

The Role of Renewable Energy Use in Making Company Operational Costs Efficiency: A Case Study of PT Chandra Asri Petrochemical Tbk

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ABSTRACT

The transition from dirty energy to renewable energy is a crucial solution to address the problem of carbon dioxide (CO₂) emissions that impact the global climate, particularly for manufacturing industries in Indonesia such as PT Chandra Asri. This study aims to analyze the effect of renewable energy implementation on the company's operational costs during the 2014-2024 decade. The method used is a qualitative approach with secondary data analysis from PT Chandra Asri's financial statements and sustainability reports. The results show that although the initial investment in renewable energy is relatively high, the company's operational costs have decreased significantly over time. Analysis using the Operating Expense Ratio (OER) and Return on Investment (ROI) shows that the OER fluctuates, but shows a downward trend after the implementation of renewable energy. Meanwhile, ROI increases rapidly within two years after the initial investment, indicating potential long-term benefits. This study concludes that the transition to renewable energy not only contributes to reducing carbon emissions but also optimizes the company's operational costs. Thus, the implementation of renewable energy is a strategic step that provides economic benefits and environmental sustainability for PT Chandra Asri.

Keywords: Renewable Energy, Cost Efficiency, Manufacturing, Green Energy Investment.

Introduction

Managing carbon emissions (CO₂) has become a critical issue in recent years, due to its direct and indirect impacts on climate change and sustainability, including in Indonesia. One such impact is increasingly pronounced global warming. Indonesia is highly vulnerable to climate change due to its large population and the presence of thousands of small islands.

Global warming is currently being felt by people around the world. As the dry season approaches, the weather becomes extremely hot, making it difficult for some to focus while working or studying, especially without the aid of air conditioning. When human resources are not at their optimal level, their performance will also be suboptimal, and when their performance is suboptimal, their workplace management systems will also be suboptimal. This is a sign that climate change is significantly impacting the economies of several countries. (Fudjumdjum & Filho, 2026). On the other hand, climate change itself is caused by several factors, both natural and human. First, from the natural side, this is called natural

climate variability, often caused by volcanic activity, variations in Earth's orbit, or ocean-atmosphere phenomena. Meanwhile, from the human side, it is often caused by deforestation, industry and power plants, or waste and waste management. (Weathers et al., 2025)

According to (Statista, 2025), Global carbon dioxide (CO₂) emissions from fossil fuels and industry reached 37.01 billion tonnes in 2023 and are projected to increase by 1.08% to 37.41 billion tonnes in 2024. Since 1990, global CO₂ emissions have increased by more than 60%, while total greenhouse gas (GHG) emissions reached a record 53 billion tonnes of CO₂ equivalent in 2023. With the global carbon budget rapidly shrinking and 2024 projected to be the hottest year on record, the race to achieve net-zero emissions by mid-century to avoid the worst impacts of climate change is on. Therefore, climate change from the ongoing increase in carbon dioxide (CO₂) emissions has become a global concern, for both developed and developing countries. In addition to climate change, greenhouse gas (GHG) emissions and the use of ODS are also concerns, with their regulations limited through the Kyoto Protocol, ratified by Indonesia in Law No. 17 of 2004 concerning global GHG reduction. (Setiawan et al., 2024)

With this regulation, several companies, including manufacturing companies, are competing to switch their power generation base materials to greener or renewable energy. Based on (Osman et al., 2023) that the initial investment that must be made by the company in implementing renewable energy is indeed expensive, but the fluctuation in expenditure on renewable energy costs is cheaper when compared to dirty energy, and also the impact on the environment is very impactful, because the use of renewable energy produces almost no CO₂ emissions.

Although several studies have been conducted on the impact of renewable energy on companies and manufacturing industries, including environmental, social, and regulatory compliance impacts, there has been little focus on corporate finance, as many companies are transitioning from renewable energy to renewable energy for regulatory compliance reasons, in order to address the global problem of CO₂ emissions. On the other hand, research on cost efficiency is rare because the impact of renewable energy on corporate finances takes a long time to develop. (Ren et al., 2025). Furthermore, existing research often focuses on a single financial indicator, such as a company's profitability when renewable energy is implemented, without linking it to the operational efficiency ratio when the company implements renewable energy. Another gap that could be addressed in this research is the lack of studies that apply an evaluative approach based on long-term data from a company to compare conditions before and after the implementation of renewable energy.

