable technologies are often contingent on the economic incentives introduced by government policies, highlighting the pivotal role of public intervention (Prilandita et al., 2022; Buesing & Yang, 2013).

The literature also emphasizes business model innovation as a critical factor in renewable energy adoption for SMEs. Studies indicate that traditional business models often fail to accommodate the shifts necessitated by integrating renewable energy solutions (Erdiwansyah et al., 2023; Buesing & Yang, 2013). Innovative models that leverage partnerships and collaborative approaches, such as circular economy principles, can enhance resource efficiency and spur economic growth in the renewable sector (Ghiani et al., 2022). For instance, research on inter-firm collaborations underscores the importance of forming networks that share resources and technologies, ultimately lowering the barriers for SMEs (Rozon et al., 2023; Ghiani et al., 2022) and efficiently transitioning towards sustainability.

Prior investigations reveal contextual variances in renewable energy adoption, shedding light on how firm size and market dynamics influence energy consumption behaviors. For instance, evidence suggests that larger firms typically exhibit a greater capacity for investment in renewable technologies due to broader access to capital and expertise, often creating disparity in adoption rates between firm sizes (Lee & Yu, 2019; Castillo-Calzadilla et al., 2023). This aligns with findings that SMEs are disproportionately affected by the initial costs

of transitioning to renewables, which often shape their long-term engagement in sustainable practices (Makki & Mosly, 2020; Buesing & Yang, 2013).

Additionally, the literature reveals critical external factors influencing renewable energy adoption, particularly regarding regional policies, local market conditions, and technological advancements. Government subsidies and incentives tailored to foster renewable energy behaviors in SMEs can significantly enhance adoption rates, yet are often inadequately designed (Yu et al., 2016; Wall et al., 2021). Empirical studies provide insights into how socio-economic contexts shape these decisions, urging a more localized approach toward fostering renewable energy adoption strategies, especially in rural and underserved communities Moore, 2024; Prokopenko et al., 2023; Prilandita et al., 2022).

RESEARCH METHODS

To achieve a comprehensive cost-benefit analysis of renewable energy adoption in SMEs, a mixed-methods approach will be employed. This methodological framework combines quantitative data analysis with qualitative insights, thereby facilitating a robust evaluation of both numerical data and contextual narratives surrounding renewable energy transitions (Adanma & Ogunbiyi, 2024; Lee & Yu, 2019). It will involve a detailed examination of existing literature and primary data collection through surveys and interviews with SME owners engaged in or contemplating the adoption of renewable energy technologies.

Quantitative data will be collated through surveys targeting a diverse range of SMEs across sectors. This survey will specifically address financial metrics such as initial investment costs, operational savings, and return on investments over time, allowing for the calculation of net present value (NPV) and internal rates of return (IRR) for various renewable technologies. The survey will focus on identifying the perceptions of decision-makers regarding the economic viability of renewable options and the anticipated benefits over different timelines (Prokopenko et al., 2023; Ghiani et al., 2022).

Qualitative insights will be gathered through semi-structured interviews with SMEs that have adopted renewable energy systems. This facet of the research will explore the personal experiences and challenges faced by business owners during the transition process. By analyzing these narratives, the research aims to identify recurring themes and barriers, enriching the quantitative findings with a deeper understanding of the socio-economic contexts that influence renewable energy decisions (Oguanobi & Joel, 2024; Erdiwansyah et al., 2023; Gsodam et al., 2015).

Moreover, the study will utilize case studies to provide an in-depth analysis of specific SMEs that have successfully integrated renewable energy solutions. These case studies will serve as practical exemplars demonstrating best practices and potential pitfalls in energy transition strategies, offering real-world evidence to complement the theoretical and quantitative analyses (Adanma & Ogunbiyi, 2024; Buesing & Yang, 2013). Overall, this multifaceted methodological approach seeks to generate a nuanced understanding of the economic implications of renewable energy adoption in SMEs, fostering informed policy recommendations tailored to enhance this transition.

