Techno Economic Feasibility Of Geothermal Power Plant In Indonesia Using Retscreen Considering Carbon Credit Mechanism To Achieve Indonesia’s Ndc 2060

FINAL PROJECT

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By
MAURA CHRISANTIA HUSEIN
Student ID: 29122076
(Master of Business Administration Program)

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ABSTRACT

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By
Maura Chrisantia Husein
Student ID: 29122076
(Master of Business Administration Program)

Indonesia’s geothermal reserves made the country has abundant geothermal energy potential but its utilization is still minimum due to insufficient investor participation. In the PLN Power Supply Generation (RUPTL PLN) indicates that there are a potential of 330 MW geothermal power plant in Gunung Kembar. This study conducts a feasibility analysis of Gunung Kembar 330 MW geothermal power plant with the aim of attracting investors to engage in renewable energy utilization project and achieve the National Determined Contributions (NDC) for the year 2060. Four Scenarios were developed to determine the feasibility of the project based on the carbon credit prices and the lifetime of the project. First scenario was developed to assess the current condition of Indonesia’s profitability on geothermal power plant considering a 2 USD per ton CO2 as stated by UU. No 7 2021 and a lifetime of 25 years. Second scenario considered the increase of incentives from 2 USD per ton CO2 to 18 USD per ton CO2 with the same lifetime as the first scenario. Third scenario considered the change in the lifetime project from 25 years to 30 refers to existing Sarulla 330 MW geothermal power plant. And the last scenario is the proposed scenario with the carbon credit price is fixed to 50 ton per CO2 refers to the suggestions of the International Monetary Fund, and the lifetime of the project are fixed to 30 years. RETScreen modelling results showed that the suitable power capacity for 1 unit from 330 MW is to be 21 MW based on the consideration of the availability of steam flow and other aspects. Financial analysis showed that the Internal Rate of Return from Scenario I is 11.6% which is slightly above the discount rate (10%), the Scenario II IRR and NPV are higher than the Scenario I but still high on LCOE for 0,091. Scenario III and Scenario IV are also have a positive IRR and NPV with lower LCOE than the Scenario I and II and showed that the project is very profitable for Indonesia’s investors. Therefore, it is recommended for Indonesia’s government to increase the carbon pricing in the nation for 50 USD per ton CO2 in order to gain more profit and attract investors to engage in investing on the renewable energy project.

Keywords: Feasibility Study, Geothermal Power Plant, Carbon Credit Price, RETScreen, Indonesia Renewable Energy

ABSTRAK

Studi Kelayakan Tekno-Ekonomi Dari Pembangkit Listrik Tenaga Geotermal Di Indonesia Menggunakan Retscreen Dengan Memperhitungkan Mekanisme Kredit Karbon Untuk Mencapai Ndc Indonesia Tahun 2060

Oleh
Maura Chrisantia Husein
Student ID: 29122076
(Program Studi Magister Administrasi Bisnis)

Cadangan panas bumi di Indonesia membuat negara ini memiliki potensi energi panas bumi yang melimpah, namun pemanfaatannya masih minim karena partisipasi investor yang kurang memadai. Dalam RUPTL PLN disebutkan bahwa teradapt potensi pembangkit listrik tenaga panas bumi sebesar 330 MW di Gunung Kembar, Aceh. Penelitian ini menganalisis kelayakan Pembangkit Listrik Tenaga Panas Bumi (PLTP) Gunung Kembar 330 MW dengan tujuan menarik minat investor untuk terlibat dalam proyek pemanfaatan energi terbarukan dan mencapai National Determined Contributions (NDC) untuk tahun 2060. Empat skenario dikembangkan untuk menentukan kelayakan proyek berdasarkan harga kredit karbon dan durasi proyel. Skenario I dikembangkan untuk menilai kondisi profitabilitas Indonesia saat ini dalam pembangkit listrik tenaga panas bumi dengan mempertimbangkan harga karbon kredit sebesar 2 USD/tCO2 dan 25 tahun durasi proyek. Skenario II dikembangkan dengan harga karbon kredit 18 USD/tCO2 dan durasi 25 tahun, Skenario III dengan harga yang sama namun durasi yang lebih panjang 30 tahun, dan Skenario IV dengan harga 50 tCO2 dan durasi waktu 30 tahun. Hasil pemodelan RETScreen menunjukkan bahwa kapasitas yang sesuai untuk satu unit dari 330 MW kapasitas adalah 21 MW, berdasarkan pertimbangan data steam flow dan aspek lainnya. Analisis keuangan menunjukkan bahwa Internal Rate of Return (IRR) dari Skenario I adalah 11.6%, sedikit di atas discount rate yang telah ditetapkan yaitu 10%. Internal Rate of Return (IRR) dan Net Present Value (NPV) Skenario II lebih tinggi daripada Skenario I tetapi masih memiliki angka LCOE yang cukup tinggi yaitu sebesar 0.091. Skenario III dan Skenario IV memiliki nilai IRR dan NPV yang positif dengan LCOE lebih rendah dibandingkan dengan Skenario II dan II dan menunjukkan bahwa proyek ini sangat menguntungkan bagi para investor. Oleh karena itu, disarankan agar pemerintah Indonesia meningkatkan penetapan harga penurunan karbon di Indonesia agar proyek energi terbarukan lebih memiliki keuntungan yang tinggi dan menarik bagi para investor untuk berinvestasi.

Keywords: Studi Kelayakan, Pembangkit Listrik Tenaga Panas Bumi, Kredit Karbon, RETScreen, Energi Terbarukan Indonesia

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By
Maura Chrisantia Husein
Student ID: 29122076
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Institut Teknologi Bandung

Approved

Date 7 Maret 2024

Supervisor

Ir. Dzikri Firmansyah Hakam, S.T., Pg.Dip., M.Sc., Ph.D.

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The Author rezognizes that this study is not without its imperfections. As a result, the Author encourage constructive criticism and suggestions to improve the overalll quality of the research. It is anticipated that this investigation may bring forth innovative viewpoints on renewable energy in the context of Indonesia.

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Chapter I Introduction

I.1 Background

Energy plays a vital role in the worldwide economy. As conventional energy from fossil fuels becomes more restricted, mainly in response to concerns about climate change and other environmental issues, the promotion of renewable energy is widespread for smilar reasons. Within the realm of electrical power, various Renewable Energy Sources like geothermal, biomass, hydro, tidal, wind and solar contribute to electricity generation (Tambunan et al., 2020)

Indonesia has set a new target of achieving net-zero emissions by the year of 2060 based on its update of Nationally Determined Contribution (NDC) presented at the United Nations Framework Convention on Climate Change (UNFCCC) (Kanugrahan & Hakam, 2023). Indonesia’s NDC included several key commitments and actions to be taken by 2030. One of the notable element of Indonesia’s commitment in the Paris Agreement includes reducing greenhouse gas emissions by 32% by 2030, and reducing carbon emissions (Hakam et al., 2012)

Indonesia can reduce greenhouse gas emissions by utilizing renewable energy through a combination of policies, investments, and initiatives. One of the key strategy that Indonesia can take to achieve this goals is to invest in a diverse range of renewable energy technologies, including solar, wind, hydroelectric, geothermal, and biomass. This is aligned with Indonesian’s government target which is 23% renewable energy utilization by 2025 (ESDM, 2022).

The Ministry of Energy and Mineral Resources, Directorate General of New Renewable Energy and Energy Conservation (EBTKE), on January 17 2022 stated that the capacity of new renewable energy power plants (PLT EBT) in 2021 is reaching 11,157 MW. The capacity of the renewable energy power plants are consist of Hydropower of 6.601,9 MW, Geothermal of 2.276,9 MW, Bioenergy of 1.920,4 MW, Solar Power of 200,1 MW, Wind Power of 154,3 MW, and Hybrid Power of 3,6 MW (ESDM, 2022).

In utilizing renewable energy, the incorporation of a carbon credits trading mechanism is a significant component in reducing greenhouse gas emission. Carbon credits are a licenses that grant the holder permission to discharge an amount of carbon dioxide or an equivalent quantity of other greenhouse gases, and one effective way to reduce greenhouse gas emissions (Kenton, W., 2007). Indonesia Stock Exchange has launched its first carbon emission credit trading market on 26 September 2023 with the name Indonesia Carbon Exchange (IDX Carbon), with the aim of creating a market to fund cuts in greenhouse gas emissions (PwC Indonesia, 2023)

Indonesia is in the *ring of fire* area and holds 40% of Indonesia's geothermal reserves made the country has abundant geothermal energy potential and is the world's largest geothermal energy potential (Nasruddin et al., 2016). Based on data from the Geological Agency – Ministry of Energy and Mineral Resources in December 2020, Indonesia's total geothermal energy potential is estimated at 23,7 GW(ESDM, 2022). As per 2021, Indonesia has 17 geothermal power plants that spread across the country and actively operating in Indonesia. The Indonesian government is in the process of implementing ambitious plans to rapidly grow geothermal energy sector. According to the Rencana Umum Energi Nasional (RUEN), Indonesia plans to reach 7,24 GW of geothermal power by 2025 that requires US $15 billion in investment, and 9.3 GW by 2035 (Tampubolon, 2020).

One of the island in Indonesia and generate the most geothermal energy is Sumatra Island. Sumatra Island lies at the meeting point of two tectonic plates which are the Eurasian Plate and Indo-Australian Plate. This convergence often results in earthquakes and creates regions with geothermal potential. (ESDM, 2011). According to RUPTL PLN 2021-2030, the biggest geothermal energy potential site in Sumatra Island is Gunung Kembar. Gunung Kembar is a mountain on the North Sumatera, Indonesia. Gunung kembar has a height of 3.058 meters, and has a geothermal energy potential of 330 MW (PLN, 2021). For this reason, Gunung Kembar 330 MW is chosen to be the case study of project valuation of geothermal power plants in Indonesia.

I.2 Business Issue

Renewable energy sources currently contribute to less than 1% of the total power generated (Kanugrahan & Hakam, 2023). As a result, in order to achieve Indonesia's NDC 2060, it is imperative to intensify the utilization of renewable energy particularly in geothermal power as it is stands as one of the nation's largest renewable energy sources. West Sumatera has 17 geothermal energy points and the greatest potential for investment but is still waiting for the investors to fund the project. Until 2021, the total geothermal potential energy that has just been utilized for power plant is still very small, 562 MW out of 9,679 MW (RUPTL PLN 2021-2030). Geothermal development is a high-risk business involving capital-intensive physical asset as well as long cycle times (Dewi et al., 2022a)

There are also risk and challenges in developing the geothermal energy power plant in Indonesia such as geological complexity that lead to drilling difficulties and increased cost. Exploring and verifying geothermal resources for electricity generation involves substantial financial risk and can be quite expensive (Gehringer & Loksha, 2012) . It is expected that an exploration drilling program in Indonesia will cost approximately US$30 million. The development of geothermal energy typically proceeds through a series of phases, starting with preliminary surveys and surface studies. This is followed by exploration drilling to confirm the presence and temperature of the geothermal resources. If successful, the next phase is delineation drilling. If a well does not yield a sufficient flow or hot water or steam, it can result in financial losses for project developers (Gehringer & Loksha, 2012)Hence, the high cost of geothermal development during the exploration and construction stage caused the financial challenges that made geothermal projects is less attractive to the investors (Dewi et al., 2022b)

The lack of investors also caused by the low or uncertainty of the profitability of the project, which could be determined through NPV and IRR. The profitability also affected by the fiscal aspect incentives such as carbon credit and tariff (Setia Nugraha et al., 2017). The effective Carbon Rates 2021 report from The Organization from Economic Co-Operation and Development (OECD) stated that the minimum benchmark for carbon pricing is 30 euros per ton of CO2. Meanwhile, the Indonesia’s carbon credits price is approximately 1,81 euros per ton of CO2 where this value is far below the global recommendation (Judith J, 2021).

As a result, only a few investors are interested in developing geothermal energy in Indonesia (Dhaniswara et al., 2022).There are 3 major obstacles of geothermal development in Indonesia which is technical, financial and politics challenges. According to RUPTL PLN 2021-2030, there is a potential site or geothermal energy in Gunung Kembar for 330 MW and this is the largest potential in Aceh province. For this reason a feasibility study by considering carbon credit price is needed to determine the economic potential to attract investors to fund the project in Gunung Kembar in order to achieve PLN's target in enhancing the role of geothermal power in the country's energy mix.

I.3 Research Questions and Research Objectives

This research aims to provide a financial viability on the project of geothermal power plant at Gunung Kembar as a case study, in achieving the goals of this research, there are several questions that need to be answered:

1. Does the project of Gunung Kembar 330 MW Geothermal Power Plant financially and economically viable
2. What is the proposed carbon credit price that could attract more investors?

This study aims to analyze the financial viability of the potential geothermal energy in Indonesia by assessing the case study of 330 MW Gunung Kembar potential site and identify possibilities of adding incentives such as GHG reduction emission incentives (carbon credit sales) in attracting the investor to takeover this project in order to support the usage of geothermal energy in Indonesia.

I.4 Research Scope and Limitation

The scope of this research is as follows:

1. This research provides an overview about geothermal energy power plant feasibility around financial aspect.
2. This research calculation is conducted using Renewable-energy Energy-efficiency Technology Screening (RETScreen) software based on available data from related literature.
3. This research uses data from PLN that updated until 2023.
4. The technical data used for calculations are mainly assumption from several similar studies (Moya et al., 2018; Prasad & Raturi, 2022; Rakhmadi & Sutiyono, 2015)

I.5 Research Novelty

In recent years, despite Indonesia's possessing one of the world's largest geothermal energy potentials and capable of enhancing the coutry's energy mix, the exploration and utilization of geothermal power plants remain limited. Several studies have examined the feasibility of geothermal power plants whether it uses RETScreen or not. For instance, (Moya et al., 2018) and (Prasad & Raturi, 2022) conducted research on the pre-feasibility of geothermal power plants outside Indonesia using RETScreen. (Dhaniswara et al., 2022) focused on the financial feasibility of geothermal development projects, employing project financing strategies and capital budgeting. Unfortunately, studies about feasibility study of geothermal power plant using RETScreen in Indonesia are still absent and this study aims to bridge this gap in the existing research.

Furthermore, geothermal power plants have the advantage of generating a continuous and reliable supply of electricity 24/7, making them an ideal choice for Indonesia, which has a substantial geothermal potential. Despite this promising opportunity, the development of geothermal projects in Indonesia encounters significant challenges, primarily due to the high initial costs and investment risks. According to (Judith J, 2021) , Indonesia's carbon credits are notably lower than the globally recommended levels. In light of these circumstances, the objective of this study is to conduct a comprehensive financial analysis and scenario assessment, which considers carbon credits and other key factors. This study aim to contribute in proving that enhancing Indonesia's carbon credit system can be advantageous for investors.

Chapter II Literature Review

II.1 Previous Research on Geothermal Energy

Studies on economic feasibility of renewable energy power plants have been carried throughout globally. Based on the author's research and review of journals, there has been more of PV power plant research on their economic feasibility using RETScreen, rather than geothermal (Baccay Sy et al., 2020; Horn et al., 2004; Khalid & Junaidi, 2013; Mišnić et al., 2022; Owolabi et al., 2019).

The studies on economic feasibility of geothermal power plants have also been carried out in several nations, including those by Kahraman & Olcay, (2023); Moya et al., (2018); Prasad & Raturi, (2022);and Van Erdeweghe et al., (2018). All of this research shows a positive result of NPV and IRR stating that the geothermal power plant project is feasible to be conduct in their countries. A study by Moya et al., (2018) explores various scenarios related to the technical, financial, economic, and environmental aspects of geothermal energy development in Ecuador. It considerds different incentives for electricity generation and grants. The results of the study shows that the payback period of the project for all scenario is ranges from 3 to 6 years.