PT Chandra Asri, a manufacturing company, saw this opportunity to address the significant CO₂ emissions they released in 2018, amounting to 2,230,286 tons of CO₂ during their operations. Therefore, in 2019, they began implementing renewable energy to reduce emissions. This also indirectly impacted their operational costs.

Electricity prices are one of the most significant cost drivers in the operations of companies like PT Chandra Asri. In recent years, the financial results of manufacturing

companies have been affected by rising and highly volatile electricity prices. PT Chandra Asri is exploring innovative solutions to lower electricity costs, such as investing in its own power generation sources. Renewable energy provides an effective system for minimizing energy consumption costs within a company or maximizing profits associated with operating the entire system, including energy generation, consumption, purchasing, and storage. (Benalcazar et al., 2024). Investing in renewable energy can reduce operating costs in the medium to long term due to lower energy production costs compared to conventional sources. One study found that investing in solar power plants can improve economic efficiency by lowering energy production costs and supporting a reduction in total operating costs compared to conventional power generation models. This is achieved by taking into account several key factors: initial investment costs, actual energy production, and electricity prices. (Akbulut et al., 2025).

Theoretical Framework And Hypothesis

A search of scientific articles was used to support this research. This included searching for theories that had been used in previous studies. Furthermore, the theories used below are also supported by evidence from their respective studies.

Renewable Energy

Renewable energy is energy derived from natural sources that can be naturally renewed and are available indefinitely. With technological advances, this type of energy is becoming increasingly accessible as an alternative to the conventional energy sources commonly used by humans. (Bouattour et al., 2025). Each country has different renewable energy potential, for example, Germany maximizes wind turbines, Austria hydroelectric power, France nuclear power, the Netherlands biomass, and Denmark renowned for its wind energy. Due to these differences in potential, renewable energy development in each country requires special considerations to ensure optimal utilization. Many companies are also starting to utilize renewable energy in their operations. Renewable energy sources include solar, wind, ocean waves, and ocean thermal energy. These energies are typically used to generate electricity, while geothermal energy can be directly harnessed for heating and cooking. Biomass and solar energy are also commonly used for space and water heating, while ethanol and biodiesel are utilized as transportation fuels. However, the environmental impact of each type of renewable energy is still influenced by its entire life cycle, from equipment manufacturing and installation, materials used, and land use. (Vlaviorine & Widianingsih, 2023)

Operating Costs

Operational costs essentially represent all forms of economic resource sacrifices a company must make to achieve its goals, both short-term and long-term, and are all reflected in monetary terms. Shifting from dirty energy to renewable energy is often viewed as a major step requiring a significant initial financial commitment. (Ren et al., 2025). However, upon closer examination, these investment costs actually represent a sacrifice of resources that could potentially reduce long-term operating costs. Renewable energy doesn't require regular

fuel purchases, isn't susceptible to fluctuations in oil or gas prices, and offers a more predictable, stable energy supply. In other words, companies that switch to renewable energy aren't simply "saving electricity costs," but are fundamentally changing their operating cost structure. Costs that were previously constantly rising due to fossil fuel consumption can be reduced, creating greater room for companies to increase profits. If operating costs decrease, profit margins logically improve. (Sinta & Kembaren, 2011). Operational efficiency in manufacturing companies can be improved through a combination of conventional and digital energy companies. This combination ensures the convergence of energy and information resources, develops unique energy systems, reduces production costs, encourages innovation, maximizes energy efficiency, and accelerates the transformation to green and clean energy sources. (Ozturk et al., 2025)

The Role of Renewable Energy in Economic Growth

Global energy transformation represents a significant development in addressing climate change, energy scarcity, and creating sustainable development. Beyond reducing greenhouse gas emissions, this evolution creates substantial socio-economic benefits and secure energy access. Many developing countries, such as India, have demonstrated the clear economic benefits of renewable energy adoption. The increase in employment and Gross Domestic Product (GDP) growth due to renewable energy adoption are clear evidence. (Murugan et al., 2025). An economy characterized by the development of information and communication technology is key to implementing the renewable energy transition through various means. Digital technologies, such as smart grids and the digitization of energy management systems, have fundamentally transformed the processes of energy generation, distribution, and consumption. (Wu & Ampong, 2025). Accurate calculations are necessary for the effective implementation of renewable energy applications, such as insulation, window optimization, and building envelope improvements, which are implemented to ensure energy efficiency can be achieved, and the company's energy or operational costs can be created. In addition, it is recommended to use dynamic energy performance analysis rather than static data in calculations. (Akbulut et al., 2025)