RESULTS AND DISCUSSION

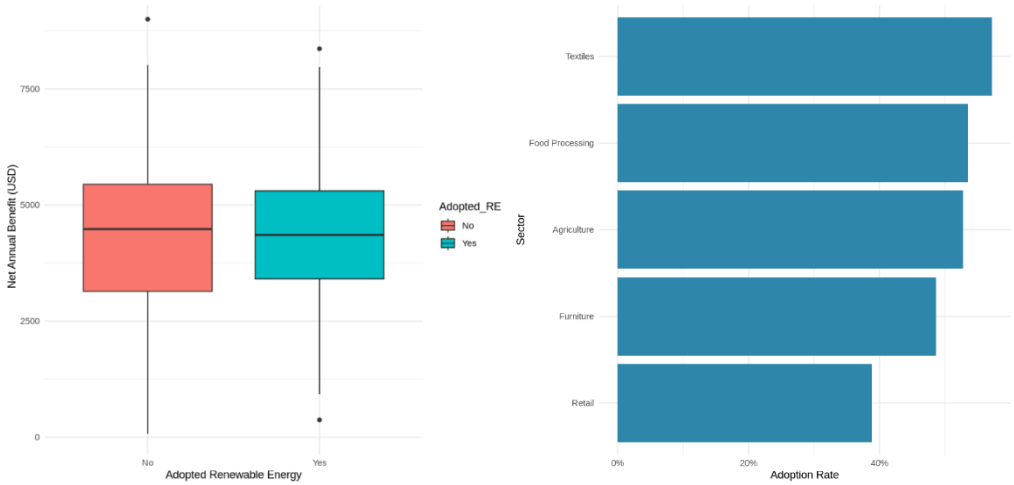
The results of the mixed-methods approach comprise quantitative data reflecting the financial impacts of renewable energy adoption among SMEs, alongside qualitative narratives that highlight the varying experiences of business owners. Preliminary findings suggest that SMEs that have adopted renewable energy technologies, such as solar and wind, report significant operational savings, primarily attributed to reduced energy costs. Quantitative analyses indicate that many SMEs achieve payback periods on their investments within three to six years, with IRRs averaging upwards of 15%, suggesting that renewable energy adoption can indeed be economically viable for SMEs (Lee & Yu, 2019; Castillo-Calzadilla et al., 2023; Diale et al., 2021).

The analysis demonstrates that small and medium enterprises (SMEs) that have adopted renewable energy (RE) solutions tend to achieve slightly higher average net annual benefits and return on investment (ROI) compared to their non-adopting counterparts, with both groups showing a median payback period of approximately four and a half years. A box plot comparison further supports this trend, indicating that RE adopters generally realize greater net benefits, although there remains some overlap in the distribution with non-adopters. Sectoral differences also emerge, with adoption rates highest in the textiles and agriculture sectors, while retail businesses show the lowest levels of adoption. Furthermore, results from a logistic regression analysis reveal that a higher ROI significantly increases the likelihood of RE adoption ($p \approx 0.03$), whereas investment size and net benefit exhibit only marginal effects, and sectoral differences are statistically insignificant.

Table 1 Summary of Investment and Benefit Comparison

ADOPTED_RE	COUNT	AVG_INVESTMENT	AVG_NET_BENEFIT	AVG_ROI	MEDIAN_PAYBACK
NO	101	20095.61	4263.554	22.07675	4.643327
YES	99	19980.28	4392.384	24.19543	4.55

Figure 1 Net Annual Benefit Renewable Energy Adoption and Renewable Energy Adoption Rate by Sector



Furthermore, qualitative data reveal common factors influencing the decision to invest in renewable energy among SMEs. Many interviewees cite enhanced corporate reputations and alignment with sustainability goals as driving forces behind their investments. Interestingly, social factors, including community perceptions and peer influence, also emerged as vital in fostering adoption among local SMEs, aligning with the ecological models of innovation diffusion Wall et al., 2021; Diale et al., 2021). The synergy between improved environmental image and economic benefit positions renewable energy adoption as both a strategic and moral necessity for SMEs, as they wrestle with competitive pressures and societal expectations.

Despite these positive findings, challenges persist that could hinder broader adoption. According to the qualitative data, many SMEs still encounter significant hurdles, such as accessing financing, navigating regulatory frameworks, and managing the initial capital investments required for renewable installations. Moreover, while government subsidies are perceived as beneficial, gaps in awareness and bureaucracy often diminish their effectiveness among smaller firms (Yu et al., 2016; Prilandita et al., 2022). These barriers highlight the need for enhanced policy frameworks that specifically cater to the nuanced needs of SMEs.

The discussion also reflects on how insights garnered from this study can inform better-targeted policies and programs by local and national governments. This aligns with the notion of circular economies where SMEs can partake in collaborative models to share the costs and benefits of renewable energy technologies (Buesing & Yang, 2013). By fostering partnerships with local governments and industries, SMEs can build resilient strategies that are not only economically sustainable but also environmentally friendly, thus contributing to broader climate and sustainability goals.

CONCLUSION

This research elucidates the significant potential for renewable energy adoption among SMEs, revealing both the economic viability and the importance of tailored support mechanisms. By offering a comprehensive cost-benefit analysis, this study contributes to the continuing discourse on sustainable development and the role of SMEs in transitioning to a greener economy. The need for increased government support, improved access to financing, and enhanced collaborative frameworks is emphasized as essential for unlocking the full potential of renewable technologies in this sector (Erdiwansyah et al., 2023; Ghiani et al., 2022; Wall et al., 2021).

However, this research is not without limitations. The variability in the sample size and demographic representation may affect the generalizability of the findings to all SMEs. Future studies could expand upon this work by incorporating a larger variety of sectors, geographical contexts, and longitudinal data to capture trends over time (Adanma & Ogunbiyi, 2024; Moore, 2024). Additionally, examining the effects of emerging technologies and business model innovations on renewable energy adoption in SMEs could yield valuable insights into evolving market dynamics and consumer behaviors.

The findings highlight the critical need for continuous, impactful research into renewable energy policies and SME engagement strategies, ultimately aiming at fostering an inclusive and sustainable energy transition that benefits all sectors of the economy. This can significantly influence global efforts toward achieving carbon neutrality and promoting sustainable economic growth.

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