Meanwhile study by Prasad & Raturi, (2022) shows that the payback period of the project is 4 years. Both of the studies are using the same system for their geothermal power plants which is the Organic Rankine Cycle (ORC) that could transfer low heat into power. This research utilizes RETScreen software to analyze the techn-economic and environmental aspects of the project considering three different scenarios. The first scenario involves theinstallation and comissioning of the Organic Rankine Cycle (ORC) geothermal power plant with no support other than the elctricity export tariff rate. Scenario 2 is similar to Scenario 1 but includes additional incentives such as a clean energy production incentive, a renewable capacity development incentive, and a participation in an emission trading system. Scenario 3 involves the installation and commissioning of the Organic Rankine Cycle (ORC) by the investor, with electricity not being exported to the grid but used at a local facility that includes the sam additional incentives as Scenario 2. The results shows that additional incentives are needed for scenario 3 to have a positive

Net Present Value (NPV). The risk analysis and Monte Carlo simulation show that the project is financially viable when incentives are given, and potential investors must negotiate an attractive elctricity export tariff rate to minimze the risk of having a negative NPV.

Unfortunately, according to the author's knowledge, only 2 feasibility studies of geothermal power plant in Indonesia that has been carried out authored by Rakhmadi & Sutiyono (2015) and Yunan et al., (2013), but neither of these studies utilized RETScreen for their research. A study by (Rakhmadi & Sutiyono, 2015) did a feasibility research to Sarulla 330 MW Geothermal Power Plant at Aceh and shows result that the project is economically feasible with initial cost for 5,000 USD per kilowatt-hour and Operation & Maintenance costs for 156 USD per kilowatt-hour.

A study about technical and economical analysis of a hybrid resource are conducted by (Astolfi et al., 2011). This research evalauates the performance, economic feasibility, and a potential of a solar-geothermal hybrid power plat based on an Organic Rankine Cycle (ORC). The study found that the solar field cost was a major contributor to the LCOE, and the choice of plant size was influenced by land availability and electric grid demand. Off-design simulations and detailed solar field modeling were conducted, and the results indicated that the solar-geothermal hybrid concept could represent a good opportunity for lower cost electricity production (LCOE).

Another study that conduct research about optimization of different energy systems is the research by (Yao et al., 2018). The study presents a thermo-economic analysis of a power generation system integrating a natural gas expansion plant with a geothermal ORC in Tianjin, China. This hybrid power utilization of power generation system resulting in a net profit of 3,97 Million USD and a payback period of 1.99 years. The results indicate a net profit and a short payback period, making it a promising power generation solution.

As shown on the Table 1, the table provides a comprehensive overview of various research studies examined by the Authors. It presents a comparative analysis of incentives given, energy, capacity, initial investment, methodoloy/tools, and results. Notably, the feasibility studies for geothermal power plants using

RETScreen remain limited in comparison to those for photovoltaic power plants. Additionally, it appears that the incentives allocated for renewable energy power plants are still low.

No	Title and Author	Location	Energy	Capacity	Initial Investment	Incentives/ Grants	Methodology / Tools	Result
1	(Owolabi et al., 2019)	Nigeria (6 locations)	Solar	6 MW	$14,400,000	Not Specified	RETScreen	**Feasible** with NPV and IRR are positive and higher than the required rate of return with a PP of 14 – 16 years.
2	(Moya et al., 2018)	Ecuador (6 locations)	Geothermal	22 MW	$114,3 million	Grants of 3 M USD; 0,01 USD/kWh of clean energy produced; 132,1 USD/MWh for electricity generation	RETScreen	**Feasible** with a positive NPV and relatively short PP for all scenarios, except Scenario IIIA.
3	(González-García et al., 2023)	Mexico	Geothermal	96 MW	Not Specified	Not Specified	Cash flow analysis, ,project financing, NPV&BEP calculation	**Feasible** with positive NPV, and the BEP is reached after 5 years which relatively low.

No	Title and Author	Location	Energy	Capacity	Initial Investment	Incentives/ Grants	Methodology / Tools	Result
4	(Prasad & Raturi, 2022)	Fiji, South Pacific Ocean	Geothermal	10 MW	$6000/kW	US$ 0,07/kWh for clean energy production; US$ 300/kW for renewable capacity development; and US$ 34/ton CO2 for emission trading	RETScreen	Some scenario is **feasible with no incentives/grants (positive NPV, low LCOE)**, and the other is **not feasible with incentives (negative NPV)**
5	(Baccay Sy et al., 2020)	Ethiopia	Solar	100 MW	Not Specified	Not Specified	RETScreen	**Feasible** with a positive NPV and the cost of production is lower than existing power generation in the country.
6	(Rakhmadi & Sutiyono, 2015)	Sumatera, Indonesia	Geothermal	330 MW	US$ 100 million	US$ 4 million grants	The Monte Carlo Simulation	The project is economically **feasible**

No	Title and Author	Location	Energy	Capacity	Initial Investment	Incentives/ Grants	Methodology / Tools	Result
7	(Kahraman & Olcay, 2023)	10 locations in India	Geothermal	50 MW	$282.330	Not Specified		**Feasible** based on the PP, IRR, and NPV value are all positive and higher than the required rate of return.
8	(Khan et al., 2023)	Saudi Arabia	Wind	100 MW	US$ 1612/kW, US$ 2574/kW, US$ 1745/kW, US$ 1278,4/kW-	Not Specified	RETScreen, SAM.	**Feasible** from the result of a positve NPV and a payback period that relatively short which was 4,2 years.
9	(Asamoah et al., 2023)	Ghana	Wind	50 MW	$2000/kWh	Not Specified	RETScreen	**Feasible** and potential for financial returns because the NPV result is positive and the IRR is higher than the required rate of return.

No	Title and Author	Location	Energy	Capacity	Initial Investment	Incentives/ Grants	Methodology / Tools	Result
10	(Mišnić et al., 2022)	Montenegro	Solar	5 MW	$903/kWh	Not Specified	(ARIMA), Neural Network Auto Regression (NNAR)	**Feasible** because the NPV shows positive result, IRR is higher than the required rate of return, and the PP is realatively short for 7,1 years.
11	(Khalid & Junaidi, 2013)	Pakistan	Solar	10 MW	$35 million	Not Specified	RETScreen	**Not Feasible** due to the low IRR
12	(Horn et al., 2004)	Egypt	Solar	95 MW, 90 MW and 80 MW	118,5 million (95 MW,90 MW), 119,6 million (80 MW)	US$50 million	NPV and LCOE calculation	**Feasible** based on the NPV and the LCOE result.
13	(Ayub et al., 2015)	Nevada, US	Solar & Geothermal	Not Specified	US$ 66,3 million	Not Specified	EES (Engineering Equation System)	The LCOE of the hybrid system can be decreased by 2% compared to stand-alone geothermal system, making

No	Title and Author	Location	Energy	Capacity	Initial Investment	Incentives/ Grants	Methodology / Tools	Result
								the project **feasible**
14	(Astolfi et al., 2011)	USA & Italy	Solar & Geothermal	4,6 MW	Not Specified	Not Specified	Matlab TM, Meteonorm.	**Feasible** due to its lower-cost electricity production and the LCOE is low.
15	(Yao et al., 2018)	China	Natural Gas & Geothermal	Not Specified	Not Specified	Not Specified	Exeergy and exergoeconomic analysis, EES.	**Feasible,** indicated by the net profit of US$ 3,97 M and a relatively short PP of around 2 years.
16	(Montiel-Bohórquez et al., 2022)	Colombia	Municipal Solid Waste	56 MW	US$ 268,7 M	50% of the cost grants	LCOE calculation with various scenarios	**Feasible**, with the LCOE is 24% lower than the base case

No	Title and Author	Location	Energy	Capacity	Initial Investment	Incentives/ Grants	Methodology / Tools	Result
17	(Susilowati et al., 2023a)	Indonesia	Solar & Biomass	Not Specified	Not Specified	USD 20/tCO_2	NPV and IRR calculation	**Feasible** based on the NPV and IRR result which is all accepted and higher than the WACC.
18	(Van Erdeweghe et al., 2018)	Europe	Geothermal	Not Specified	Not Specified	Not Specified		**Feasible** to used in low-temperature GPP with a high electricity price, a high price evolution over time and a low discount rate.
19	(Yunan et al., 2013)	Indonesia	Geothermal	226 MW	Not Specified	USD 5-10/tCO_2	NPV&IRR calculation, ISM techniques, AHP.	**Feasible** based on the positive NPV(no incentives) and IRR (no incentives)

No	Title and Author	Location	Energy	Capacity	Initial Investment	Incentives/ Grants	Methodology / Tools	Result
20	(Alhassan et al., 2023)	Ghana	Solar	420 MW	567,030,000 USD	Not Specified	RETScreen	**Feasible,** with lower LCOE, positive NPV and 12 year payback.

Table II.1 Several Studies on Renewable Energy Sources Power Plant

II.2 Overview of Indonesia’s Utilization of Renewable Energy in Generating Electricity

Indonesia has pledged to reduce its greenhouse gas emissions by 20% by 2030 independently, and by up to 38% with international collaboration as outlined in the 2060 Paris Agreement (ESDM, 2022) Furthermore, in 2014, the government renewed its National Energy Policy, setting two key objectives : achieving nearly 100% electrification by 2020 and increasing the proportion of renewable energy in the national energy mix to 23% by 2025. (Kanugrahan & Hakam, 2023).

Despite having ambitious renewable energy targets and abundant potential in renewable energy sources like hydropower, geothermal, biogas, biomass, solar power, and ocean energy, the primary driver electrification projects in Indonesia continues to be coal power plants (Primadhyta, 2018). There remains a significant disparity in energy access and quality, particularly between Indonesia’s main western islands and the rural eastern islands. Some major islands with high GDP, such as Java, Bali, and Sumatera, have excess electricity supply, while rural areas lack access to this fundamental necessity.

Table II. 2 Renewable Energy Potential and Utilization in Indonesia (PLN, 2021)

No	Type of Energy	Potential	Installed Capacity	Utilization
1	Geothermal	29.544 MW	1.438,5 MW	4,9%
2	Hydro	75.091 MW	4.826,7 MW	6,4%
3	Mini-micro Hydro	19.385 MW	197,4 MW	1%
4	Bioenergy	32.654 MW	1.671 MW	5,1%
5	Solar	207.898 MW (4,80 kWh/m2/hari)	78,5 MW	0,04%
6	Wind	60.647 MW (>4m/s)	3,1 MW	0,01%
7	Tidal wave	17.989 MW	0,3 MW	0,002%

As shown in Table II.2, solar power exhibits the highest renewable energy potential at 207,898 MW, followed by hydro power, wind power, bioenergy, geothermal, mini-miro hydro, and lastly tidal wave. On the other hand the most harnessed renewable energy sources are hydro power (6.4%), followed by bioenergy (5.1%), and geothermal (4.9%). Approaching the year 2025, PLN depends significantly on hydro, geothermal, and biomass to attain the 23% share of renewable energy. Numerous projects, particularly those related to hydro and geothermal sources have the potential for delay and the deployment of biomass encounters pricing challenges. Consequently, there is a risk that renewable energy targets may not be achieved (IESR, 2023).

II.3 Geothermal Power Plant

Geothermal power plants is created by converting thermal energy that is generated inside the Earth's crust and delivered to the surface as the heat sink by heat conduction or convection. The fundamental benefit of geothermal energy is that it is unaffected by weather, seasons, or climate because it produces thermal energy all year long (Sahdarani et al., 2020). Geothermal energy systems have a the potential to be the most affordable source of sustainable renewable fuel for based-load direct use and power generation that produces no emissions and has a minor environmental impact (Goldstein et al., 2011).

There are three fundamental types of geothermal power plants which are the dry steam plants that utilize steam directly extracted from a geothermal reservoir to rotate generator turbines, second is flash steam plants that extract high-pressure hot watrer from deep beneath the earth's surface, convert it into steam. Lastly is binary-cycle power plants that transferred heat from geothermal hot water to another liquid (U.S EIA, 2022).

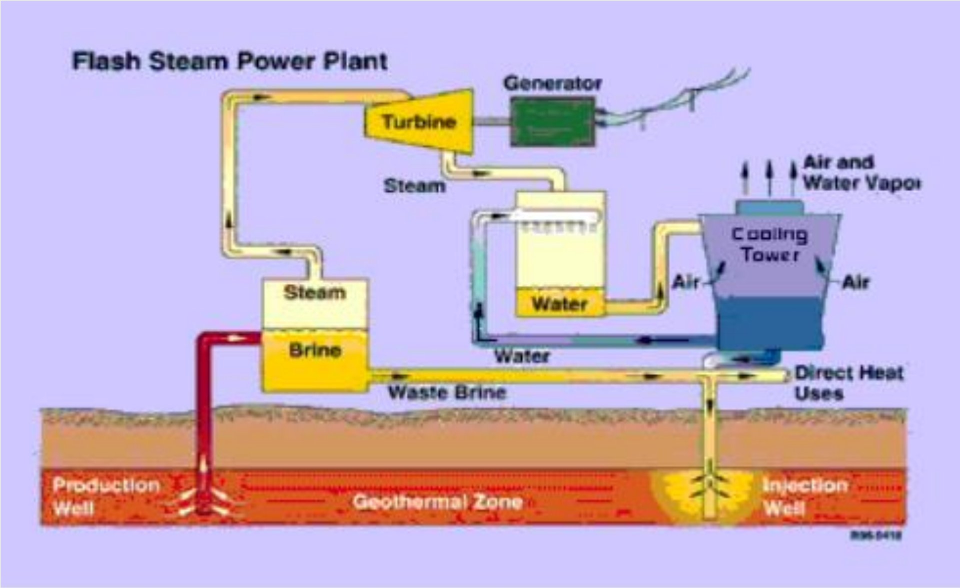


Figure II.1 Geothermal Power Plant System (Suharmanto et al., 2015)

As shown in Figure II.1, geothermal power plants operate on a similar basis to generating steam power, using heat from deep inside the earth to directly drive a turbine generator which then generates electricity. Because the hot steam that is produced still contains other substances like water, minerals, and salt, it must go through a procedure before it can be used. Steam is created by raising water above hot rocks in the earth’s interior, where it condenses into steam. Following purification, the produced steam is used to transport power after turning turbines (Suharmanto et al., 2015). The installed geothermal capacity in the world in 2016 was 12.7 GW. Geothermal power plants produced about 80.9 TWh in 2015, or about 0.3% of the world's electricity.