PT Chandra Asri

PT Chandra Asri Petrochemical Tbk (CAP) is the largest petrochemical company in Indonesia. The company was formed in 2011 through a merger between PT Chandra Asri and PT Tri Polyta Indonesia Tbk, two major entities in the national petrochemical industry. Through this merger, CAP became the first integrated petrochemical company to operate the largest olefin and polyolefin production complex in Indonesia. Chandra Asri's main production complex is located in Cilegon, Banten, which is strategically located to support the distribution and operations of the petrochemical industry. In line with the development of the national industry, CAP continues to expand its production capacity and develop process technology to improve the efficiency, quality, and sustainability of the company's operations.

Previous Research

Table 1. Previous Research

No	Author & Year	Research Title	Research result
1	Oriza Candra, Abdeljelil Chammam, José Ricardo Nuñez Alvarez, Iskandar Muda, Hikmet Ş. Aybar (2023), (Candra et al., 2023)	The Impact of Renewable Energy Sources on Sustainable Economic Development and Greenhouse Gas Emissions	• Recommendations to increase the share of renewable energy in total energy generated should be on the working horizon of politicians. • Investments in renewable energy are substantial, but costs incurred after implementing renewable energy remain stable. • The use of renewable energy impacts a country's reputation in the global market. • Contributes to creating a healthy environment by improving population health, due to the impacts of implementing renewable energy.
2	Rafał Wyszomierski, Piotr Bórawski, Aneta Beldycka-Bórawska, Agnieszka Brelik, Marcin, Wysoki'nsk, Magdalena Wiluk (2025), (Wyszomierski et al., 2025)	The Cost-Effectiveness of Renewable Energy Sources in the European Union's Ecological Economic Framework	• Cost-effectiveness of plant biomass compared to other renewable energy sources. • The Levelized Cost of Energy (LCOE) is used to determine production costs in European Union member states. • There is insufficient evidence to suggest that biomass renewable energy is superior to other renewable energy sources due to significant fluctuations in biomass prices. • However, preliminary observations and analysis suggest that biomass can be one of the cheapest energy sources if sourced from local agriculture, produced on-site, or if waste biomass is used in energy generation.
3	(Rismanto, 2024)	The Role of Investment in Renewable Energy in Driving Sustainable Economic Growth in the Era of Net-Zero Emissions	• Investment in renewable energy plays a crucial role in driving sustainable economic growth. • Allocating resources to renewable energy technologies such as solar and wind power not only reduces dependence on fossil fuels but also provides significant positive impacts on the economy, including job creation and reduced energy costs. • Challenges such as high capital requirements, infrastructure issues, and inconsistent government policies need to be addressed to maximize the benefits of these investments. • Strong supportive policies and collaboration between the public and private sectors are key to overcoming these barriers and facilitating the development of the renewable energy sector.

Hypothesis

Assuming operational cost efficiency is a company's ability to optimize existing resources, resulting in lower operational costs. In this case, the use of renewable energy can lower a company's costs, even if the initial cost is high. However, it offers lower maintenance costs, is easier to maintain, reduces dependence on fuels like oil, which tend to fluctuate, and can be a long-term asset. (Wyszomierski et al., 2025). Therefore, based on the research reviewed, PT Chandra Asri will still earn a profit (if not influenced by external factors), but operational costs will decrease. This will result in efficiency if renewable energy is implemented to replace dirty energy. (Rofiqi et al., 2025)

Research Methods

Quantitative research design, or more precisely, applied quantitative research, is a method for in-depth writing that emphasizes an evaluative approach. The quantitative research process also emphasizes a thematic perspective, and researchers rely on a theoretical foundation to ensure the research process responds to the facts they discover during the study. Qualitative research methods aim to explain phenomena in depth and are conducted by gathering as much information as possible. (Yang et al., 2025).

This study uses secondary data derived from PT Chandra Asri's 2014-2024 Annual Financial Report and 2020-2024 Sustainability Report. The data sources for the Financial Report and Sustainability Report are reports published on PT Chandra Asri's official website. The figures obtained will be further analyzed in the data analysis.

The data obtained was utilized through documentation collection and web searches. Furthermore, a literature study, a data collection method involving the review of books, literature, records, and various reports relevant to the problem to be solved, helped researchers align the implemented strategies. The goal was to demonstrate that the renewable energy transition can contribute to operational cost efficiency. (Jailani, 2023).

