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Financial Impact Analysis of Carbon Pricing on Geothermal Power Plant Project Investment at PT PLN (Persero)

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ABSTRACT: Climate change is a significant global challenge, mainly driven by greenhouse gas (GHG) emissions. The energy sector is a major contributor to GHG emissions, accounting for approximately 73% of global emissions in 2022. Within the energy sector, electricity emitted 13 GtCO2 or contributes approximately 35% of global emissions related to energy. To address this challenge, PLN, a state-owned electrical utility in Indonesia, has declared a roadmap to achieve Net Zero Emissions by 2060. The company has also implemented some strategic initiatives to achieve the goal. Carbon pricing is one of the key efforts that enable PLN to receive incentives for reducing GHG emission while also enhancing financial performance. This study examines effects of implementing a carbon trading mechanism on the financial metrics of a 110 MW Geothermal Power Plant project investment. The results demonstrate a 13.58% increase in NPV, a faster payback period from 8.37 to 7.67 years, and a 0.31% rise in the MIRR. These results indicate the potential improvements in project investments financial performance that PLN can achieve while still aligning with global environmental objectives.

KEYWORDS: Carbon pricing, Energy transition, Financial performance, Geothermal power plant, Net zero emissions, Project investment.

1. INTRODUCTION

Climate change is a substantial worldwide problem that posing threats to the environment, human health, social welfare, and economic development. According to the Intergovernmental Panel on Climate Change (IPCC), a United Nations body for assessing the science related to climate change, rising temperatures lead to extreme heatwaves, changed precipitation patterns, and disturbances to ecosystems, which intensify issues such as deforestation and the loss of biodiversity (IPCC, 2018). These changes increase health hazards, including heat-related illnesses and diseases transmitted by vectors, specifically affecting vulnerable populations (Watts et al., 2021). Extreme weather events have a significant on social welfare, leading to relocation, food shortages, and resource conflicts (Adger et al., 2018).

The energy sector is a major contributor to greenhouse gas (GHG) emissions on global scale, accounting for about 73% of emissions in 2022 (International Energy Agency, 2022). The emission are primarily generated by electricity generation, which contributes 35% of these emissions. This emphasizes the need for a transitioning to renewable energy sources that have lower carbon emission. Carbon trading is a key mechanism to encourage this transition, by providing incentives for reducing GHG emissions through the establishment of emission limits and allowing organizations to trade carbon credits.

Various carbon pricing mechanisms have been implemented internationally. The European Union's Emissions Trading System (EU-ETS) and China's National Emissions Trading System are widely recognizes examples, although countries like South Korea, Thailand, and Singapore also implemented other strategies customizes to their contexts. Indonesia is now working on implementing carbon pricing programs. The government exploring potential mechanisms through the Carbon Pricing Working Group (CPWG) and integrating these concerns into national development plans (DNPI, 2020; Government of Indonesia, 2016).

PT PLN (Persero), Indonesia's state-owned electricity company, plays a vital role in facilitating this transformation. PLN, as a major electricity provider, makes a significant contribution to the country's GHG emissions. The company’s objectives is to achieve Net Zero Emissions by 2060, with a primary focus on developing a green ecosystem and reducing reliance on fossil fuels. However, PLN faces challenges such as dependency on conventional energy sources, financial risks caused by fossil fuel market fluctuations, and limited funding.

To bridge the gap between its current operations and sustainability goals, PLN is implementing strategies like decarbonize coal and gas plants, expand renewable capacity and its supporting system. This transformation requires substantial investment in renewable infrastructure, which has a direct influence on financial indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period.

This objective of this study is to assess the financial impact of carbon pricing implementation on PT PLN's investment decisions in renewable energy projects. The objectives are:

1. To analyze the changes in financial indicators included IRR, NPV and Pay Back Period resulting from the implementation of carbon pricing in PLN's renewable energy power plant development projects.
2. To develop recommendations for an implementation plan that enables PLN to effectively leverage carbon pricing mechanisms, supporting investment decisions for renewable energy power plant development projects

However, this study focuses only to the quantitative methods used to asses financial impact analysis of implementing carbon credit on project investment decision for the expansion plan of renewable energy at PLN. The study will compare two scenarios: the business-as-usual approach where no participation in the carbon credit scheme and the scenario where participation in carbon credit scheme takes place.