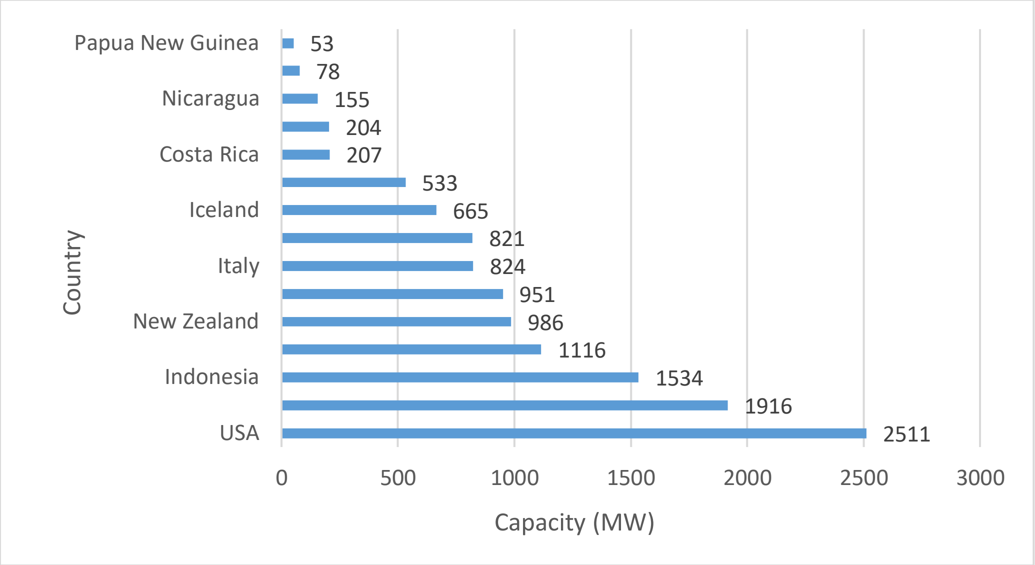


Figure II.2 Installed Geothermal Power Capacity by Countries in 2016 (Ito et al., 2017)

According to Figure 2.2, the Philippines (1.916 MW), Indonesia (1.534 MW), and the United States (2.511 MW) have the most installed geothermal power capacity (Ito et al., 2017). Based on the book “Geothermal Potential” released by the Ministry of energy and Mining Resources (ESDM), Indonesia’s geothermal potential that can be exploited is 9.000 MW, spread over 50 fields, with a minimum potential of 12.000 MW. The total geothermal energy potential is 23.965 Mwe, consisting of resources of 9.339 Mwe and reserves of 14.626 Mwe (Pristiandaru, 2023). The potential energy installation capacity of provinces in Indonesia are shown in Table II.3 below.

Table II.3 Potential Energy Installation of Indonesia's Provinces (PLN, 2021)

No	Province	Potential Energy (Mwe)					Total	Installed Capacity
		Resources		Reserved				
		Speculative	Hipotesis	Expected	Possible	Proven		
1	Sumatera	2.276	1.557	3.735	1.041	1070	9.679	562
2	Jawa	1.265	1.190	3414	418	1.820	8.107	1.235,8
3	Bali	70	21	104	110	30	335	0
4	Nusa Tenggara	190	148	892	121	12	1.363	12,5
5	Kalimantan	151	18	13	-	-	182	0
6	Sulawesi	1.365	362	1041	180	120	3.068	120
7	Maluku	560	91	497	6	2	1.156	0
8	Papua	75	-	-	-	-	75	0
	Total	**5.952**	**3.387**	**9.696**	**1.876**	**3.054**	**23.965**	**1.948,3**

As shown in Table II.3, it represents speculative, hypothetical, and expected reserves, along with possible and proven installed capacities in Megawatts electric (Mwe). Overall, the total potential energy resources up to 5,952 Mwe with proven installed capacity at 1,948.3 Mwe across the provinces listed. The highest potential energy resource among the provinces listed in Table II.3 is in Sumatera, with a speculative resource of 2,276 Mwe.

II.4 Carbon Credit

A carbon credit is an exchangable asset that grants its holder permission to emit either 1 ton of CO_2 or the equivalent amount of another GHG (Kishwan, 2023). These credits are used to compensate the emissions produced by individuals, governments, or industries, and potentially obtaining extra revenues by participating in carbon trading (Susilowati et al., 2023b). Carbon trading is used when the company's emissions exceed its quota of carbon credits, forcing it to purchase credits from other companies which have spare carbon credits (Yuvika Gupta, 2011). The energy consumption of businesses is impacted by carbon trading mechanisms, which in turn cut emissions and affect the financial gains of primary power plants that reduce their carbon production (He et al., 2023). A study by Cong & Wei (2010) also stated that national carbon trading will likely raise electricity costs, boost the presence of renewable energy facilities, enhance investment profits, and ultimately reduced emissions within the country’s power industry. Therefore, in terms of maximizing investment returns, the company needs to choose its investment approach depending on changes in carbon trading prices (Huang et al., 2023).

II.4.1 Indonesia Crediting Mechanism

The Indonesian ministry of Environment and Forests introduced a ministerial regulation on October 20 2022 that provides guidelines for domestic carbon trading. The regulation specifies that carbon credit generation and trading will be applicable in sectors like energy, waste, industrial processes, agriculture, forestry, and other sectors with sufficient technological capabilities (World Bank, 2023). The implementation of carbon trading mechanism specification units and markets are explain in the figure belows:

Carbon market types in IDX Carbon	**The tradable carbon units in IDX Carbon**
• Carbon unit frading on the 1OX can enty be conducied by and between ID Carbos users • Carbon Units must be registered in SRY PPl and IDX Carbon. • The unit trading volume is a multipie of one lot or one tonne of COOn • There are four types of markets on IDX Carbon. namely: (il auction market (ii) regular markets. (iii) negotiated markets: and (iv) non-regular markets. Various trading faciors (e.g. the subject and the object of trading) will vary depending on the types of markets on which trading takes place	Carbon Units in the form of: 1. PTBAE-PU sipulated by the secioral ministries; and 2. SPE-GRK (issued by SRN PPI). International verified carbon units (VOU) unregistered in SRN PPI can be traded by and in the ID Carbon, provided that: 1. Registered, validated, and verified by institution accredited by international registration system operator; 2. Fulfil the trading requirement by foreign Carbon Exchange, and 3. Other requirement as stipulated by OK.

Table II.4 Indonesia Carbon Trading Mechanism (PwC Indonesia, 2023)

As shown in Table 3, IDX carbon offers various types of carbon markets, including auction markets, regular markets, negotiated markets and non-regular markets. Trading of carbon units within IDX Carbon is facilitated exclusively among ID Carbon users, with units required to be registered in SRY PPI and IDX Carbon. The trading volume is based on multiples of one lot or one tonne of CO_2. Tradable carbon units include PTBAE-PU specified by sectoral ministries and SPE-GRK issued by SRN PPI. Additionally, iternational verified carbon units (VOU) unregistered in SRN PPI can be traded in ID Carbon under specific conditions, such as registration, validation, and verification by accredited international isntituions, meeting trading requirements of foreign Carbon Exchanges, and complyign with other stipulated requirements by relevant authorities. (PwC Indonesia, 2023).

II.5 Internal Rate of Return

For years, economists and engineers have employed the Internal Rate of Return (IRR) as a tool to assess the profitability or potential profitability of projects. The concept of IRR is grounded in Discounted Cash Flow (DCF) Procedures, a methodology used to proportianally value cash flows at the present time, thereby representing their worth relative to future cash flows in subsequent years (Mellichamp, 2017).

The higher an investment's Internal Rate of Retur (IRR), the more attractive it becomes for continued investment. Consequently, IRR serves as a tool to rank multiple potential investment options under consideration by an organization, In a scenario where all other factors are equal among different investments, the one with the highest IRR is recommended as the top priority. IRR is occasionally termed as the economic rate of return (Reniers et al., 2016a)

Relying solely on IRR to assess the viability of an investment is not advisable. Typically, IRR is combined with ROI for more informed decision-making. This is due to the fact that IRR offers an approximation of the annual growth rate, whereas ROI offers an estimation of the overall expected growth of an investment (Belhaj, 2023).

II.6 Payback Period (PP)

For The payback period (PP) is determined by calculating the time required, usually expressed in years, to recover an investment and establish the break-even point. The PP of a particular safety investment serves as a potential factor in deciding whether to proceed with the safety project, as companies generally find longer PPs less desirable (Reniers et al., 2016b). PP commonly used in situations where predicting long-term cash flows over several years poses challenges due to the lack of information beyond the break-even point. It can serve as initial assessment tool or a screening mechanism or high-risk projects during periods of financial ucertainty (Coker, 2007)

In a logical sense, energy systems exhibiting shorter payback periods are economically more advantageous compared to those with longer payback priods. Consequently, a shorter payback period is linked to greater sustainability (Dincer & Abu-Rayash, 2020).

II.7 Net Present Value (NPV)

Net Present value (NPV) serves as an indicator of he cash profit, expressed in the present value terms, that the project generates after recouping the initial investment. Consequently, it functions as a definitive measure of the overall profitability of the entire project (Balasubramanian et al., 2021).

NPV of an investment is determined by the contrast between the present value of the benefits and costs associated with the investment. The following points defines the significance of NPV (Tiwari & Sahota, 2018):

- Positive NPV indicates that undertaking the project will enhance the financial position of the investor
- Negative NPV signifies a financial loss
- Zero or null NPV suggests that the present value of all benefits over the useful lifetime equals the present value of all costs.

NPV and IRR serve different purposes in assessing profitability. NPV primarily calculates the dollar benefit or added value of a project for shareholders but does not offer insights into the safety margin or the amount of capital at risk. Hwne comparing mutually exclusive projects for ranking purposes, NPV is consistently considered superior to IRR (Belyadi et al., 2017).

II.8 Levelized Cost of Electricity

Levelized Cost of Electricity (LCOE) refers to the current value of the cost of the generated electricity (typically measured in cents/kWh). This calculation considers the lifespan of the project/facility, construction cost, operation and maintenance cost, and fuel costs (Ragheb, 2017). LCOE differs depending on the technology, location, and specific project due to factors such as renewable energy sources, initial ivestment, operational expenses, and technology efficiency (Papapetrou & Kosmadakis, 2022). A price of electricity higher than this threshold would result in higher return on investment, while a price below it would lead to a lower return on investment or even a loss (Ghose & Franchetti, 2018).

LCOE serves as a valuable measure of cost effectiveess because it can be calculated without making assumptions about the selling price of electricity to the grid or consumers. By using LCOE, assessing the financial viability under particular circumstances becomes straightforward by directly comparing the LCOE against the potential selling price of electricity (Papapetrou & Kosmadakis, 2022)

Several studies have been conducted to estimate the LCOE of geothermal power plants in different locations. Institute for Essential Services Reform (IESR) estimated the LCOE of geothermal power plant in Indonesia to be between 5,84 and 10,28 cents per kWh (IESR, 2019). Another study conducted by IRENA revealed that the global weighted average LCOE fell by 22% to USD 0,056 kWh (IRENA, 2023). This significant reduction positions geothermal power as competitive alternative among various sources of power plant.

II.9 Conceptual Framework

RETScreen Expert is a clean management software that capable of assessing the viability of a renewable energy project based on the scenario by the user. In this research, there are several 5 steps of analysis to reach the viability of the project which are the Energy Model, Greenhouse Gas Emission Reduction (emission analysis), the Financial Analysis Model (FAM), and the Sensitivitiy and Risk Analysis.

To conduct the feasibility analysis of energy model, the user need to input several energy data in the energy worksheet which are the steam flow, capacity factor, operating pressure, steam temperature, back pressure, and steam turbine (ST) efficiency. The expected power capacity of the power plant can be calculated using these inputs. The next step is the cost analysis in RETScreen feasibility analysis where the cost worksheet shows the cost breakdwon for the project that include initial costs and annual costs. For this research, the initial cost and operation & maintance cost will be gathered from the similar literature.

Emission analysis worksheet is designed to estimate potential reduction in greenhouse gas emissions from the proposed facility. By entering various parameters, including the region’s base case electricity system and gHG emission factors for different fuel types, it can illustrate a comparison of gHG emissions between the base case and the proposed scneario. The emission analysis worksheet also translates this GHG comparison into different units, such as liters of gasoline, barrels of crude oil, etc. This emission analysis will help in understanding the project's impact in terms of emissions.

In the financial analysis, the worksheets consist of various financial parameters categorized into three types: general parameters, finance parameters, and income tax analysis parameters. General parameters include inputs such as inflation rtae, discount rate, reinvestment rate, and project life. Finance parameters encompass incentives and grants, debt ratio, debt interest rate, and debt term. Income tax analysis parameters involve the effective income tax rate, depreciation method, depreciation tax basis, and tax holiday duration. By utilizing these parameters, RETScreen generates outputs like yearly cashflow, IRR, Simple Payback Periode, Equity Payback Period, Net Present Value, Annual Life Cycle Savings, Benefit-Cost Ratio, debt service coverage, GHG reduction cost, and LCOE. These output items will assist the decision-makers in evaluating the project.

Last is the risk analysis, which enables users to perform sensitivity analysis on multiple factors, is the last stage of the RETScreen feasibility analysis. For characteristics including starting cost, operation and maintenance cost, debt ratio, debt interest rate, and debt term, customers can set desired sensitivity levels. Users can assess the desired metrics, such as NPV, electricity production costs, and payback duration, using this risk analysis. The feasibility analysis process graph of Gunung Kembar 330 MW geothermal power plant is shown in Figure II.3 below.