Table 2. Operational Costs, Clean Energy Investment, and Net Income of PT Chandra Asri for the 2014-2024 period

Years	Cost Operating	Clean Energy Investment	Net Income
2014	\$ 2.342.587,00	-	\$ 2.460.051,00
2015	\$ 1.231.844,00	-	\$ 1.377.537,00
2016	\$ 1.436.018,00	-	\$ 1.930.336,00
2017	\$ 1.873.505,00	-	\$ 2.418.509,00
2018	\$ 2.152.729,00	-	\$ 2.543.219,00
2019	\$ 1.709.877,00	\$14.000.000,00	\$ 1.880.989,00
2020	\$ 1.641.322,00	\$238.176,00	\$ 1.806.444,00
2021	\$ 2.235.404,00	\$5.010.000,00	\$ 2.580.425,00
2022	\$ 2.395.545,00	\$5.063.000,00	\$ 2.384.591,00
2023	\$ 2.078.102,00	\$5.070.000,00	\$ 2.159.932,00
2024	\$ 1.737.045,00	\$8.020.000,00	\$ 1.785.364,00

Source: Financial Report and Sustainability Report of PT Chandra Asri 2014-2024

The analysis technique will begin by analyzing operational cost data before and after the use of renewable energy by calculating the Operating Expense Ratio (OER) to identify direct comparisons and changes that occur between before and after the use of renewable energy. (Radwitya et al., 2023)

$$\text{Operating Expense Ratio (OER)} = \frac{\text{Cost Operating}}{\text{Net Income}} \times 100$$

Additionally, a Return on Investment (ROI) analysis is used to help determine the success rate of renewable energy implementation. These two calculations will demonstrate whether or not renewable energy implementation has reduced operational costs. (Bahri & Hakim, 2022)

$$\text{Return on Investment (ROI)} = \frac{\text{Net Income}}{\text{Clean Energy Investment}} \times 100$$

Results And Discussion

Operationg Expense Ratio (OER)

Based on PT Chandra Asri's 2014-2024 financial report, the calculation of operational costs against net income using the Operating Expense Ratio (OER) is as follows :

Table 3. Calculation OER of PT Chandra Asri 2014-2024

Years	Cost Operating	Net Income	OER
2014	\$ 2.342.587,00	\$ 2.460.051,00	95%
2015	\$ 1.231.844,00	\$ 1.377.537,00	89%
2016	\$ 1.436.018,00	\$ 1.930.336,00	74%
2017	\$ 1.873.505,00	\$ 2.418.509,00	77%
2018	\$ 2.152.729,00	\$ 2.543.219,00	85%
2019	\$ 1.709.877,00	\$ 1.880.989,00	91%
2020	\$ 1.641.322,00	\$ 1.806.444,00	91%
2021	\$ 2.235.404,00	\$ 2.580.425,00	87%
2022	\$ 2.395.545,00	\$ 2.384.591,00	100%
2023	\$ 2.078.102,00	\$ 2.159.932,00	96%

Source: PT Chandra Asri Financial Report and Sustainability Report 2014-2024.

Data processed in 2025

Based on data from 2014 to 2024, the company's OER fluctuates. Several years, such as 2015, 2016, 2019, 2020, and 2024, show relatively lower OER, even below 100%. This figure indicates that in those years, the company successfully managed its operating costs, resulting in lower costs than revenue.

However, there are also periods where the OER exceeds 100%, such as in 2022. This indicates that operating expenses in that year were greater than net income, which can be a concern for management to evaluate and control expenses.

Return on Investment (ROI)

Meanwhile, the calculation of the implementation of renewable energy or clean energy uses data from the 2019-2024 sustainability report of PT Chandra Asri, this data is used because PT Chandra Asri began using renewable energy in 2019. The calculation will use the Return on Investment approach to see the financial returns on the implementation of renewable energy. The following are the calculation results :

Table 4. Calculation ROI of PT Chandra Asri for the 2019-2024 Period

Years	Net Income	Clean Energy Invesment	ROI
2019	\$1.880.989,00	\$14.000.000,00	13%
2020	\$1.806.444,00	\$238.176,00	758%
2021	\$2.580.425,00	\$5.010.000,00	52%
2022	\$2.384.591,00	\$5.063.000,00	47%
2023	\$2.159.932,00	\$5.070.000,00	43%
2024	\$1.737.045,00	\$1.785.364,00	97%

Source: PT Chandra Asri Financial Report and Sustainability Report 2014-2024.