In addition, there are limitation of this study, which are:

1. The results of the study may become outdated if new policies or regulations are released and implemented, which may affect results of the study.
2. The results depend on the type, capacity, and location of the renewable energy power plant used as a case study.
3. The study focuses on a carbon credit scheme which is aligned with the project case and regulations at the time of the study was conducted.
4. The study does not provide specific recommendations for PT PLN (Persero) or other stakeholders but offers insights for further research and decision-making.

2. LITERATURE REVIEW

2.1 Energy Transition

Energy transition is broadly defined as the process of shifting from one energy system to another, which usually involves a change in the primarily fuel source or energy technology. This transition often includes shifting away from fossil fuels like coal, oil, and natural gas, and towards renewable energy sources such as wind, solar, hydropower and geothermal. The process of energy transition is complex, often covering technological, economic, and social changes that might span several decades. According to Sovacool (2016), energy transitions are usually prolonged affairs, requiring significant shifts in not only technology but also in political regulations, tariffs, pricing regimes, and user behaviors.

The global energy transition is gaining momentum as countries and regions increasingly prioritize the shift from fossil fuels to renewable energy sources in response to climate change and sustainability goals. This transition is marked by a growing demand on renewable energy technologies such as solar, wind, hydropower, and geothermal, together with a gradual phasing out of coal and oil fuel power plants. Renewable energy capacity has been expanding rapidly, driven by developments in technology, decreasing costs, and supportive regulation released by government.

In Southeast Asia, including Indonesia, the pace of the energy transition is accelerating, although it faces unique challenges. Indonesia, with its abundant coal resources, has relied heavily on fossil fuels to meets its energy needs. However, the government has recognized the importance of transitioning to a more sustainable energy mix and has set aggressive targets to increase the share of renewables in its energy portfolio. The Indonesian government's energy roadmap outlines plans to achieve 23% renewable energy in the national energy mix by 2025. This strategy primarily focus on the development of geothermal, hydro, solar, and wind energy. The country is also exploring the potential of bioenergy and tidal energy to diversify its renewable energy sources.

2.1.1 Impact on Financial Performance

The energy transition has significant implications for the financial performance of energy companies. As companies shift from using fossil fuels to utilizing renewables energy sources, capital expenditures (CAPEX) are increasingly directed towards the development and deployment of renewable energy infrastructure. This shift often requires substantial upfront investment in new technologies and facilities, such as solar farms, wind turbines, and energy storage systems. While the initial capital outlay can be high, the long-term operating costs associated with renewable energy are generally lower than those of fossil fuel-based systems. Renewables have the advantage of low or zero fuel costs, which reduces the ongoing operational expenditures (OPEX) and improves profit margins over time (Brealey, Myers, & Allen, 2020; Damodaran, 2012).

Revenue generation is also impacted by the energy transition. Renewable energy projects can benefit from government incentives, carbon pricing mechanisms, and increasing demand for clean energy, all of which can enhance revenue streams. However, energy companies must also navigate market volatility, changes in regulatory frameworks, and the gradual decline in demand for fossil fuels. In Indonesia, the energy transition presents both risks and opportunities for financial performance, with the potential for enhanced profitability through strategic investments in renewables and participation in carbon trading schemes (Fischer & Newell, 2008).

2.1.2 Challenges and Opportunities

The adoption of renewable energy poses several obstacles for energy companies, especially in countries like Indonesia where fossil fuels have long dominated the energy source. One of the key challenges is the existing infrastructure, which is often designed for the extraction, processing, and distribution of fossil fuels. Replacing this infrastructure to support renewable energy sources can incur significant cost and require substantial amount of time (Mun, 2010). In addition, energy companies must struggle with regulatory uncertainty, as governments continue to adjust laws and incentives regarding the transition to clean energy. This unpredictable situation can have effect on investment decisions and long-term planning.

Another challenge is the variability and intermittency of renewable energy sources such as solar and wind, which require advanced grid management and energy storage solutions to ensure a stable and reliable energy supply. In Indonesia, the geographic diversity of the archipelago presents difficulties in logistic for the project development of renewable energy, especially in remote or underdeveloped areas.

Although facing these obstacles, the energy transition has significant opportunities for both financial and environmental benefits. Companies that successfully manage the transition might get advantages from a lower operational costs, increase market competitiveness, and opportunities to generate new revenue streams through renewable energy projects and carbon pricing mechanisms (Ekins et al., 2011). Furthermore, the transition also aligns with broader environmental goals by reducing greenhouse gas emissions, improving air quality, and contributing to sustainable development.