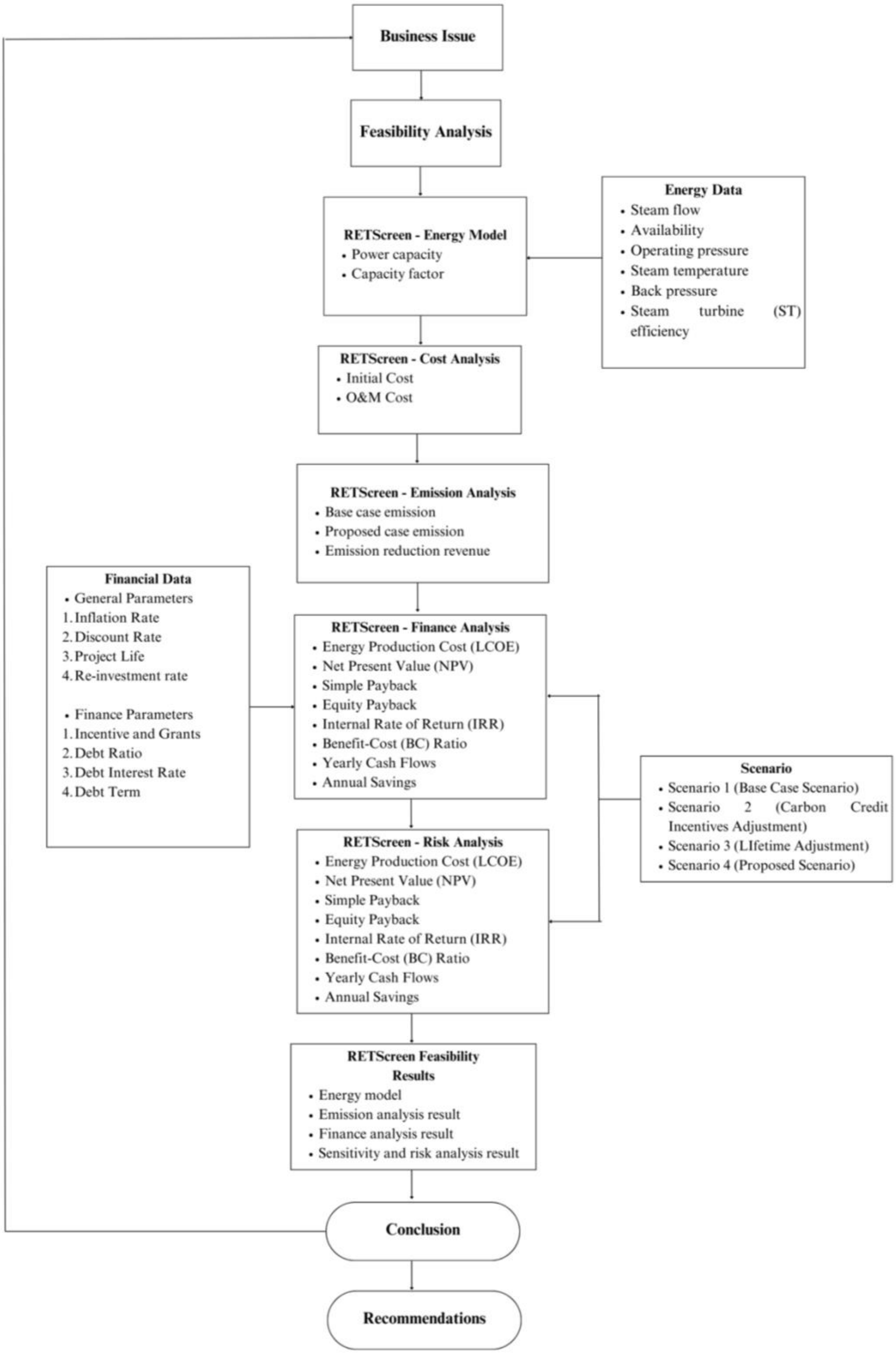
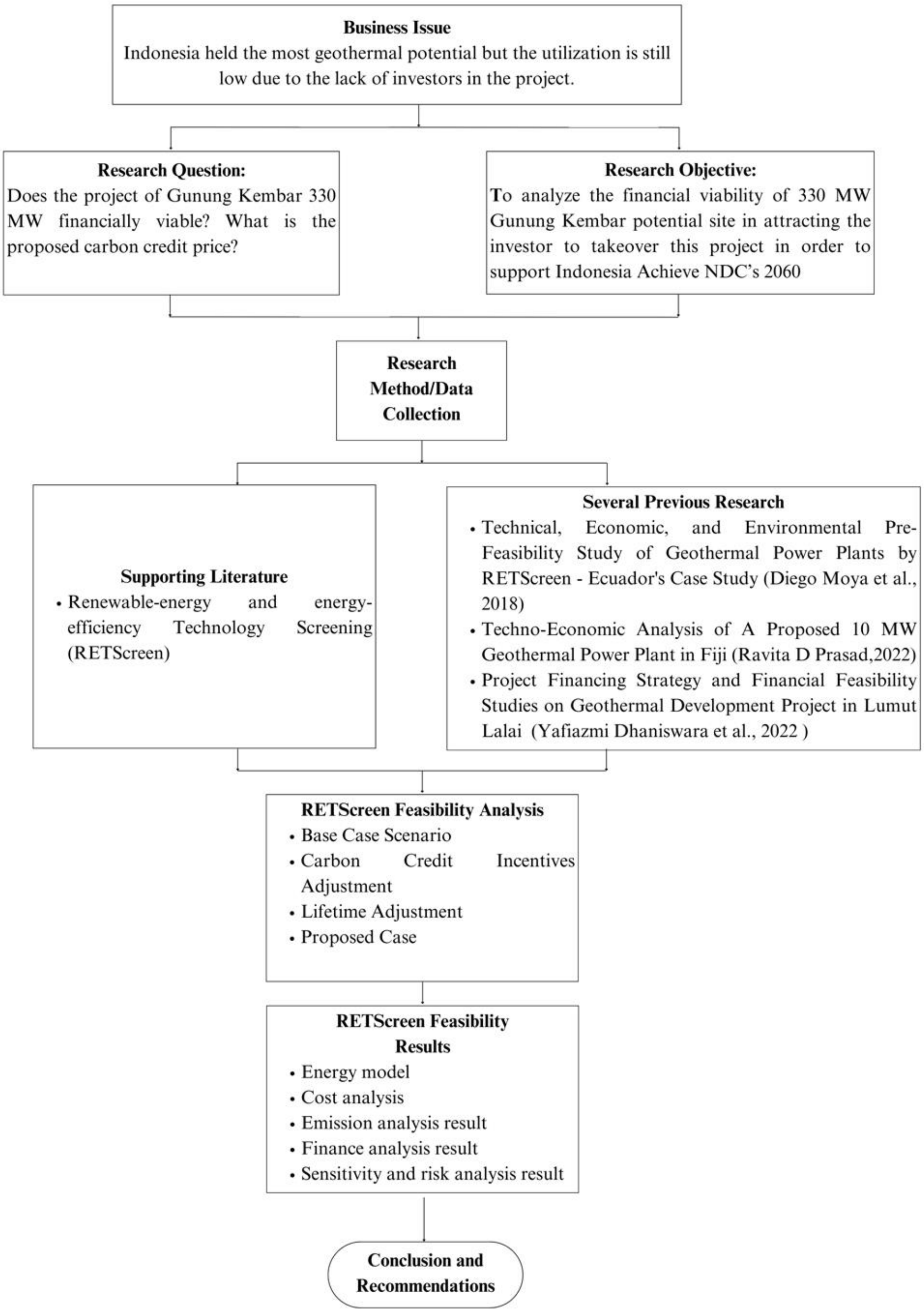


Figure II.3 Conceptual Framework

Chapter III Research Methodology

III.1 Research Methodology



Business Issue
Indonesia held the most geothermal potential but the utilization is still low due to the lack of investors in the project.

Research Question:
Does the project of Gunung Kembar 330 MW financially viable? What is the proposed carbon credit price?

Research Objective:
To analyze the financial viability of 330 MW Gunung Kembar potential site in attracting the investor to takeover this project in order to support Indonesia Achieve NDC's 2060

Research Method/Data Collection

Supporting Literature
- Renewable-energy and energy-efficiency Technology Screening (RETScreen)

Several Previous Research
- Technical, Economic, and Environmental Pre-Feasibility Study of Geothermal Power Plants by RETScreen - Ecuador's Case Study (Diego Moya et al., 2018)
- Techno-Economic Analysis of A Proposed 10 MW Geothermal Power Plant in Fiji (Ravita D Prasad,2022)
- Project Financing Strategy and Financial Feasibility Studies on Geothermal Development Project in Lumut Lalai (Yafiazmi Dhaniswara et al., 2022)

RETScreen Feasibility Analysis
- Base Case Scenario
- Carbon Credit Incentives Adjustment
- Lifetime Adjustment
- Proposed Case

RETScreen Feasibility Results
- Energy model
- Cost analysis
- Emission analysis result
- Finance analysis result
- Sensitivity and risk analysis result

Conclusion and Recommendations

Figure III.1 Research Design

As shown in the Figure 5, this study initiates with a business issue, which subsequently refined into a research question and research objective. The overreaching goal is to provide a comprehensive perspective on the valua proposition of the geothermal project. To achieve this objective, the data will be meticulously gathered and collected from various secondary sources, including prior research and relevant literature.

Subsequently, the next step entails the execution of a comprehensive feasibility analysis utilizing RETScreen software, which will be conducted based on four scenarios: Nase Case Scenario, Carbon Credit Incentives Adjustment, Lifetime Adjustment, and Proposed Scenario. Each of there scenarios is desgined to illuminate different facets of the project's feasibility, considering various parameters and factors such as carbon credit prices and lifetime of the geothermal project. The output derived from this feasibility study will be a comprehensive solutions and formulation of recommendations. These findings based on the diverse scenarios analyzed will contribute in understanding the geothermal project's viability and provide valuable insights for stakeholders and decision-makers involved in the renewable energy sector.

III.2 Data Collection

The data is collected from quantitative and qualitative sources, with the availability data from secondary data that gathered by consulting relevant documents, conducting a review of existing literature, and accessing other related sources. The data gathered are mainly from Bank Indonesia (2023a, 2023b); Moya et al., (2018); Prasad & Raturi, (2022); Rakhmadi & Sutiyono (2015); and Sitompul et al., (2022)

III.3 Data Analysis

In this research, the feasibility analysis will be conducted using the RETScreen software. This model assesses the energy generation of diverse clean and sustainable technologies, considering life-sycle expenses and reductions in greenhouse gas (GHG) emissions. This software relies on various parameters to compute the electricity production of the power plant. Several parameters are also taken from previous research (Moya et al., 2018; Prasad & Raturi, 2022; Rakhmadi & Sutiyono, 2015).

III.3.1 Climate Analysis

This research will use RETScreen software to conduct the feasibility analysis. This model requires several parameters to calculate the electricity production of the power plant. The input data for climate analysis was gathered from NASA satellite using RETScreen Software. The details about climate data which will be used in this study are shown in Table III.1.

Month	**Air Temperature (°C)**	**Relative Humidity (%)**	**Precipitation (mm)**	**Daily solar radiation ($kWh/m^2/d$)**	**Atmosphere pressure (kPa)**	**Wind speed (m/s)**	**Earth temperature (°C)**
January	25,7	83,8	143,53	4,42	99,6	2,2	26,3
February	26,2	82,2	102,20	5,02	99,5	2,1	26,7
March	26,6	81,9	165,85	5,22	99,5	2,0	27,3
April	27,0	82,5	162,00	4,98	99,4	1,9	27,6
May	27,1	82,7	206,77	4,83	99,4	1,7	27,8
June	27,0	81,5	159,30	4,82	99,5	1,7	27,6
July	26,7	81,3	187,86	4,60	99,5	1,6	27,4
August	26,6	81,9	215,14	4,50	99,5	1,8	27,3
September	26,3	83,8	270,60	4,30	99,5	1,9	27,0
October	26,1	84,9	295,12	4,22	99,5	2,1	26,8
November	25,9	86,1	292,80	3,87	99,5	2,2	26,5
December	25,7	85,7	270,32	3,82	99,6	2,4	26,2
Annual	26,4	83,2	2.471,49	4,55	99,5	2,0	27,0
Source	NASA	NASA	NASA	NASA	NASA	NASA	NASA

Table III.1 Site Climate Data

III.3.2 Techno-Economic Feasibility Study

Techno-economic analysis is a technique utilized to appraise and gauge the economic viability and feasibility of a technology or project. It melds both technical and economic considerations to ascertain whether a technology or project is financially tenable and how it can be enhanced. Techno-economic analysis is prevalent in fields and domains where substantial technology advancements and investment choices hold significance, including sectors like energy, manufacturing, and telecommunications. Pre-feasibility studies for geothermal projects aids in approximating the initial and yearly expenditures, energy savings, and production. This approach allows concentrated development efforts before actual construction (Olasolo et al., 2016). Initial data required to calculate the power capacity and grid-exported electricity for the Energy Model by RETScreen is presented in Table III.2 below.

Input Parameter	Value	Unit	Reference
Installed capacity	Up to 330	MW	(PLN, 2021)
Capacity factor	90	%	(Carlin, 2004)
Steam Flow	722,000	Kg/h	PLTP Sarulla
Operating pressure	6	Bars	(Prasad & Raturi, 2022)
Steam temperature	300	Celcius	PLTP Sarulla
Back pressure	3.95	Bars (ORC)	Moya et al., 2018)
Steam turbine efficiency	80	%	(Prasad & Raturi, 2022)

Table III.2 Energy Model Initial Data

In RETScreen mode, technical analysis was defined by the energy model. As shown in Table 5, it presents the initial data to calculate the power capacity based on the steam flow, capacity factor, operating pressure, steam temperature, back pressure, and steam turbine efficiency. Most of the data from Table III.2 are gathered from similar studies,with the steam flow of 722,000 kg/h specifically chosen based on data from the Sarulla 330 MW geothermal plant. There is no data provided regarding the steam flow of Gunung Kembar, so this selection is made under the assumption that both sites are located in the same province, so the steam flow beneath the land are assumed to be the same. For this Gunung

Kembar 330 MW geothermal power plant, the power plant will be using Organic Rankine Cycle (ORC) systems with the back pressure of 3.95 bars adjusting the steam temperature of 300 Celcius. The typical capacity factor of geothermal energy is 90% according to (Carlin, 2004), the high percentage is attributed to the continuous and uninterrupted energy supply offered by geothermal sources.

Parameter	**Value**	**Unit**	**Reference**
Installed initial cost	5000	USD/kW	(Moya et al., 2018; Rakhmadi & Sutiyono, 2015)
O&M cost	156	USD/kW	(Rakhmadi & Sutiyono, 2015)
Discount Rate	10	%	(Prasad & Raturi, 2022)
Inflation rate	5	%	Bank Indonesia, 2023
Debt ratio	70	%	Assumption
Debt interest rate	6	%	Bank Indonesia, 2023

Table III.3 Financial Analysis Initial Data

The financial initial data used in RETScreen modelling are shown in Table 6. based on the study by Moya et al., (2018) and Rakhmadi & Sutiyono, (2015), typical geothermal power plant initial cost is 5,000 USD per kilowatt-hour, excluding the exploration and drilling costs. Meanwhile the assumption for Operation & Maintenance cost for this Gunung Kembar 330 MW geothermal power plant are 156 USD per kilowatt-hour, refers to the existing Sarulla 330 MW geothermal power plant. The inflation rate stands at 5% as determined by Bank Indonesia per December 2023 inflation (Bank Indonesia, 2023b). The debt ratio established at 70% as it is the value typically used in renewable energy power plants (Alhassan et al., 2023).

When conducting the financial analysis of this research, several parameters are evaluated to determine the project's economic feasibility. These parameters include the Net Present Value (NPV), Levelized Cost of Electricity (LCOE), Internal Rate of Return (IRR), and Benefit-Cost (B/C) ratio which will be calculated using RETScreen Expert Software. NPV is the difference between the present value of projects' cash inflows and projects' cash outflows. The equation used to calculate the NPV, IRR, B/C ratio, and PP are presented in Equation 1 to 4.

Net Present Value (NPV):

$$\text{NPV} = \frac{\Sigma benefits - \Sigma cost}{(1+)^{n}} \tag{1}$$

where *n* is the number of years from the start of the project and *i* signifies the discount rate.

Levelized Cost of Electricity (LCOE):

$$\text{LCOE} = \frac{\Sigma cost}{annual\ energy\ production\ (MWh)\ x\ project\ lifespan} \tag{2}$$

GHG Emission Reduction Cost (GRC)

$$\text{GRC} = \frac{\text{NPV}}{\Delta GHG} \tag{3}$$

Equity Payback (EP):

$$\text{EP} = \sum_{n=o}^{N} Cn \tag{4}$$

where *Cn* is the cash-flow after tax in year *n*.

Internal Rate of Return (IRR):

$$0 = \sum_{n=0}^{N} \frac{\text{Cn}}{(1+IRR)^{n}} \tag{5}$$

where *Cn* is the cash-flow after tax in year *n*, and *n* is the number of years from the start of the project.

Three distinct scenarios are being examined with the assistance of RETScreen to assess their influence on the parameters of Net Present Value (NPV) and the levelized cost of electricity (LCOE). The scenarios studied are:

a. **Scenario 1: Base Case**

On the base case scenario, the geothermal power plant is installed and comissioned by the investor with no grant from the government but tariff given as 0,078 USD/kWh Based on PerPres No.112 2022, and a clean production incentives from the sales of carbon credit for US$ 2/tCO_2 based on the Regulation Number 7 of 2021 with a lifespan of the project for 25 years based on the usual term for geothermal project by World Bank (Gehringer & Loksha, 2012)

b. **Scenario 2: Carbon Credit Incentives Adjustment**

In this scenario, the clean energy production incentive from the sales of carbon credits are changing to US$ 18/tCO_2 according to the range of Indonesia’s carbon price by ESDM (Binekasri, 2023; Setiawan, 2023) . The electricity tariff is the same as scenario 1 which is 0,078/kWh but the lifetime project is changing to 25 years based on the usual term for geothermal project by World Bank (Gehringer & Loksha, 2012).

c. **Scenario 3: Lifetime Adjustment**

This scenario is still the same as scenario 2 which is an additional incentives from the sales of carbon credit but with different values for US$ 18/tCO_2 as stated by ESDM (Binekasri, 2023; Setiawan, 2023). The lifetime of the project remained the same as scenario 2 for 30 years according to Rakhmadi & Sutiyono (2015), and the tariff is also the same as scenario 1 and 2 which is 0,078/kWh.

d. **Scenario 4: Proposed Case**

This scenario will have various changes in order to achieve the best results. The carbon credits will be established at a rate of 50 USD/ tCO_2 as suggested by the International Monetary Fund that stated middle-income countries are suggested to set their price floors per ton carbon at 50 USD (Chateau et al., 2022). Meanwhile, lifespan will be set at 30 years according to the existing project of PLTP Sarulla (Rakhmadi & Sutiyono, 2015).

