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Economic Analysis of Remaining Geothermal Reserves to Increase Geothermal Power Plant Capacity in Achieving National Energy Mix Target

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Geothermal Proven Reserves, Monte Carlo Simulation, Net Present Value

Abstract
In order to meet the renewable energy mix target related to the installed capacity of Geothermal Power Plants in 2025 of 7,200 MW, with the potential of geothermal resources of 23,060 MW, only 2,360 MW has been utilized as a Geothermal Power Plant. In the Geothermal Working Area "XYZ" there are potential geothermal reserves of 464 MW, but only 55 MW (12%) has been utilized as a Geothermal Power Plant. Increasing the generating capacity in the "XYZ" Geothermal Working Area that has been operating can reduce the risk level of geothermal resources, initial investment costs, and plant construction time because the geothermal development process does not start from the initial stage. The purpose of this study is to evaluate and analyze the investment in geothermal power plant capacity development using Monte Carlo Simulation in decision-making, by taking into account uncertain variables such as capacity factor, interest rate, inflation, tax, proportion of equity financing, and construction period. The analysis results show that the investment scheme for developing generating capacity by maximizing geothermal reserves increases the probability of a positive Net Present Value.

1. Introduction

The continuous use of fossil energy will result in global problems, such as depletion of energy reserves, thereby increasing the price of fossil fuels in the global market. In addition, the use of fossil fuels can cause environmental damage that leads to global warming and climate change. Population growth can cause more severe environmental damage, thus encouraging humans to explore and exploit fossil energy sources. The potential of renewable energy in Indonesia is very diverse, including hydroelectricity, geothermal, wind, solar, and biomass. However, in 2022, only 12.3% of the target of 23% of energy in 2025 will come from renewable energy sources (Direktorat Jenderal EBTKE, 2023).

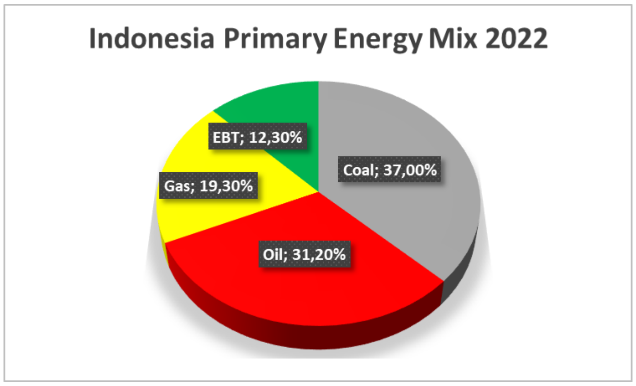

Figure 1[1]
(Direktorat Jenderal EBTKE, 2023)

The installed renewable energy generation capacity until 2022 is 12.55 GW (Kementerian Energi dan Sumber Daya Mineral, 2023) as shown in Figure 2. After water energy, geothermal energy is one of the largest renewable energy sectors.

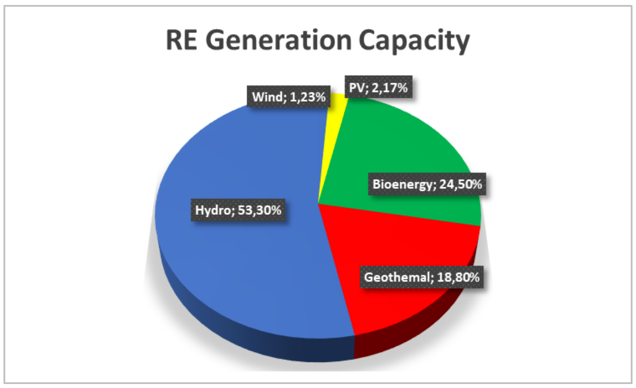

Figure 2 Installed RE Power Plant Capacity in 2022 (Direktorat Jenderal EBTKE, 2023)

Indonesia is one of the countries with the largest geothermal energy potential in the world, with a potential of 23,060 MW, but only 2,360 MW has been exploited as Geothermal Power Plants (Kementerian Energi dan Sumber Daya Mineral, 2023). The lack of utilized geothermal capacity that has been utilized is a result of high uncertainty or risk factors at the geothermal exploration stage (Witter et al., 2019). In addition, there are risks that arise in utilized geothermal development projects such as completion or delay risks, risks of non-absorption of electrical energy, price risks, operational risks, and regulations (Nur et al., 2023).