The energy transition in Indonesia is not only a corridor to achieving climate goals but also an opportunity to enhance energy security, reduce dependency on fossil fuel imports, and create employment opportunities in the renewable energy sector. Indonesia has the capacity to become a leader in sustainable energy in Southeast Asia by utilizing its abundant renewable resources. This would not only stipulate economic growth but also addressing environmental issues.

2.2 Regulatory Frameworks and Policy on Carbon Pricing

Regulatory frameworks and policies on carbon pricing are crucial in facilitating the global energy transition. These frameworks offer economic incentives for the reduction of GHG emissions and encourage investments in renewable energy.

2.2.1 Global Overview

Carbon pricing mechanisms have become a crucial global instrument in the fight against climate change, with various governments and regions apply different approaches to restrict GHG emissions. Some of the more notable mechanisms are carbon taxes, cap-and-trade systems, and emissions trading schemes (ETS).

- Carbon Taxes: These are direct taxes enforced on the carbon content of fossil fuels. The purpose is to incentivizes businesses and individuals to reduce their carbon footprint. Countries like Sweden and Canada have successfully implemented carbon taxes, resulting in significant reductions in emissions while sustaining economic growth (World Bank, 2023).
- Cap-and-Trade Systems: Under this system, a limit or cap is set on the total amount of GHG emissions that are allowed. Companies receive or buy emission allowances, which they can trade with one another as needed. Over time, the cap is gradually decreased, increasing the cost of emissions and encourages the use of cleaner technologies. The European Union Emissions Trading System (EU ETS) is one of the most well-developed cap-and-trade systems, covering various sectors across the EU (IPCC, 2014; European Commission, 2020).
- Emissions Trading Schemes (ETS): Similar to cap-and-trade, ETS allows for the buying and selling of emission allowances in a regulated market. The ETS of China, launched in 2021, is the largest in the world, covering power plants initially and has future plans to expand to other sectors. This initiatives is designed to help China achieve its carbon neutrality goals by the year 2060 (IEA, 2021; ADB, 2021).

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2.2.2 Indonesia's Carbon Pricing Policies

Indonesia, as a major developing economy with a heavy reliance on fossil fuels, has started to gradually adopt carbon pricing policies as part of its roadmap climate change strategy. The country's regulatory framework includes several key initiatives aimed at mitigating emissions and promoting sustainable development.

- National Determined Contribution (NDC): As part of the Paris Agreement, Indonesia has made a National Determined Contribution (NDC) which is committed to reduce its GHG emissions. Indonesia aims to achieve a reduction of 29% by 2030 under a business-as-usual scenario, With international assistance, Indonesia is targeting a higher reduction up to 41%. The NDC is a fundamental element of Indonesia's climate policy, provide guidance to reduce emissions across various sectors, including energy (Ministry of Environment and Forestry, Indonesia, 2021).
- Low Carbon Development Initiative (LCDI): the LCDI is integrated into Indonesia's national development planning, that highlights the importance of energy transition to a ;ow-carbon economy. It outlines strategies for emissions reduction while fostering economic development, which explore the potential implementation of carbon trading and carbon tax systems (Bappenas, 2019).
- Carbon Pricing Regulation: In 2021, Indonesia introduced Presidential Regulation No. 98, which lays the groundwork for carbon pricing, including carbon trading and carbon tax schemes. This regulation signals Indonesia's commitment to incorporating carbon pricing into its climate strategy, with the goal of achieving net-zero emissions by 2060.
- Business scale initiatives: To carry out environmentally sound business activities in line with Net Zero Emission initiatives, PLN has issued Board of Directors Regulation Number 161 of 2021 concerning Strategic Policy for Climate Change Management as a guideline and governs of climate change management within PLN (PLN Sustainability Report, 2023)

Indonesia is currently in the initial phases of implementing carbon pricing policies, which are a significant move toward aligning the country's economic growth with its climate goals. These policies are expected to play a crucial role in guiding investment decisions, particularly in the energy industry.

2.3 Financial Modelling

Financial modeling is an essential tool for assessing the financial implications of carbon pricing on investment decisions, especially in the energy sector. It use quantitative methods to forecast the financial outcomes of projects, allowing decision-makers to evaluate risks, profitability, and overall feasibility.