III.3.3 RETScreen Software

Figure III.2 RETScreen Software

Renewable-energy and Energy-efficiency technology Screening (RETScreen) software was developed by the Ministry of Natural Resources of Canada in collaboration with National Aero-Programme (UNEP) that serves the purpose of assessing energy generation, total costs over a system’s lifespan, and reductions in greenhouse gas emissions for a range of potential renewable energy (Moya et al., 2018). Furthermore, it offers standardized and unified financial assessment along with sensitivity and risk analysis to ascertain both the financial feasibility and potential risks associated with the project (Owolabi et al., 2019). The software is employed by more than 750,000 individuals across every country and territory globally. Additionally, RETScreen serves as an educational and research instrument in over 1,400 universities and colleges worldwide and is regularly refrenced in academic literature (Energypedia, 2021)

RETScreen can model a wide range of energy sources and technologies, from traditional to unconventional, covering areas like energy efficiency, heating and cooling, power generation (including renewables and conventional methods), and combines heat and power. It also integrates databases and global energy resource maps for analysis (Energypedia, 2021). The RETScreen software considers various factors including the energy resource availability at the project site, performance of equipment, initial project expense, 'base case' credits, on going project expense, avoided energy costs, financing, taxes and income, environmental attributes of displaced energy, as well as the decision maker's interpretation of cost-effectiveness (Iacobescu & Badescu, 2012).

Key advantage of utilizing RETScreen software is its ability to simplify the project evaluation for decision-makers. The financial analysis worksheet includes input elements for financial parameters (discount rate, debt ratio, debt term, etc) and provides calculated outputs related to financial feasibility (Net Present Value, Internal Rate of Return, Equity Payback Period, Simple Payback Period, etc. (Mirzahosseini & Taheri, 2012).

Furthermore, the focus of RETScreen software data onboarding service is dedicated to assist public sectors owners or operators in managing an extensice pertfolio of facilities in seamlessly and efficiently integrating diverse data into the RETScreen platform. The goal of this software is to achieve a swift, precise, and automated integration process. The scope of this service typically includes collecting data, generating a RETScreen portfolio file, implementing RETScreen measurement and verification, conducting initial benchmark and pre-feasibility analysis, and providing optional follow-up and technical support (Natural Resources Canada, 2023).

Chapter IV Results and Dicsussion

IV.1 Scenario 1: Base Case Scenario Analysis

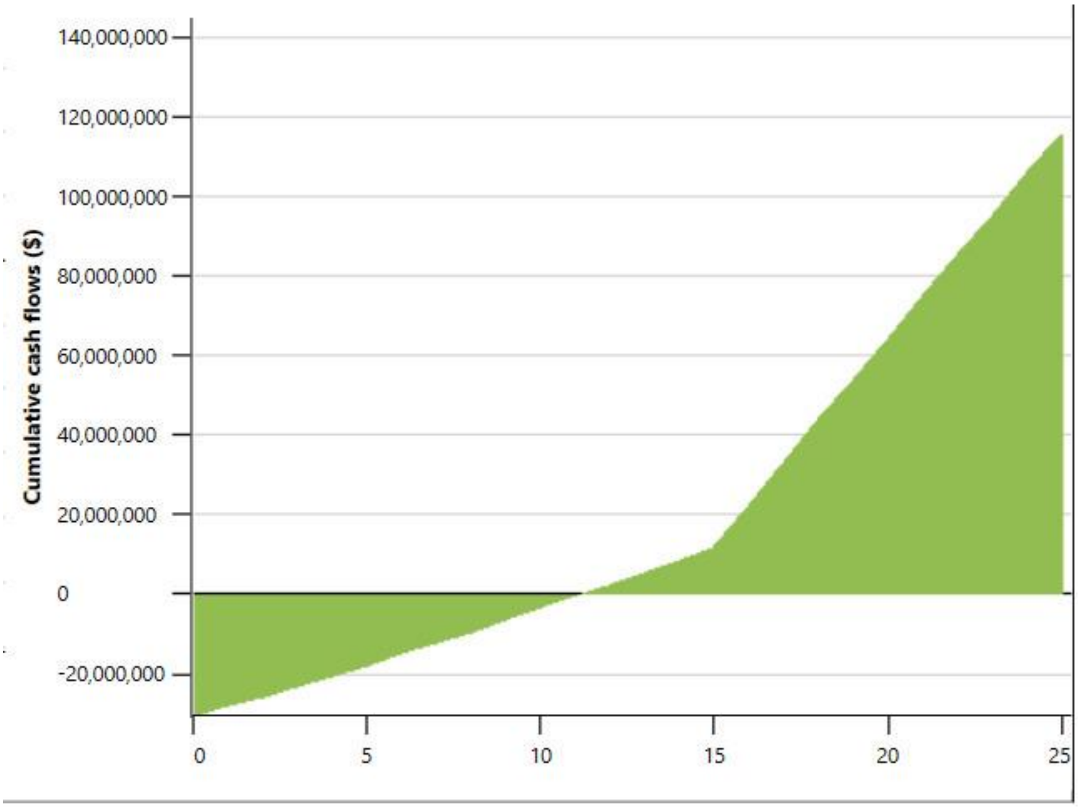


Figure IV.1 Cash Flow of Base Case Scenario

In this base case scenario, the tariff of geothermal electricity for US$ 0,0781/kWh was assumed and the clean production incentives from the from carbon credit sales were set at 2 USD/tCO2. As illustrated in Figure IV.1, Scenario 1 demonstrates an equity payback period of 11.2 years, indicating that positive cash flow would be realized after this timeframe, with a cumulative total cash flow of USD 115,758,143. Based on the results of the baseline scenario, the pre-tax internal rate of return-equity is 11.6%, surpassing the discount rate of 10%. Additionally, the pre-tax internal rate of return-assets stands at 2.2%, the simple payback period is 10.6 years, NPV amounts to USD 22,423,379, GHG reduction cost is -4.9 USD/tCO2, the cost-benefit ratio is 1.2, and the levelized cost of energy (LCOE) is 0.091 USD/kWh.

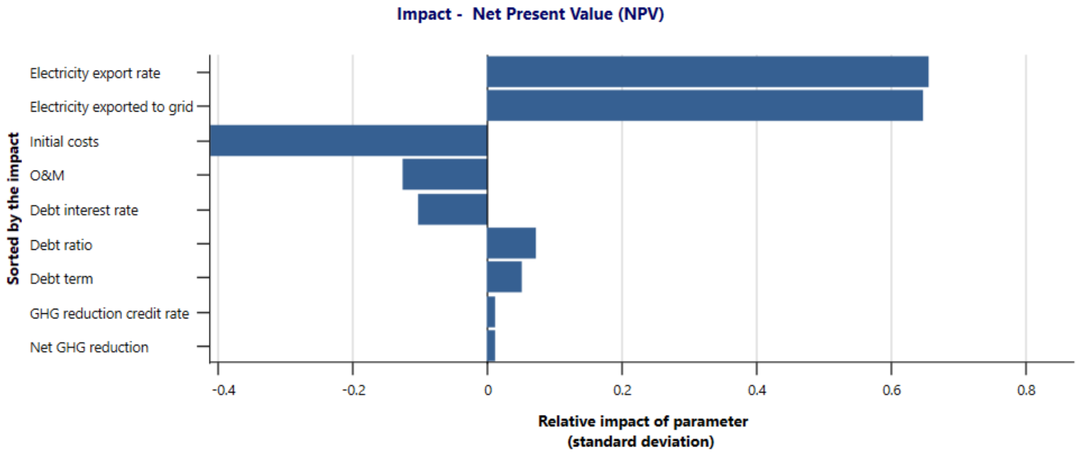


Figure IV.2 Sensitivity Analysis of Scenario 1: Base Case Scenario – NPV

In Figure IV.2 depicts that the predominant factor impacting the NPV is the rate of electricity export. The second most sensitive parameter is the amount of electricity exports to the grid, followed by initial costs, O&M costs, debt interest rate, debt ratio, debt term, GHG reduction credit rate and lastly net GHG reduction. Based on the results, higher electricity export rates correlate with increased project profitability, while lower electricity export rates correspond to decreased project profitability

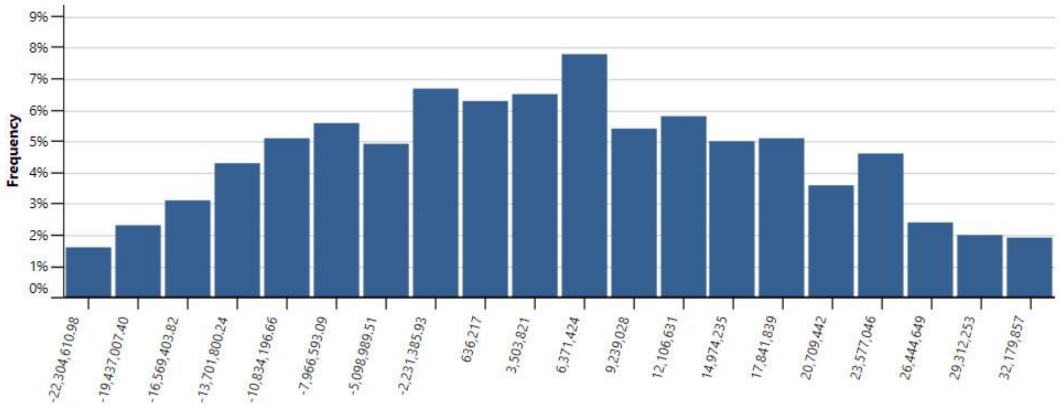


Figure IV.3 Distribution of Scenario 1: Base Case – NPV

In Figure IV.3, illustrates that the probabilities of NPV < 0 are located dominantly on the left side of the graph, suggesting that projects tend to be profitable based on the base case scenario. From 1,000 Monte Carlo simulations, the NPV for the base case scenario ranges from -23,755,200 USD to 33,616,369 USD, with a 40% probability of NPV < 0, indicating potential unprofitability. This implies that 60% of the simulations result in a profitable outcome.

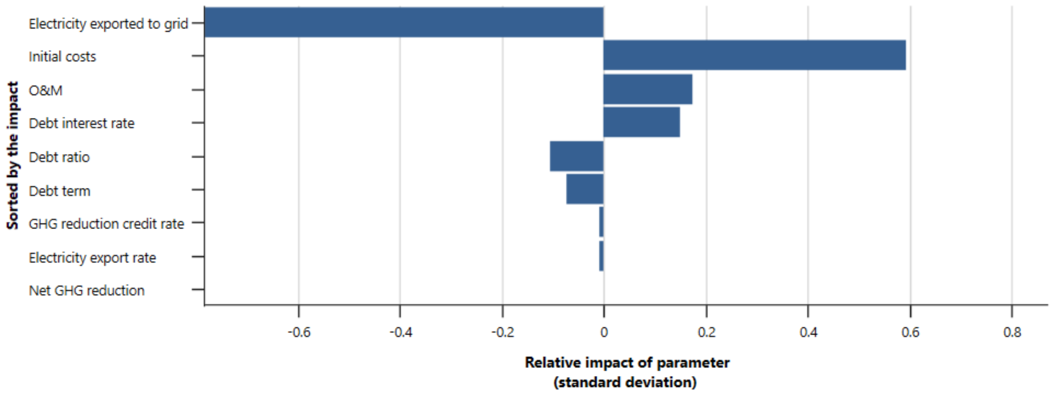


Figure IV.4 Sensitivity Analysis of Scenario 1: Base Case – LCOE

In Figure IV.4, it shows that the most sensitive or the most important parameter to LCOE is the amount of electricity exported to the grid. The second most impactful parameter is the initial cost, followed by O&M, debt interest rate, debt ratio, debt term, GHG reduction credit rate, electricity export rate and lastly Net GHG reduction. This results, implies that an increase in the quantity of electricity export to the grid contributes to project profitability, while a decrease in the quantity of electricity exported to the grid raises the likelihood of project unprofitability.

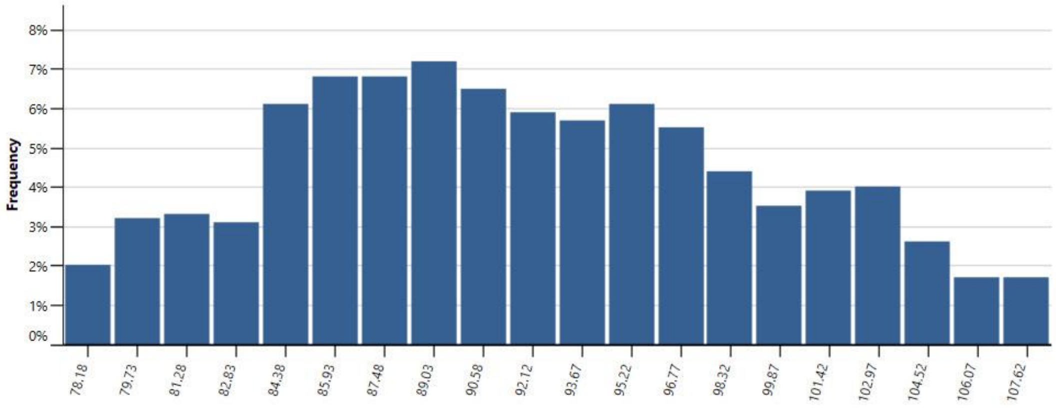


Figure IV.5 Distribution of Scenario 1: Base Case – LCOE

In Figure IV.5, it shows the probabilities of LCOE < 92.12 USD/MWh tends to be higher compared to LCOE > 92.12 USD/MWh. The LCOE of the project still lower compared to average electricity production cost in Aceh based on the based case scenario. From 1.000 Monte Carlo simulations, the cost savings scenario’s LCOE range from 48.3 USD/MWh to 101 USD/MWh, with 52% probability of

LCOE < 92.12 USD/MWh, which means 48% of the simulations the project has LCOE >92.12 USD/MWh.