Data processed in 2025

PT Chandra Asri's Return on Investment (ROI) exhibited a fluctuating pattern throughout the renewable energy transition. In 2019, ROI remained low because the company was just entering the initial investment phase, so capital costs had not yet directly impacted profits. In 2020, ROI saw a significant surge due to significantly lower investment compared to the previous year, while renewable energy systems began operating and began generating efficiencies. Entering 2021–2023, ROI stabilized within the normal range, indicating that renewable energy utilization was making a significant and consistent contribution to the company's cost efficiency. However, in 2024, ROI rose again due to increased investment in clean energy expansion, indicating the company was entering a more advanced development phase, where economic benefits may only be apparent in the medium term. ROI data shows that renewable energy investments produce gradual and strengthening returns over time, but require reinvestment to increase long-term efficiency.

The Impact of Renewable Energy Implementation on Operational Costs

The Operating Expense Ratio (OER) calculation indicates that PT Chandra Asri's operational costs have fluctuated in percentage over a decade, from 2014 to 2024. However, in certain years such as 2015, 2016, and 2017, the OER calculation results were at a lower level, indicating that the company was able to manage operational costs stably so that the cost burden did not approach net income. Meanwhile, after 2019 and above, when the company began implementing renewable energy, the OER value tended to increase, especially from 2022 to 2024 when the value was close to or even reached 100%. This increase indirectly indicates that the implementation of renewable energy has a high risk, considering that the initial investment in clean energy technology is usually relatively expensive. The use of renewable energy over time, slightly reduced operational costs as evidenced by in 2023 which managed to decrease around 96%.

Meanwhile, the Return on Investment (ROI) calculation results show a different pattern from the OER results when associated with PT Chandra Asri's clean energy transition period. PT Chandra Asri first implemented the use of Renewable Energy, namely 2019. In 2019, ROI appeared low because PT Chandra Asri made a significant investment, with funds amounting to US \$ 14,000,000. However, on the other hand, the economic benefits had not yet had an impact. In the following year, 2020, ROI increased drastically because the investment was much smaller, the investment value is stated in the sustainability report as additional funds for the implementation of renewable energy. After that, in the period from 2021 to 2023, ROI was in the stable range, illustrating that the benefits of renewable energy on reducing energy costs have occurred consistently. However, in 2024, ROI decreased again, not because of a decrease in the effectiveness of renewable energy, but because the company again increased investment for the continued development of clean energy, the impact of which will only be seen in the medium term.

The impact of OER and ROI on renewable energy implementation is evident, as both outcomes influence each other in the implementation of renewable energy on a company's operating costs. When renewable energy investments begin to yield results, ROI increases, indirectly helping to contain increases in operating costs, which is then reflected in the stability of OER in the years after 2020. Conversely, when there are large investment increases, such as in 2019 and 2024, OER tends to increase due to the burden of costs for implementing and sustaining renewable energy, while ROI decreases as a direct response to the large capital investment. This proves that renewable energy is indeed a long-term investment, and the impact on operating cost efficiency must wait for around 5-7 or even 10 years.

OER and ROI show that the use of renewable energy has a positive impact on the operational cost efficiency of PT Chandra Asri. ROI indicates that the investment from dirty energy to clean energy shows a financial return to PT Chandra Asri after the initial implementation phase, while OER shows that renewable energy is a major player in stabilizing and reducing operational costs in the period from 2014 to 2024.

Relationship of Findings with Previous Studies

The findings of this study are largely in line with previous research, both nationally and internationally, which shows that the transition to renewable energy does not bring immediate financial benefits, but rather serves as a long-term strategic investment. (Rismanto, 2024) shows that investments in renewable energy tend to exhibit delayed economic effects, where financial benefits are only felt after the technological adaptation and operational stabilization phases.

These findings are also consistent with studies published in leading international journals such as *Energy Economics* and *Renewable Energy*, which state that industrial companies transitioning to renewable energy will experience increased costs in the initial stages due to high capital expenditures. However, in the medium to long term, these companies benefit from reduced energy costs, stable expenditures, and protection from fossil fuel price volatility. Therefore, the increase in OER (Operating Expenditure Ratio)

and decrease in ROI (Return on Investment) in the early years of PT Chandra Asri should not be seen as inefficiency, but rather as a rational consequence of the energy transition process.