Several key techniques being widely used in financial modelling. Discounted Cash Flow (DCF) analysis is widely used method that involves the projection of future cash flows and then discounting their value to their current value using a specified discount rate. The method is useful for evaluating the long-term viability of energy projects, where significant initial investment is required, and returns are realized over an extended period (Damodaran, 2012).

Scenario Analysis is another critical approach that enables analysts to assess the influence of various assumptions and external factors on project outcomes. Investors can evaluate the outcome of project financial performance under different market or regulatory conditions by developing multiple scenarios, such as high, medium, and low carbon pricing. This method is crucial in making comprehensive perspective of project's potential risks and making preparations for different future scenarios.

Sensitivity Analysis is a method that supplements scenario analysis by examining how changes in specific factors, such as carbon prices, exchange rate, energy price, affect the financial performance of a project. This methodology helps in identification of the key variables that contribute to the value of a project value and the potential risks that may interfere the realization of expected returns.

2.3.1 Application in Energy Projects

Financial models are essential for evaluating the economic feasibility of investments in renewable energy. DCF models are commonly used to assess the net present value (NPV) and internal rate of return (IRR) of projects, providing critical insights into their potential profitability. When analyzing renewable projects, using the DCF method, it is typically involves accounting for initial capital expenditures, operating and maintenance costs, revenue from energy sales, and savings or earnings from carbon credits (Brealey, Myers, & Allen, 2020).

Scenario analysis is particularly applicable in energy projects because of the inherent uncertainties associated with energy prices, technological advancements, and regulatory policies. For example, a scenario may simulate several potential outcomes of carbon

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pricing, allowing investors to understand how stricter carbon regulations could increase the profitability of renewable energy projects by raising the cost of fossil fuel.

Sensitivity analysis improve these evaluations by testing the potential effects of various key assumptions, such as the availability of government subsidies or fluctuations in energy demand, could impact project outcomes. This approach helps investors in determining which factors require close monitoring and proactive management.

2.3.2 Carbon Pricing Integration

Incorporating carbon price into financial models is to create accurate prediction of the financial performance of energy projects in a carbon-constrained world. Carbon pricing, whether implemented through taxes or cap-and-trade mechanisms, has a direct impacts on the cost structure of energy projects, especially those that reliant heavily on fossil fuels. The model then can help in forecasting additional costs for carbon emissions or potential revenues from carbon credits, so offering a more comprehensive view of the financial aspects of a project. Integrating carbon pricing requires adjustments to both revenue and cost estimates in the financial model. For example, a DCF model could include additional cash flows related to the sale of carbon credits generated by a renewable energy project. In contrast, the model in a fossil fuel project would take into account the additional expenses incurred as a result of carbon taxes. This integration allows for a more precise evaluation of project's net profitability and the potential risks linked to future regulatory changes.

2.4 Capital Budgeting

Capital budgeting analysis to review Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period of the project under various scenarios. This include calculation of cost of capital using Capital Asset Pricing Model (CAPM) or Dividend Discount Model (DDM).

Net Present Value (NPV)

NPV calculates the difference between the present value of cash inflows generated by the project and the present value of cash outflows, discounted at a specific rate. A positive NPV indicates that the projected earnings (adjusted for time and risk) exceed the initial investment, making the project financially viable.

When carbon pricing is incorporated into the model, the cash flows take into account the extra expenses related to carbon emissions or the potential income from carbon credits. This modification can have a considerable impact on the Net Present Value (NPV), as increased carbon pricing can decrease the appeal of fossil fuel projects while increasing the feasibility of investments in renewable energy. The NPV method's adaptability permits the inclusion of different scenarios, such as variations in carbon pricing, energy costs, and regulatory policies.

Internal Rate of Return (IRR) and Modified Internal Rate of Return (MIRR)

The Internal Rate of Return (IRR) is another key metric in capital budgeting which represent the discount rate at which the NPV of all cash flows (both inflows and outflows) from a particular project equals zero. IRR represents the estimated yearly rate of return that a project is estimated to generate.

In energy projects, IRR is often used to compare the profitability of different investment options. When carbon pricing is introduced, the IRR can be significantly affected, particularly for projects with high carbon emissions. For renewable energy projects, which generally have lower or zero carbon emissions, the IRR might increase as the cost savings from avoided carbon taxes or revenues from carbon credits improve the overall financial performance of the project.