IV.2 Scenario 2: Carbon Credit Incentives Scenario

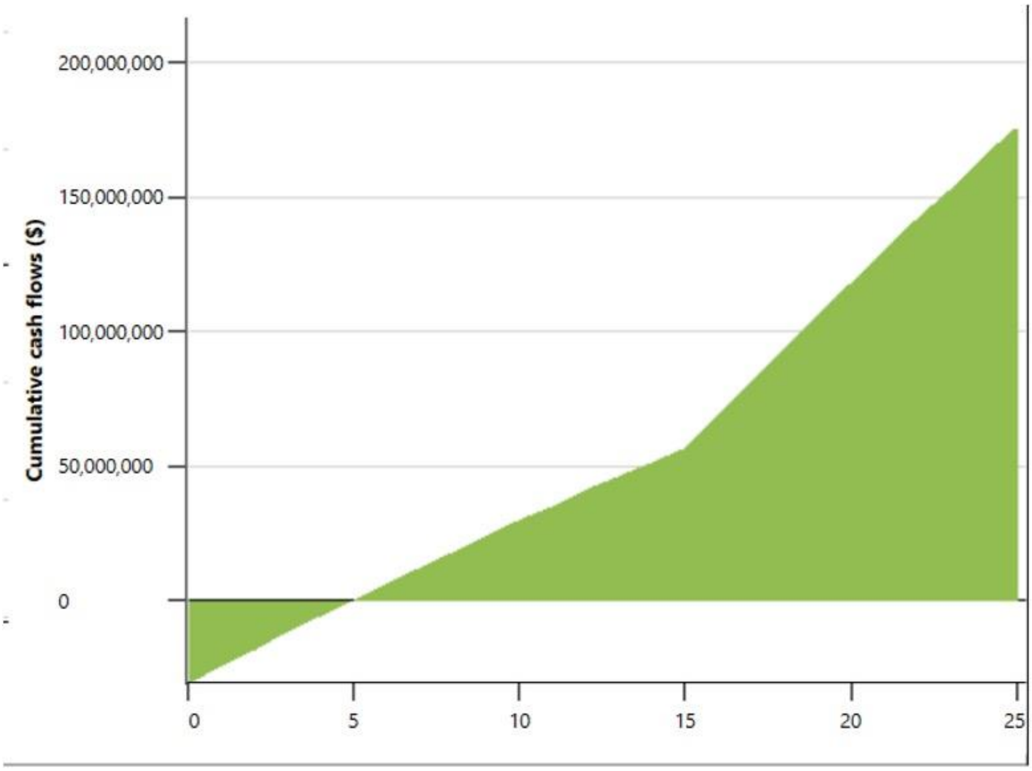


Figure IV.6 Cash Flow of Scenario 2: Carbon Credit Incentives Scenario

In this base case scenario, the tariff of geothermal electricity for US$ 0,0781/kWh was assumed and the clean production incentives from the from carbon credit sales were set at 18 USD/tCO2. As illustrated in Figure IV.6, Scenario 1 demonstrates an equity payback period of 6.7 years, indicating that positive cash flow would be realized after this timeframe, with a cumulative total cash flow of USD 165,392,171. Based on the results of the baseline scenario, the pre-tax internal rate of return-equity is 16.9%, surpassing the discount rate of 10%. Additionally, the pre-tax internal rate of return-assets stands at 4.5%, the simple payback period is 8.8 years, NPV amounts to USD 23,545,522, GHG reduction cost is -20.9 USD/tCO2, the cost-benefit ratio is 1.8, and the levelized cost of energy (LCOE) is 0.091 USD/kWh.

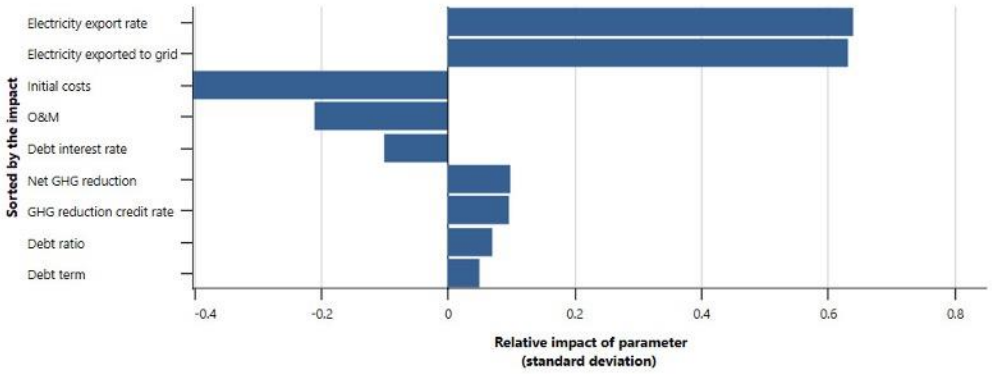


Figure IV.7 Sensitivity Analysis of Scenario 2: Carbon Credit Incentives Scenario – NPV

In Figure IV.7, the graph illustrates that the primary factor impacting NPV is the rate of electricity exported. The second most sensitive is the amount of electricity exported to the grid, followed by initial costs, O&M, debt interest ratem net GHG reduction, GHG reduction credit rate, debt ratio, and lastly debt term. Essentially, the higher the electricity export rates will increase the profit of the project, whereas lower rates results in decreased profitability of the project.

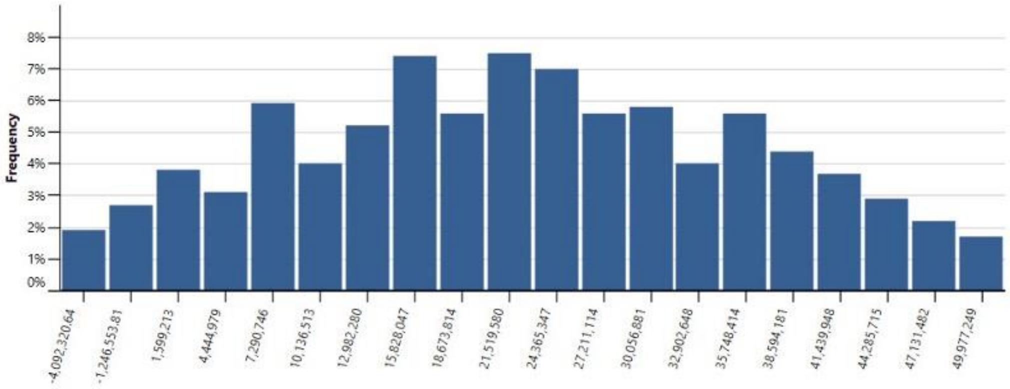


Figure IV.8 Distribution of Scenario 2: Carbon Credit Incentives Scenario – NPV

In Figure IV.8, illustrates that the probabilities of NPV < 0 are predominantly located on the left side of the graph, suggesting that projects in general tend to be profitable based on the base case scenario. From 1,000 Monte Carlo simulations, the NPV for the base case scenario ranges from -5,525,704 USD to 51,434,634 USD, with a 10% probability of NPV < 0 indicating potential unprofitability. This implies that 90% of the simulations result in a profitable outcome.

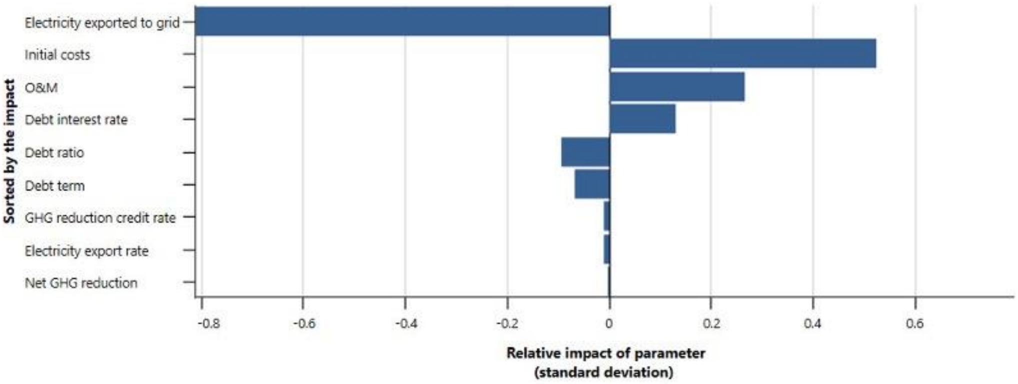


Figure IV.9 Sensitivity Analysis of Scenario 2: Carbon Credit Incentives Scenario – LCOE

In Figure IV.9, it shows that the most sensitive or the most important parameter to LCOE is the amount of electricity exported to the grid. The second most impactful parameter is the initial cost, followed by O&M, debt interest rate, debt ratio, debt term, GHG reduction credit rate, electricity export rate, and lastly net GHG reduction. These results implies that an increase in the quantity of electricity exported to the grid contributes to project profitability, while a decrease in the quantity of electricity exported to the grid raises the likelihood of project unprofitability.

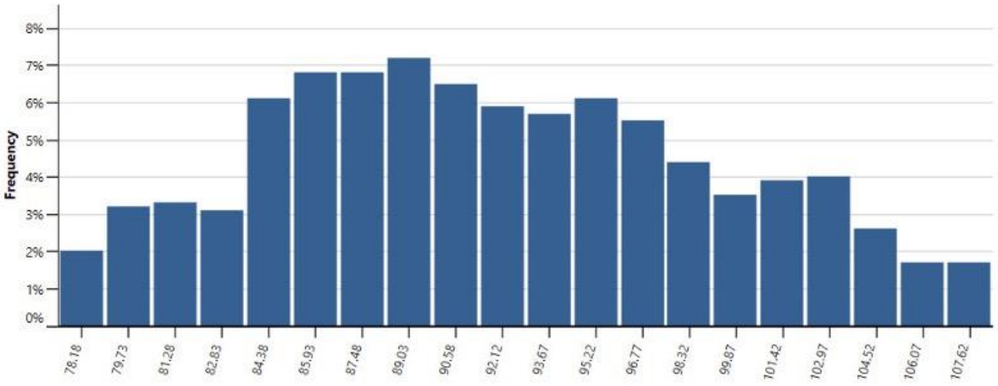


Figure IV.10 Distribution of Scenario 2: Carbon Credit Incentives Scenario – LCOE

In Figure IV.10, it shows the probabilities of LCOE < 92.12 USD/MWh tends to be higher compared to LCOE > 92.12 USD/MWh. The LCOE of the project tends to be lower compared to average electricity production cost in Aceh based on the Scenario 2. From 1.000 Monte Carlo simulations, the LCOE of Scenario 2 ranges from 77.40 USD/MWh to 108 USD/MWh, with 52% probability of LCOE < 92.12

USD/MWh, which means 48% of the simulations the project has LCOE >92.12 USD/MWh.

IV.3 Scenario 3: Lifetime Adjustment Scenario

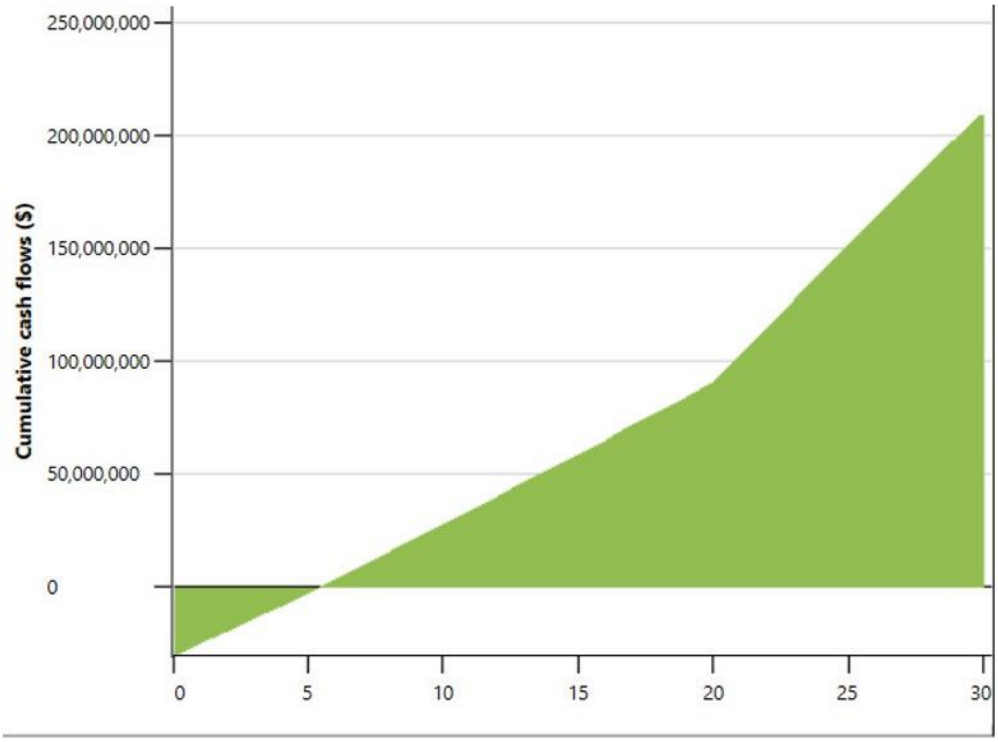


Figure IV.11 Cash Flow of Scenario 3: Lifetime Adjustment

In this base case scenario, the tariff of geothermal electricity for US$ 0,0781/kWh was assumed, the clean production incentives from the from carbon credit sales were the same at 18 USD/tCO2 , and the lifetime is elevated to 30 years (Rakhmadi & Sutiyono, 2015). As illustrated in Figure IV.11, Scenario 3 demonstrates an equity payback period of 5.4 years, indicating that positive cash flow would be realized after this timeframe, with a cumulative total cash flow of USD 209,418,920. Based on the results of the baseline scenario, the pre-tax internal rate of return-equity is 19.4%, surpassing the discount rate of 10%. Additionally, the pre-tax internal rate of return-assets stands at 5.5%, the simple payback period is 8.8 years, NPV amounts to USD 30,639,819, GHG reduction cost is -26.6 USD per ton CO2, the cost-benefit ratio is 2, and the levelized cost of energy (LCOE) is 0.088 USD/kWh.

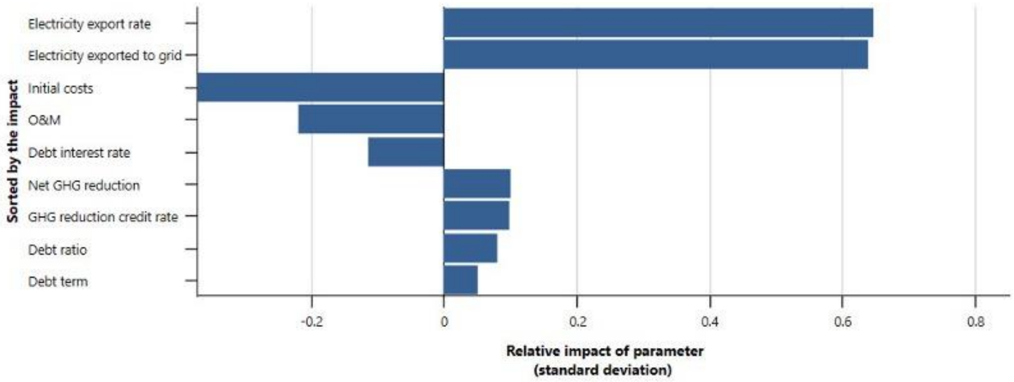


Figure IV.12 Sensitivity Analysis of Scenario 3: Lifetime Adjustment – NPV

In Figure IV.12 , illustrates that the primary factor impacting NPV is the rate of electricity export. The second most sensitive is electricity eported to the grid, followed by O&M, initial costs, Net GHG reduction, GHG reduction credit rate, debt interest rate, debt ratio, and lastly debt term. Essentially, the higher the electricity export rates will increase the profit of the project, whereas lower rates results in decreased profitability of the project.