A number of studies on the development of geothermal potential, especially the economics of power generation facilities, have been conducted in the past. Project valuation methods, such as Net Present Value (NPV*) and Discounted Cash Flow* (DCF) have been developed to factor in operation and maintenance costs. Geothermal power plant initiatives are evaluated using NPV to calculate and analyze their financial value.

This study aims to analyze geothermal development from the remaining geothermal reserves in the Geothermal Working Area "XYZ" that have not been exploited optimally, accompanied by economic evaluation to increase installed geothermal capacity, so as to show decisions from the investment side for geothermal companies and the government in the use of renewable energy.

Literature Study

Geothermal Power Plant

Geothermal energy is energy produced by heat from within the earth. Under the earth's crust there is a hot, dense layer of rock with pockets of water, which sometimes come to the surface in the form of hot springs. When water does not reach the Earth's surface naturally, sometimes water can penetrate into it, this hot water can be used as an essentially free energy source, either as hot, steam, or hot water, or as a power plant (Igwe, 2021).

In theory, geothermal power plants are identical to steam power plants, but in steam power plants, steam is generated on the surface inside the steam boiler. If the fluid in the wellhead is already in the form of steam, it can be piped directly to the turbine, where it will be converted from geothermal energy into the mechanical energy needed to spin the generator and generate electricity (Saptadji, 2018). Different countries classify geothermal power resources differently; however, it is generally categorized into three groups based on enthalpy levels, namely low (20-70°C), medium (70-150°C), and high (greater than 150°C) (Özkaraca, 2018).

Geothermal power plants operates through a closed-cycle system, where geothermal fluid sourced from energy generation wells undergoes processing to extract its thermal energy, before being injected back into the reservoir through injection wells. There are 3 (three) types of geothermal power plants, including:

1. Dry Steam Plant

   Dry steam geothermal power plants utilizes a dry steam reservoir that occurs naturally used directly to drive turbines.

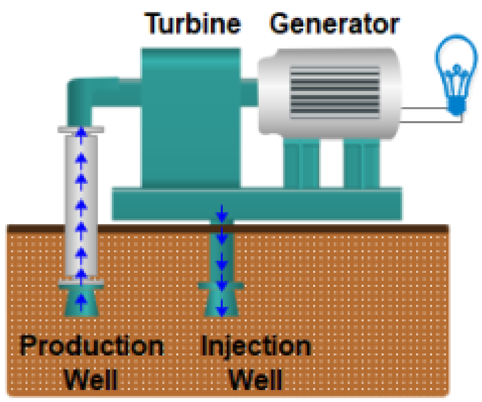

Figure 3 Dry Steam Plant (Özkaraca, 2018)

2. Flash Steam Plant

   Flash steam geothermal power plants utilizes the separation of high-pressure fluid coming from the well into water and steam through a low-pressure separator, followed by the use of separate steam to drive the turbine.

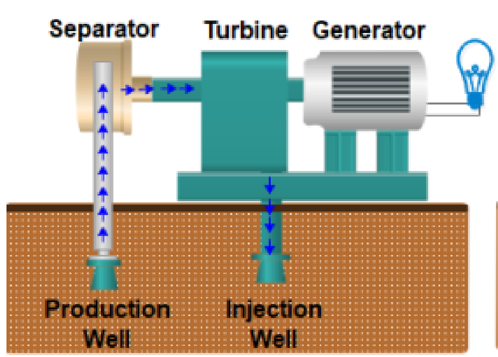

Figure 4 Flash Steam Plant (Özkaraca, 2018)

3. Binary Cycle Plant

   Binary Cycle geothermal power plants utilizes heat from geothermal fluids, which causes the fluid to evaporate at a lower temperature than water. This evaporation process takes place in the heat-exchanger, and the steam generated is used to rotate the turbine.