However, one limitation of IRR is that it assumes reinvestment of interim cash flows at the same rate as the IRR itself, which may not always be realistic. Additionally, IRR can sometimes produce multiple values for projects with alternating cash flows, making it less straightforward than NPV in certain situations. The Modified Internal Rate of Return (MIRR) is designed to address some of the limitations of the traditional Internal Rate of Return (IRR). MIRR assumes that positive cash flows are reinvested at the project's cost of capital, providing a more accurate reflection of the project's profitability. MIRR is calculated by combining the present value of cash outflows with the future value of cash inflows, using the cost of capital as the reinvestment rate. As a result, MIRR offers a more realistic and strong measure of a project's financial performance, particularly in scenarios where the traditional IRR might overestimate returns (Damodaran, 2012).

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Payback Period

The Payback Period quantifies the duration needed for an investment to generate cash flows that are adequate to recover the initial expenditure. It is useful for evaluating the liquidity risk of a project by offering a clear indication of how quickly an investment can pay for itself (Brealey, Myers, & Allen, 2020).

In the context of renewable energy projects, the Payback Period tends to be briefer for projects that benefit from subsidies, tax incentives, or carbon credits, as these factors can expedite the recovery of the initial investment. However, the Payback Period fails to consider the concept of time value of money, which restricts its capacity to accurately assess the overall profitability of a project. This restriction is especially significant for energy projects that span a long duration, as the majority of the profits are generated over an extended period.

The Discounted Payback Period method can be used to fix this problem. This approach calculates the time required to recover the initial investment by discounting the project's cash flows to their present value before summing them, provides a more accurate assessment of when an investment will break even in present value terms.

3. METHODOLOGY

The study adopts a quantitative approach to assess the financial implications of carbon pricing mechanisms on PT PLN's investment decisions. The study uses methods from financial modelling techniques to quantify the impact of carbon pricing, ensuring that the findings are measurable and replicable.

The study uses quantitative data that come from external data collection such as:

- Financial Reports and statistics data of PT PLN: to evaluate past performance and key indicators to provide a basis for future financial projections.
- Project Feasibility Documents: Examination of projects case feasibility study to provide technical data which is needed for calculation in the financial modelling.
- Regulatory Documents: Review of policies and regulations related to carbon pricing, both within Indonesia and globally, to understand the regulatory environment and its potential impact on financial outcomes.

3.1 Scenario Analysis:

The scenario analysis is carried out to figure out the NPV of a project under different conditions and to find the key input variables that have a big but uncertain effect on the project's NPV. These variables include capacity factor, escalation of electricity selling price, exchange rate, tariff of steam, and carbon credit unit price. As part of the scenario analysis, we can figure out the NPV for both the worst and best case scenarios to see how the project's value might change. The NPV range shows how risky the project is; a bigger range means there is more uncertainty and risk.

3.2 Sensitivity Analysis:

The sensitivity analysis checks how stable the financial models are by changing important factors. This helps to figure out which factors have the most significant effect on financial success and to figure out what risks might come up if these factors change.

3.3 Monte Carlo Simulation:

To take into account the fact that key inputs can change and be unclear, Monte Carlo simulation is built into the financial models. For a fuller picture of risks and returns, the analysis runs thousands of simulations with different sets of factors. This gives a probabilistic picture of how the project might turn out. By this methods, investors get information how uncertain factors including carbon price affects the ability of a project to go forward.

4. RESULT AND DISCUSSION

4.1 Analysis

The study will focus on a 110 MW geothermal power plant development project located in Sumatera Island as a case study. The base case parameters used in the study are as follows:

- Project Economic Life: 30 years
- Depreciation Straight line to zero in 30 years
- Loan interest: 0.8% with period 40 years, principal payment started after 10 years grace period

- Tariff of steam : 7.17 cents USD/kWh
- Power Plant Capacity factor : 86%
- Escalation of electricity selling price : 3.30% per year
- Escalation of steam price: 1.50% per year
- Carbon credit unit price : IDR 58,800 per tCO_{2e}
- Weighted Average Cost of Capital (WACC) : 9.74%
- Income tax: 22%

Using the total initial investment of USD 1.895,61 billions and IDR 969.700,60 billions, the 40 years net cash flow for scenario without Carbon Credit consideration and with Carbon Credit consideration are as follows:

Table 1. Comparison of the Net Cash Flow with and without Carbon Credit (in millions IDR)