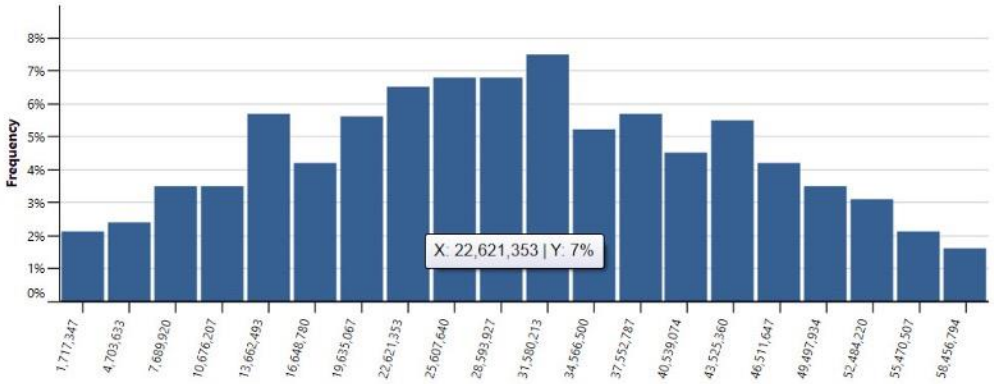


Figure IV.13 Distribution of Scenario 3: Lifetime Adjustment – NPV

In Figure IV.13, illustrates that there are not any probabilities of NPV < 0 meaning the project will have a 100% probability of being profitable. From 1,000 Monte Carlo simulations, the NPV for the base case scenario ranges from 220,825 USD to 59,994,092 USD.

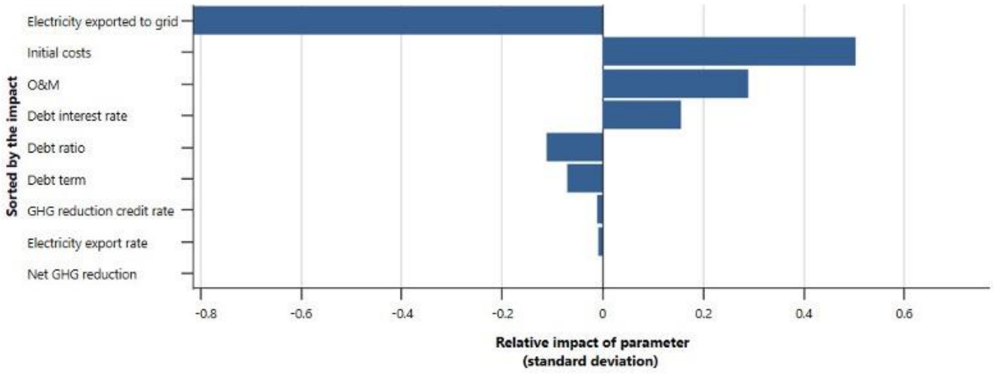


Figure IV.14 Sensitivity Analysis of Scenario 3: Lifetime Adjustment- LCOE

In Figure IV.14, it shows that the most sensitive or the most important parameter to LCOE is the amount of electricity exported to the grid. The second most impactful parameter is the initial cost, followed by O&M, debt interest rate, debt ratio, debt term, GHG reduction credit rate, electricity export rate, and lastly net GHG reduction. These results implies that an increase in the quantity of electricity exported to the grid contributes to project profitability, while a decrease in the quantity of electricity exported to the grid raises the likelihood of project unprofitability.

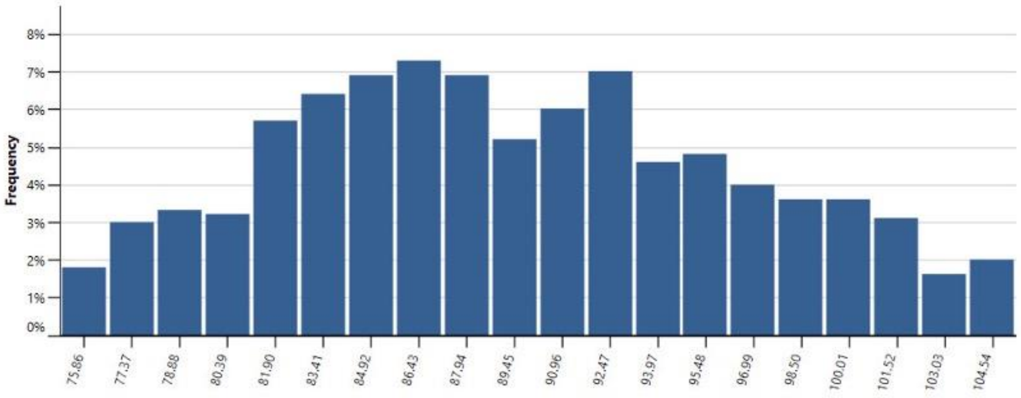


Figure IV.15 Distribution Analysis of Scenario 3: Lifetime Adjustment- LCOE

In Figure IV.15 shows the probabilities of LCOE < 89.45 USD/MWh tends to be higher compared to LCOE > 89.45 USD/MWh. The LCOE of the project tends to be lower compared to average electricity production cost in Aceh based on the Scenario 3. From 1,000 Monte Carlo simulations, the cost savings scenario’s LCOE range from 75,10 USD/MWh to 105 USD/MWh, with 52% probability of LCOE <

89.45 USD/MWh, which means 48% of the simulations the project has LCOE >89.45/MWh.

IV.4 Scenario 4: Proposed Case

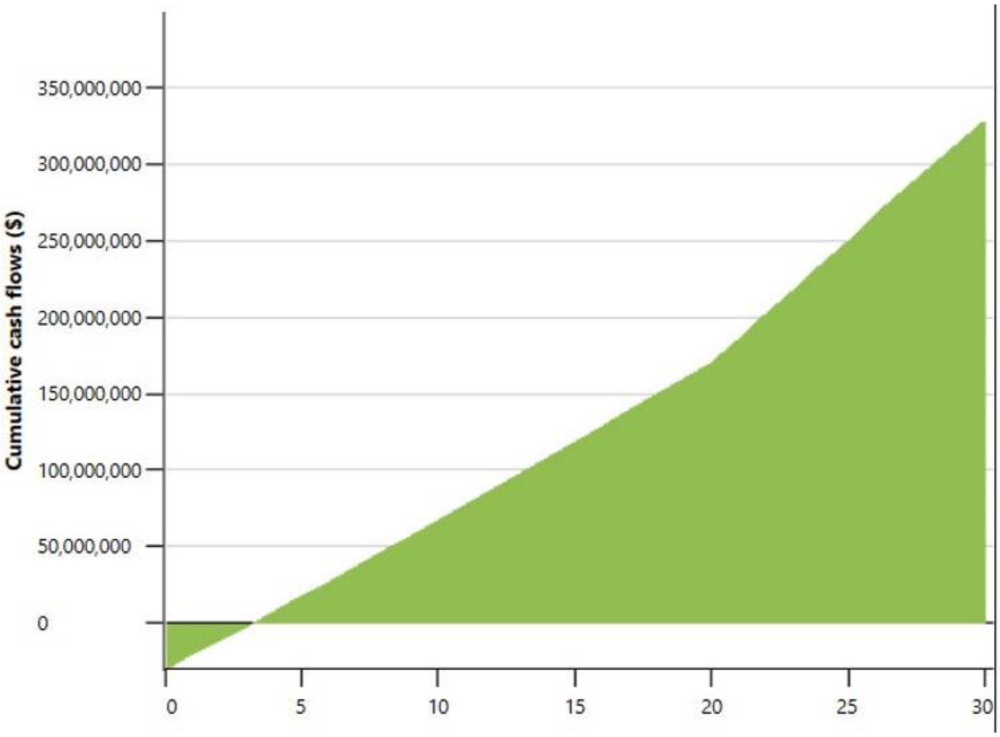


Figure IV.16 Cash Flow of Scenario 4: Proposed Case

In this base case scenario, the tariff of geothermal electricity for US$ 0,0781/kWh was assumed, the clean production incentives from the from carbon credit sales were elevated at 50 USD/tCO2 according to International Monetary Fund (Chateau et al., 2022), and the lifetime remain the same as Scenario 3 which is at 30 years (Rakhmadi & Sutiyono, 2015). As illustrated in Figure IV.16, Scenario 4 demonstrates an equity payback period of 3.2 years, indicating that positive cash flow would be realized after this timeframe, with a cumulative total cash flow of USD 328,193,237. Based on the results of the baseline scenario, the pre-tax internal rate of return-equity is 31.7%, surpassing the discount rate of 10%. Additionally, the pre-tax internal rate of return-assets stands at 9.6%, the simple payback period is 6.6 years, NPV amounts to USD 67,962,330, GHG reduction cost is -58,10 USD per ton CO2, the cost-benefit ratio is 3.2, and the levelized cost of energy (LCOE) is 0.088 USD/kWh.

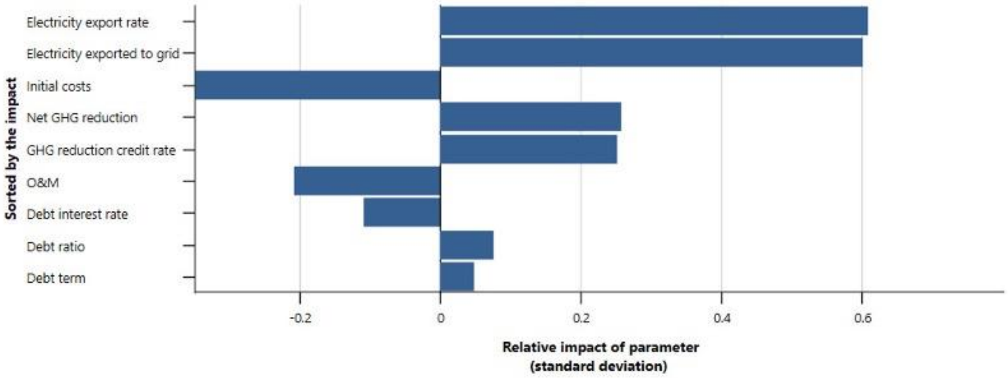


Figure IV.17 Sensitivity Analysis of Scenario 4: Proposed Case – NPV

In Figure IV.17, it illustrates that the primary factor impacting NPV is the rate of electricity exported. The second most sensitive is electricity eported to the grid, followed by initial costs, net GHG reduction, GHG reduction credit rate,, O&M, debt interest rate, debt ratio, and lastly debt term. Essentially, the higher the electricity export rates will increase the profit of the project, whereas lower rates results in decreased profitability of the project.

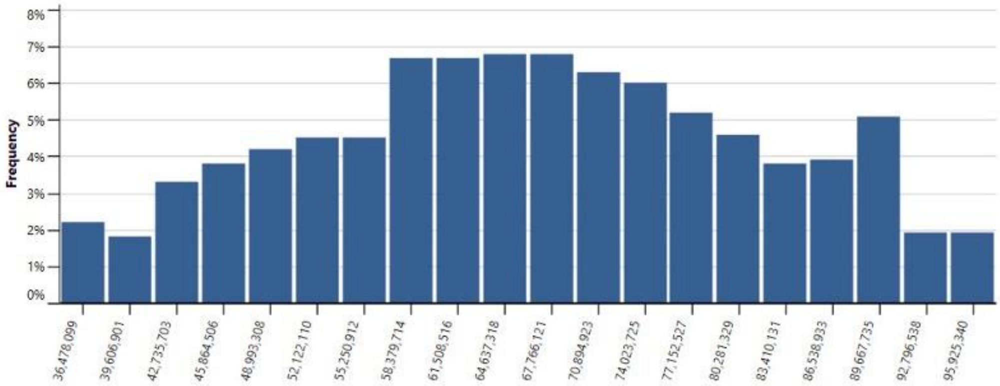


Figure IV.18 Distribution of Scenario 4: Proposed Case – NPV

In Figure IV.18, illustrates that there are not any probabilities of NPV < 0 meaning the project will have a 100% probability of being profitable. From 1,000 Monte Carlo simulations, the NPV for the base case scenario ranges from 34,887,355 USD to 97,494,617 USD.

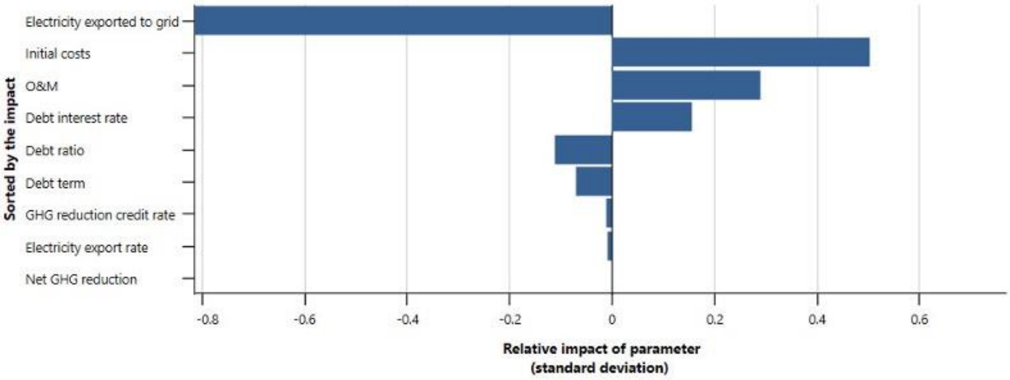


Figure IV.19 Sensitivity Analysis of Scenario 4: Proposed Case – LCOE

In Figure IV.19, it shows that the most sensitive or the most important parameter to LCOE is the amount of electricity exported to the grid. The second most impactful parameter is the initial cost, followed by O&M, debt interest rate, debt ratio, debt term, GHG reduction credit rate, electricity export rate, and lastly net GHG reduction. These results implies that an increase in the quantity of electricity exported to the grid contributes to project profitability, while a decrease in the quantity of electricity exported to the grid raises the likelihood of project unprofitability.