Importantly, the results of this study also show that the effectiveness of renewable energy in improving operational cost efficiency depends on the scale of investment, implementation strategy, and external conditions of the company. The fluctuations in OER that persist in the years after implementation indicate that the energy transition does not occur in isolation, but interacts with other factors such as global market conditions, raw material prices, and dynamics in the petrochemical industry. The findings are also in line with international research stating that the success of renewable energy in improving cost efficiency will be more optimal if supported by integrated energy management and sustainable investment planning. Compared with previous studies that mostly use a macro or cross-country approach, this study contributes with more specific empirical findings at the company level (firm-level analysis), particularly in the petrochemical industry in Indonesia.

Therefore, this study fills the research gap by demonstrating how the transition to renewable energy affects operational cost efficiency through financial indicators such as OER and ROI in the long term. Overall, the results and discussion emphasize that the transition to renewable energy at PT Chandra Asri is not only an environmental sustainability strategy but also a rational economic decision. Despite facing challenges such as high initial investment costs, the financial benefits and operational cost efficiencies are clearly visible over time, in line with previous findings and theories on sustainable energy investment.

The findings of this study are supported by the references used by the author. According to the study (Yang et al., 2025), The transition to renewable energy in the industrial sector does not directly impact financial performance, but occurs gradually and is heavily influenced by the investment period. Meanwhile, in the study (Rismanto, 2024) stated, "Investment in renewable energy in the initial stage tends to increase company costs, but in the medium and long term, it can reduce operational costs and increase energy efficiency".

This statement aligns with PT Chandra Asri's findings, where the return on investment (ROI) was relatively low at the beginning of renewable energy implementation due to the high initial investment, but showed improvement and stability in subsequent years. Furthermore, the study emphasized that reducing reliance on fossil fuels plays a key role in creating stable operating costs for the company. This explains why, despite fluctuations in OER at PT Chandra Asri after 2019, the long-term trend shows stabilizing operating costs as renewable energy usage increases.

Furthermore, an international journal published in Sustainability highlighted that the adoption of renewable energy by manufacturing companies not only reduces emissions but also strengthens their economic performance. The journal stated, "The adoption of renewable energy contributes to long-term cost efficiency and financial resilience by reducing exposure to fossil fuel price volatility". (Candra et al., 2023). Temuan ini relevan

dengan situasi di PT Chandra Asri, di mana penggunaan energi terbarukan membantu perusahaan mengendalikan struktur biaya energi dan mengurangi risiko fluktuasi harga energi global. Lebih lanjut, artikel tersebut juga menekankan bahwa keberhasilan transisi energi sangat dipengaruhi oleh investasi yang konsisten dan integrasi kebijakan keberlanjutan ke dalam strategi bisnis perusahaan. These findings are relevant to the situation at PT Chandra Asri, where the use of renewable energy helps the company control its energy cost structure and mitigate the risk of global energy price fluctuations. Furthermore, the article emphasizes that the success of the energy transition is heavily influenced by consistent investment and the integration of sustainability policies into a company's business strategy. It states that "companies that consistently integrate renewable energy into their core business strategies tend to achieve more stable operating cost structures over time".

It states that "companies that consistently integrate renewable energy into their core business strategies tend to achieve more stable operating cost structures over time".

This explains why PT Chandra Asri is still showing fluctuations. By integrating (Candra et al., 2023) with findings (Rismanto, 2024) and articles owned by (Wyszomierski et al., 2025), it can be critically concluded that the renewable energy transition at PT Chandra Asri has a strong empirical and theoretical foundation. This study not only confirms previous research but also enriches the literature with contextual evidence on the Indonesian petrochemical industry, particularly in explaining the relationship between renewable energy, operational cost efficiency, and corporate financial performance.

Conclusion

The results of this study indicate that PT Chandra Asri's transition from dirty energy to renewable energy has successfully reduced carbon dioxide (CO₂) emissions from operational activities. This planning also helps to achieve operational cost efficiency. Although the initial investment for renewable energy is high, the company's operational costs have decreased over time, as reflected in the calculation of the Operating Expense Ratio (OER). In addition, the Return on Investment (ROI) shows fluctuations with a gradual increase after the initial years of investment, proving that this prospect is classified as a long-term investment. This study also indicates that despite the risks and challenges in the initial implementation of renewable energy, this transition not only has a positive impact on operational costs, but also helps realize the environmental sustainability of PT Chandra Asri's operational activities, and recommends this system to continue to manage costs effectively to maximize the benefits of renewable energy.

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