Year	**Without Carbon Credit Consideration**		**With Carbon Credit Consideration**	
	Net Cash Flow	**Cumulative Net Cash Flow**	**Net Cash Flow**	**Cumulative Net Cash Flow**
2024	(64,185)	(64,185)	(64,185)	(64,185)
2025	(1,355)	(1,355)	(1,355)	(1,355)
2026	(924)	(2,279)	(924)	(2,279)
2027	(1,084)	(3,363)	(1,084)	(3,363)
2028	(16,065)	(19,428)	(16,065)	(19,428)
2029	(103,492)	(122,920)	(103,492)	(122,920)
2030	(6,007)	(125,356)	(6,007)	(125,356)
2031	44,409	(80,947)	44,409	(80,947)
2032	63,429	(17,518)	63,429	(17,518)
…	…	…	…	…
2058	891,695	9,088,536	914,242	9,724,531
2059	949,371	10,037,906	971,877	10,696,407
2060	1,009,258	11,047,164	1,031,724	11,728,131
2061	(96,767)	10,950,398	(96,767)	11,631,364
2062	(96,767)	10,853,631	(96,767)	11,534,598
2063	(96,767)	10,756,864	(96,767)	11,437,831
2064	(96,767)	10,660,098	(96,767)	11,341,064

Sources: Data Calculation

The results demonstrate a 13.58% increase in NPV, a faster payback period from 12,88 to 9.87 years, and a 0.31% rise in the MIRR as showed in Table 2.

Table 2. Comparison of the Financial Performance Parameters with and without Carbon Credit

Parameters	**Without Carbon Credit**	**Base Case Scenario: With Carbon Credit**
Discounted Payback Period	12.88	9.87
Net Present Value (millions IDR)	861,263	978,238
Profitability Index	14.42	16,24
IRR	23.07%	25.21%
MIRR	14.99%	15.30%

Sources: Data Calculation

4.1.1 Sensitivity Analysis:

The sensitivity analysis evaluated how variations in key variables (exchange rate, steam tariff, escalation of electricity selling price, capacity factor, and carbon credit unit price) affect the project's Net Present Value (NPV).

Table 3. Sensitivity Analysis

Parameters	Swing +20%	Swing -20%
Capacity Factor (CF)	100,00%	68,80%
Escalation of electricity selling price	3,96%	2,64%
Exchange rate	19.672,80	13.115,20
Tariff of Steam (cUSD/kWh)	8,60	5,73
Carbon Credit unit price (Rp/tCO2)	70.560	47.040

Sources: Data Calculation

The results as showed in Figure 1 indicate that the exchange rate and steam tariff have the most significant impact on NPV, with a 20% swing in either direction leading to significant changes in NPV. The carbon credit unit price, while influential, has a relatively smaller effect on the overall financial outcome, suggesting that while carbon credits contribute positively to financial metrics, they are not the primary drivers.

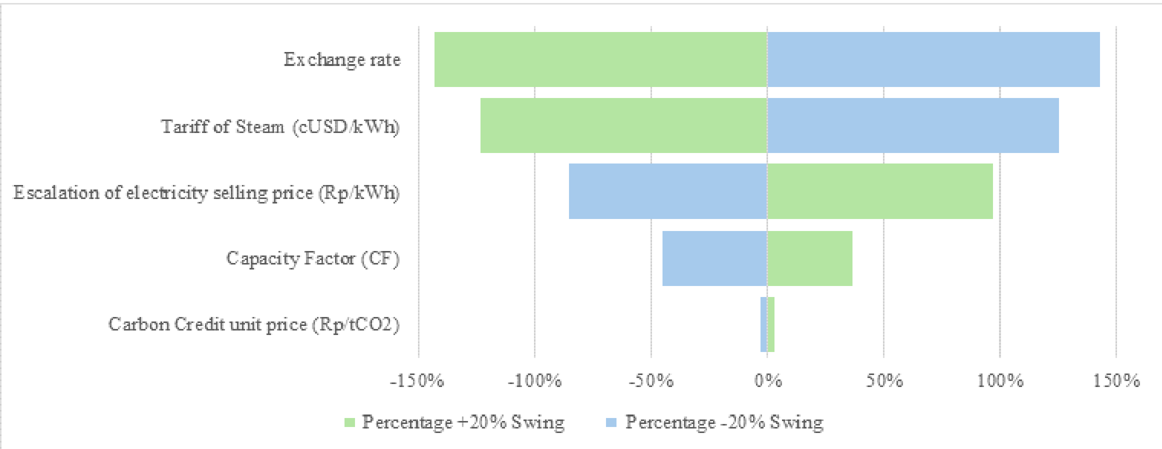

Figure 1. Tornado Diagram of Sensitivity Analysis
Sources: Data Calculation

The analysis are as follows:

- Exchange Rate: The exchange rate has the most significant impact on the outcome, with a swing of approximately -140% to +140% of base case NPV when adjusted by ±20%. This indicates that fluctuations in the exchange rate can substantially affect the financial performance of the project, possibly due to largest portion of US dollar in the cost of capital.
- Tariff of Steam (cUSD/kWh): The steam tariff also shows a substantial impact, with a swing of around -120% to +125% of base case NPV. This suggests that changes in the price paid for steam (likely a major input cost for the project) are crucial to the project's profitability.
- Escalation of Electricity Selling Price (Rp/kWh): The escalation in the electricity selling price affects the outcome but to a lesser extent than the exchange rate and steam tariff. The swing ranges from approximately -85% to +95% of base case NPV, showing that while important, the effect is moderate compared to other variables. This could mean that the project has limited control over pricing, since the electricity tariff is regulated by the government
- Capacity Factor (CF): The capacity factor, which reflects the actual output of a power plant compared to its maximum potential output, has a relatively moderate impact. The swing ranges from around -45% to +35% of base case NPV. This indicates that the

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operational efficiency of the power plant is crucial, and maintaining or improving capacity factor is vital for the project's financial viability.

- Carbon Credit Unit Price (Rp/tCO2): The carbon credit unit price has the smallest impact among the variables analysed, with a minimal swing around -2.5 to +2.5% of base case NVP. This suggests that, within the range considered, fluctuations in carbon credit prices do not significantly affect the project's financial metrics, possibly because the project either generates limited carbon credits, the carbon price is still low, or the revenue from carbon credits are a small part of the overall revenue.

4.1.2 Scenario Analysis:

Scenario analysis is conducted to determine the project's Net Present Value (NPV) under different potential scenarios. Initially, key input variables that affect the project's NPV, usually have a high degree of uncertainty but significant impact is identified. In this scenario analysis, capacity factor, escalation of electricity selling price, exchange rate, tariff of steam, carbon credit unit price are considered as key input variables.

Table 4. Key Input Variables Used in Scenario Analysis

Variables	Without Carbon Credit	With Carbon Credit		
		Worst Case	Base Case	Best Case
Capacity Factor (CF)	86%	70%	86%	91%
Escalation of electricity selling price (Rp/kWh)	3.30%	2.55%	3.30%	4.98%
Exchange rate (USD to IDR)	16,394	16,458	16,394	14,945
Tariff of Steam (cUSD/kWh)	7.17	8.00	7.17	5.00
Carbon Credit unit price (Rp/tCO2)	-	40,507	58,800	61,783
Net Present Value/NPV (millions IDR)	861,262.66	-822,865.57	978,238.11	6,356,695.24

The scenario analysis explored the financial outcomes under different carbon credit scenarios: without carbon credit, and with carbon credit (considering best case, worst case, and base case scenarios). The results reveal that:

- Without Carbon Credit: The project has a positive NPV (IDR 861.26 billions), indicating that it is financially viable. The positive NPV suggests that, even without the benefit of carbon credits, the project can generate sufficient cash flows to justify the investment.
- Base Case with Carbon Credit: The base case scenario with carbon credits results in a positive NPV (IDR 978.24 billions), 13.58% higher than the scenario without carbon credits. This scenario assumes a similar capacity factor to the "without carbon credit" scenario, but includes revenue from carbon credits at a moderate price. This positive NPV indicates that under these more likely conditions, the project is financially viable and the inclusion of carbon credits improves profitability.
- Worst Case with Carbon Credit: the project shows a significant negative NPV (-IDR 822,86 billions). This outcome is driven by a reduced capacity factor, lower escalation in electricity selling prices, a slightly higher steam tariff, and a lower exchange rate, combined with a relatively low carbon credit unit price. The negative NPV suggests that under unfavorable conditions, even with the inclusion of carbon credits, the project would result in a financial loss.
- Best Case with Carbon Credit: the project's NPV is extremely high (IDR 6,356,695.24). This scenario assumes the most favorable conditions: the highest capacity factor, the highest escalation in electricity selling prices, the lowest steam tariff, a favorable exchange rate, and the highest carbon credit price. The dramatically positive NPV suggests that under optimal conditions, the project can be extremely profitable, with carbon credits contributing significantly to the financial success.