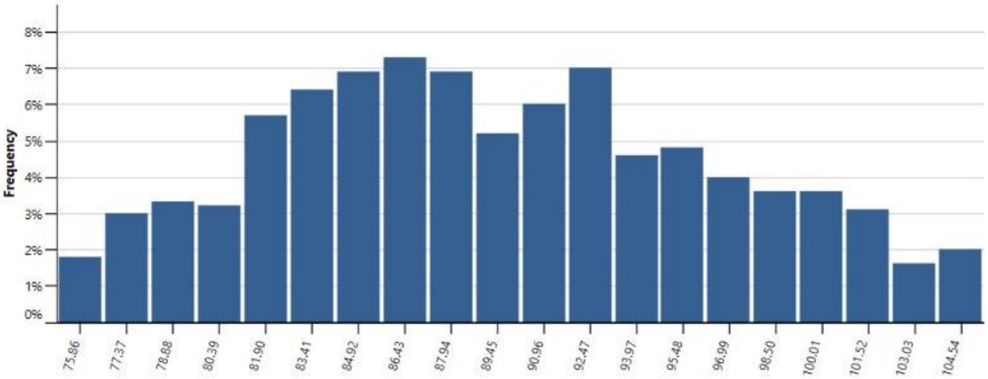


Figure IV.20 Distribution Analysis of Scenario 4: Proposed Case – LCOE

In Figure IV.20 shows the probabilities of LCOE < 89.45 USD/MWh tends to be higher compared to LCOE > 89.45 USD/MWh. The LCOE of the project tends to be lower compared to average electricity production cost in Aceh based on the Scenario 3. From 1,000 Monte Carlo simulations, the cost savings scenario’s LCOE range from 75,10 USD/MWh to 105 USD/MWh, with 52% probability of LCOE <

89.45 USD/MWh, which means 48% of the simulations the project has LCOE >89.45/MWh.

IV.5 Emission Analysis

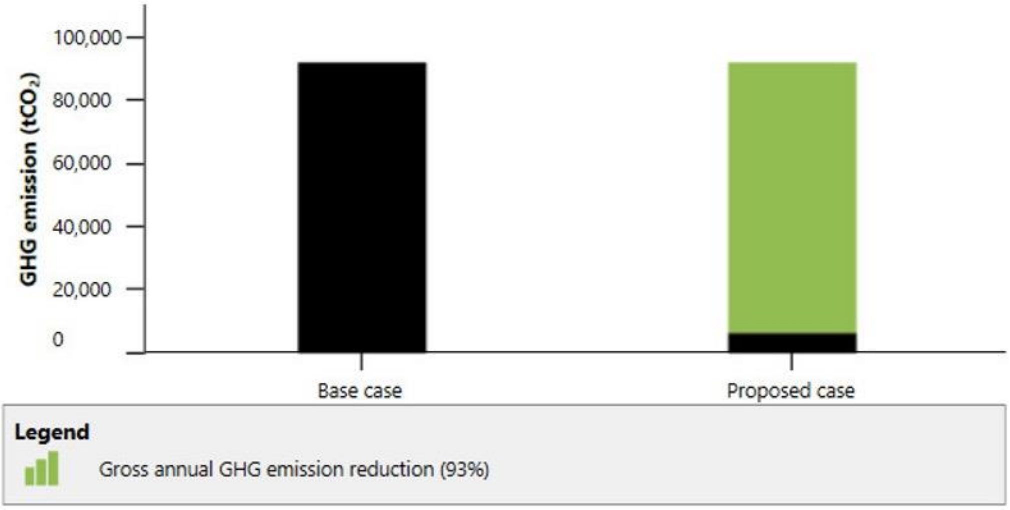


Figure IV.21 Annual GHG Emissions Reduction – Oil

The base case of this GHG emission reduction produced by diesel power plant are calculated using RETScreen. The initial scenario reveals that the electricity system in Indonesia that depend on oil has the GHG emission factor of 0.755 tons per CO2. The transmission and distribution losses of 9% (PLN, 2021) results 0.833 ton per CO2, as computed by RETScreen. Figure IV.21 showed that proposed case with 21 MW geothermal power plan across all four scenarios demonstrates the potential to reduction of 124,728.3 ton per CO2 yearly or equivalent to 22,844 liters of gasoline not consumed annually.

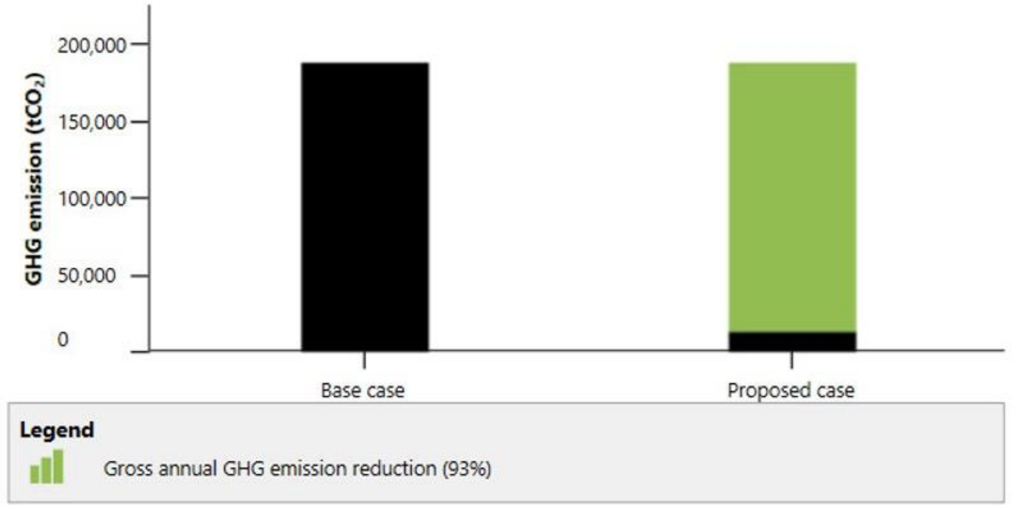


Figure IV.22 Annual GHG Emissions Reduction – Coal

The base case of this GHG emission reduction produced by diesel power plant are calculated using RETScreen. The initial scenario reveals that the electricity system in Indonesia that depend on coal has the GHG emission factor of 1.065 tCO2/MWh. The transmission and distribution losses of 9% (PLN, 2021) results 1.170 tCO2/MWh, as computed by RETScreen. Figure IV.22 showed that proposed case with 21 MW geothermal power plan across all four scenarios demonstrates the potential to reduction of 175,105 ton per CO2 yearly or equivalent to 32,070.5 liters of gasoline not consumed annually.

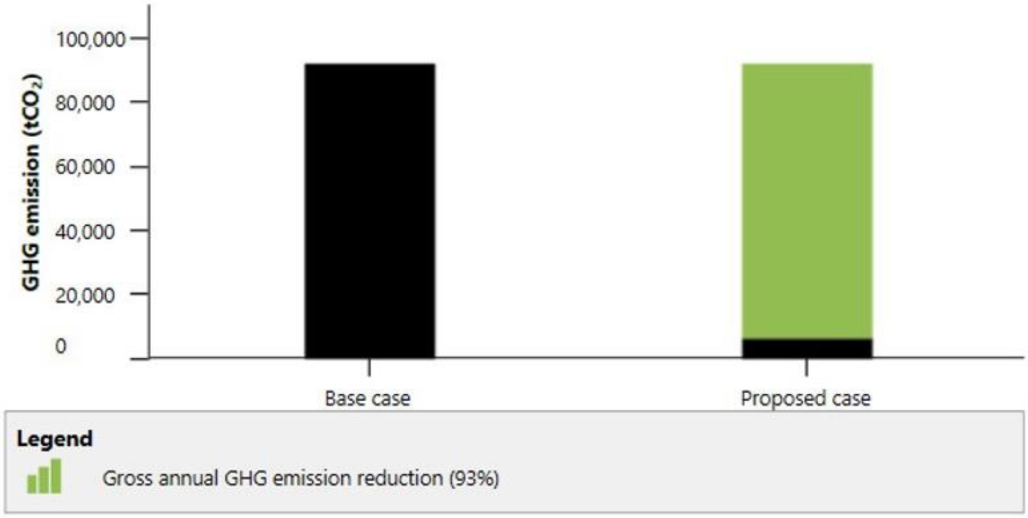


Figure IV.23 Annual GHG Emissions Reduction – Natural Gas

The base case of this GHG emission reduction produced by diesel power plant are calculated using RETScreen. The initial scenario reveals that the electricity system in Indonesia that depend on coal has the GHG emission factor of 0.520 tCO2/MWh. The transmission and distribution losses of 9% (PLN, 2021) results 0.571 tCO2/MWh, as computed by RETScreen. Figure IV.23 showed that proposed case with 21 MW geothermal power plan across all four scenarios demonstrates the potential to reduction of 85,494.7 ton per CO2 yearly or equivalent to 15,658.4 liters of gasoline not consumed annually.

Chapter V Conclusion and Recommendation

V.1 Conclusion

Financial and technical analysis of the development of Gunung Kembar 330 MW geothermal power plant in Aceh was carried out. The technical feasibility analysis from the RETScreen showed that the likely power installed capacity of the proposed case geothermal power system would be at 21 MW per unit. The RETScreen Energy Model also calculates the electricity exported to the grid to be 160,908,320 kWh. Financial analysis showed the results on all four scenarios that the carbon price in Indonesia makes the Gunung Kembar 21 MW geothermal power plant is financially feasible. However, the existing carbon price set at 2 USD/tCO_2 still consider very small if compared to what the International Monetary Fund has suggested for middle-income country (50 USD/tCO_2).

The Base Case Scenario (Scenario 1) illustrates the project's financial feasibility, assuming a carbon credit price of 2 USD/tCO_2 established by UU.No 7 Tahun 2021, and a lifetime of 25 years according to the World Bank. In this scenario, the equity payback period in this scenario is estimated at 11.2 years, signifying that positive cash flows will be generated beyond this time with a total cumulative cash flows during the duration of the project are predicted to 115,758,143 USD. The outcomes from the calculation of the Base Case Scenario are the following: a pre-tax IRR-equity of 11.6%, a simple payback period of 10.6, a net present value of 5,524,320 USD, an annual average life cycle savings (ALCS) of 608,604 USD, a levelized cost of electricity (LCOE) of 0,091 USD per kilowatt-hour, a greenhouse gas (GHG) reduction cost of -4.9 USD per ton of CO_2, and a cost-benefit ratio of 1,2.

In the Base Case Scenario, the Internal Rate of Return (IRR) are slightly above the discount rate (10%) which may not be particularly attractive to the investors. According to the statement by ESDM, the market price of carbon credits varies between 2 USD per ton CO_2 to 18 USD per ton CO_2 (Binekasri, 2023; Setiawan, 2023). In Carbon Credit Incentives Adjustment Scenario (Scenario 2), the price of carbon credit is elevated from 2 USD per ton of CO_2 to 18 USD per ton CO_2. This scenario analysis results shows that the project is financially feasible, with a net present value (NPV) of 23,545,522 USD, a pre-tax internal rate of return (IRR) of 16.9%, equity payback by 6.7 years, simple payback by 8.8 years, an annualized life cycle savings (ACLS) of 2,593,965 USD/year and energy production cost of 0,091 USD per kilo-watt hour. These findings are align with the prior research conducted by (Prasad & Raturi, 2022) that stated the incroporation of incentives led to an increased NPV and a shorter duration of equity payback period.

A study by Moya et al., (2018), shows that the longer the lifetime of the project also increase the profitability of the project. In the Proposed Case (Scenario 4), the lifetime is elevated from 25 years to 30 years according to the existing Sarulla 330 MW geothermal power plant (Rakhmadi & Sutiyono, 2015). The carbon credit price also established accordingly to the suggestions of International Monetary Fund by 50 USD per ton CO_2. The result in prposed case shows a very profitable results if the carbon credit price is increased according to the suggestions by International Monetary Fund which is 50 USD per tons CO_2. From 30 years of the project lifetime, the positive cash flows will be generated after 3.2 years which is a really short time meaning less financial risk. The LCOE also lower than the Scenario I and II and its in the range of LCOE established by (Rakhmadi & Sutiyono, 2015).

The research findings in Table V.I, offer a thorough comparison between this study and other similar research. These findings reveal significant insights, indicating that Indonesia’s electricity tariffs are considerably lower than those of other countries like Fiji and Ecuador. Additionally, the higher levelized cost of electricity (LCOE) in Indonesia is attributed to higher O&M costs in comparison to other countries. O&M costs estimates include routine operation and maintenance, major repairs, spares and consumables, staffing, and insurance (McWilliams, 2022). These results also indicates that in order Indonesia want to achieve same level of profitability to other countries, they need to increase the carbon price or else the project will not be attractive to the investors.

Research Scope					Costs		Results				
Author	**Region**	**Scenario**	**Capacity (MW)**	**Electricity Tariffs (USD/kWh)**	**Initial Costs (USD/kW)**	**O&M Costs (USD/kW/yr)**	**NPV (MUSD)**	**Simple Payback Period (Years)**	**Equity Payback Period (Years)**	**IRR (%)**	**LCOE (USD/kWh)**
This Research	Aceh, Indonesia	Scenario 1 : 2 USD/ tCO_2, 25 yrs	330	0,078	5000	156	5.5	10.6	11.2	11.6	0.091
		Scenario 2 : 18/ tCO_2, 25 yrs					24	8,8	6,69	16,9	0.091
		Scenario 3 : 18 tCO_2, 30 yrs					31	8,8	5,4	19,4	0.088
		Scenario 4 : 50 tCO_2, 30 yrs					68	6,6	3,2	31,7	0.088
(Ravita D Prasad, 2022)	Fiji	ORC GPP	10	0,1621	6000	406,3	17,3	6,9	4	N/A	0.014
		Additional Incentives					81,427	3,7	1,3		0.0136
		Electricity not exp. to grid					-40,289	20,5	None		0.0136
(Diego Moya et al., 2018)	Ecuador	Scenario I (25 yrs, 3 MUSD)	22	0,132	5181	94,80	63	4,9	3,2	32,6	0.0032
		Scenario II (15 yrs, 3 MUSD)					36	4,9	3,7	27,8	0.0041

Research Scope					**Costs**		**Results**				
Author	**Region**	**Scenario**	**Capacity (MW)**	**Electricity Tariffs (USD/kWh)**	**Initial Costs (USD/kW)**	**O&M Costs (USD/kW/yr)**	**NPV (MUSD)**	**Simple Payback Period (Years)**	**Equity Payback Period (Years)**	**IRR (%)**	**LCOE (USD/kWh)**
		Scenario III (A) (25 yrs, 3 MUSD)					-24831772	15,6	16	4,5	0.0032
		Scenario III (B) (25 yrs, 20 MUSD)					7	9,3	5,6	18,3	0.0018
(Rakhmadi & Sutiyono, 2015)	Indonesia	First Scenario	330	0,078	5000	155,56	N/A	N/A	9	14-16	0.078-0.082

Table V.1 Results Comparison to Previous Studies

V.2 Recommendation

Based on the conclusion above, there are several recommendations suggested by the Authors: the current relatively low price of Indonesian carbon credit price necessitates an increase in alignment with global rates. Indonesian government should increase the carbon credit price as suggested by the International Monetary Fund by 50 USD per ton CO_2 (Chateau et al., 2022). Increasing the carbon credit price would enhance the attractiveness of this Gunung Kembar 330 MW to investors by amplifying potential profits, and also align with the Indonesian’s target in achieving the NDC’s 2060. Another suggestions is to set the project’s lifetime for 30 years as it is likely resulted in higher Net Present Value (NPV) to the project and a shorter payback period (PP). This recommendation is align with the results from (Moya et al., 2018) where an extended project lifetime led to an increase in Net Present Value (NPV).

In pursuit of the formidable objective of attaining net-zero carbon emissions by 2060, it is advisable for the Indonesian government to strategically allocate resources towards the implementation of geothermal power plant systems such as providing grants or incentives to the geothermal power plant project. Given that one of the reasons investors are reluctant engaging in geothermal project are the high cost, governmental grants would serve as a mitigating solution to this problem. Furthermore, due to the problem of the high cost that are not very attractive to the investors since it will bring less profit, there are several recommendations to cut cost of the high cost of geothermal power plant such as reducing the cost of exploration and drilling by doing the process efficiently. This process can be done by using advanced drilling systems, improved directional drilling, better cements, and better well logging (Murphy & Niitsuma, 1999).

This study further suggests that the government should revise the geothermal tariffs since based on the results, the tariff of Indonesia’s geothermal is considerably lower than the other countries.The project’s feasibility appears challenging and not as attractive without incentives, as per calculations. Given the current geothermal tariffs, potential investors might be hesitant to participate in geothermal power plants due to the low tariff rates and the absence of renewable energy incentives like emission incentives. The Author’s recommended that the new renewable energy tariffs could increase for 30% refers to the other countries foestering a more favorable investment environment within Indonesia’s renewable energy market.

Author also recommends further research to incorporate other incentives other than carbon prices for renewable energy, such as duty-free on the power plant electrical components and tax-holiday on the property. Further investigation should be consider including duty-free incentives in the calculations, given that the Indonesian government has implemented duty-free policies for specific imported goods contributing to renewable energy production in the country. Another recommendations for future research involves exploring alternative renewable energy technologies and different locations to determine the most cost-effective and suitable technology for specific areas. This aims to assess the viability of Indonesia’s carbon price and tariffs with other renewable energy technologies.

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