The wide NPV range between the worst and best case (over Rp 7,179 billions) indicates that the project's outcome is highly uncertain and dependent on the input variables. So it is importance to understand the potential risks and rewards associated with the project, and to prepare risk mitigation strategies to ensure the project can withstand difficult conditions.

4.1.3 Monte Carlo Analysis:

The Monte Carlo simulation provided a probabilistic distribution of potential NPVs based on varying inputs, which showed how uncertain the outcomes of the project.

The result of Monte Carlo Simulation for 1000 calculations of various input of capacity factor, escalation of electricity selling price, exchange rate, tariff of steam, carbon credit unit price are as follows and showed in Figure 2:
Descriptive statistics of project's NPV (in billions USD):

- Minimum : -198
- Maximum : 4.782
- Mean : 2.230
- Standard Deviation : 970
- Median : 2.206
- Kurtosis : -0,54
- Skewness : 0,12
- Probability NPV<0 : 1,07%
- Probability NPV>0 : 98,93%
- Probability NPV>average: 100,00%

The very low probability of a NPV being negative (1.07%) means that the project is very likely to be financially viable. The project is a relatively safe investment because there is a very high probability that the NPV will be positive (98.93%). The fact that the NPV is sure to be higher than the average number also shows how strong the feasibility of the project in a lot of different situations. However, while most scenarios result in positive NPVs, there is a wide range of outcomes, with some scenarios could lead to loses. So it is important to establish a careful risk management, especially for the variables that have the most significant impact on financial outcomes.

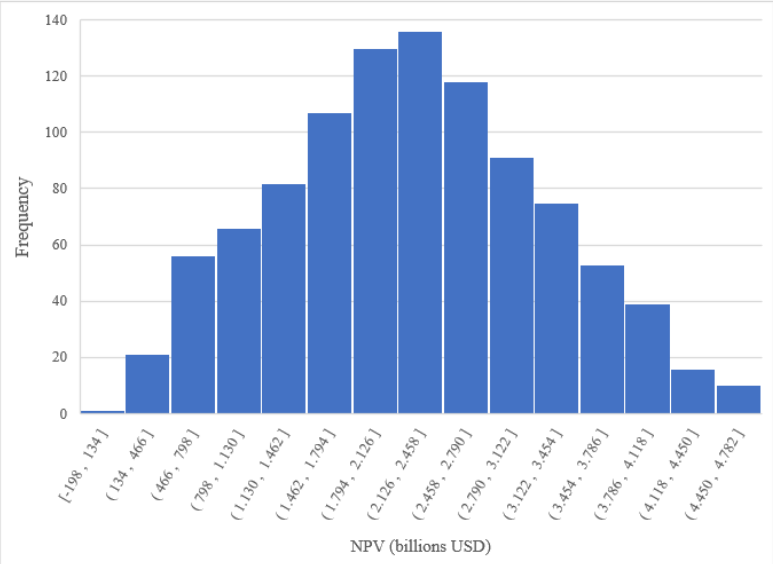

Figure 2. Monte Carlo Simulation Histogram
Sources: Data Calculation

4.2 Conclusion and Recommendation

The financial analysis demonstrates that carbon credits have a positive impact on the financial metrics of the 110 MW geothermal development project at PT PLN (Persero), which is the subject of this study case. Improvements include a 13.58% increase in NPV, a reduction in the payback period from 8.37 to 7.67 years, and a 0.31% rise in the MIRR. However, the effectiveness of carbon credits in improving profitability is highly dependent on other critical factors such as the exchange rate and steam tariff. The worst-case scenario shows that the project is still vulnerable to bad market conditions, even though the base case situation with carbon credits improves NPV, IRR/MIRR, and payback period.

Based on the analysis, it is suggested that PT PLN (Persero) adopt the following recommendation:

- Hedging and Risk Management: To manage exchange rate risks, which have the biggest effect on financial results, use robust hedging strategies.
- Negotiation of Steam Tariffs: establish a proactive negotiations to secure favorable steam tariffs in the long term, which will directly enhance project profitability.
- Maximize Carbon Credit Opportunities: Continue to explore and maximize opportunities for carbon credits, for example by participating in carbon markets that offer higher credit prices.
- Scenario Planning: make sure the scenario are regularly update to reflect current market conditions and that strategies are changes tor reflec these changes. This will ensuring that the project stay resilient under various conditions.

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