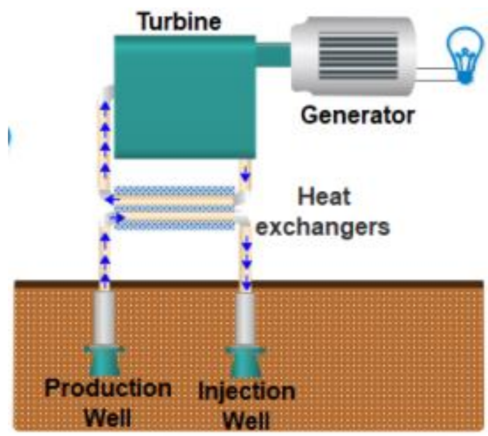

Figure 5 Binary Cycle Plant (Özkaraca, 2018)

Geothermal Development in Indonesia

Kamojang geothermal power plants is the first geothermal development for geothermal power plants in Indonesia. Starting in 1926, when the Dutch East Indies Government began drilling in the Kamojang field. A long journey to introduce geothermal energy to the Kampung Baru geothermal power plants. Only in 1983, the Kamojang geothermal power plants unit with a capacity of 130 Mega Watt (MW) began to operate effectively (Pribadi, 2020). The stages of geothermal exploitation activities consist of Preliminary Survey, Exploration, Feasibility Study, Exploitation, and Utilization (Republik Indonesia, 2014).

The figure presented below illustrates the geothermal exploitation procedure, which begins with a Preliminary Survey conducted by government and private agencies. This survey is usually run by high-ranking officials such as Ministers, Governors, and/or Regents/Mayors. After the successful auction, the Investment Coordinating Board (BKPM) will issue a Geothermal License (IPB) on behalf of the Minister of Energy and Mineral Resources (ESDM). Next, the Exploration phase will begin, followed by a *Feasibility Study (*FS). If the results of the Feasibility Study show economic feasibility, then the Electricity Supply Business License (IUPTL) will be issued, and the electricity will be purchased by PLN after there is an agreement on the Electricity Sale and Purchase Agreement (PJBL). Finally, the Exploitation and Utilization phase will be completed.

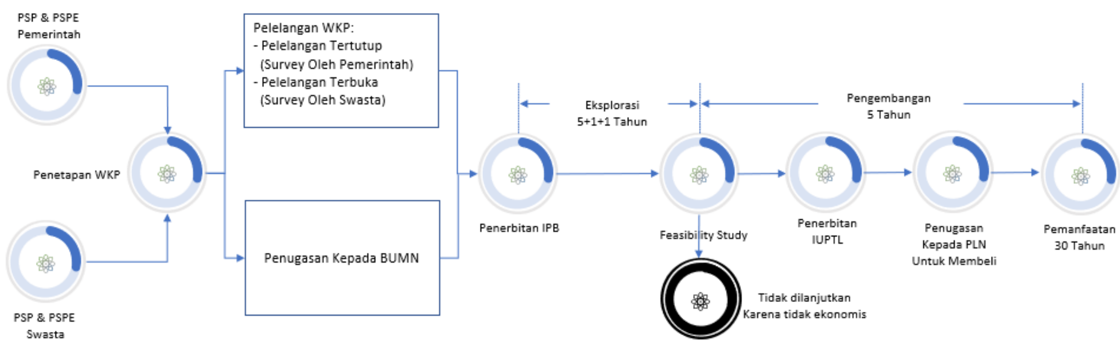

Figure 6 Process of Geothermal Power Plant Operation in Indonesia (Direktorat Jenderal EBTKE, 2021)

Geothermal Potential

In accordance with the National Standard for the Classification of Geothermal Energy Potential in Indonesia, as outlined with SNI No. 13 - 5012 - 1998, geothermal energy potential in Indonesia is categorized into five different classes. The classes are Speculative Resources, Hypothetical Resources, Possible Reserves, Probable Reserves, and Proven Reserves (Badan Standardisasi Nasional, 1998).

Table 1 Geothermal Resources and Reserves in Indonesia in 2022 (Kementerian Energi dan Sumber Daya Mineral, 2023)

No	Location	Resources		Reserve			Total
		Speculative	Hypothesis	Possible	Probable	Proven	
1	Sumatera	2,188	1,567	3,514	867	1,169	9,305
2	Jawa	1,164	1,270	3,121	363	1,855	7,773
3	Bali	70	21	104	110	30	335
4	Nusa Tenggara	215	146	731	138	33.5	1,264
5	Kalimantan	151	18	6	0	0	175
6	Sulawesi	1,352	342	996	180	120	2,990
7	Maluku	560	80	496	6	2	1,144
8	Papua	75	0	0	0	0	75
Total		5,981	5,775	3,444	8,968	1,664	3,210

Geothermal Power Plants Construction Cost Structure

The costs associated with the construction of a power plant can be classified into four main components: Component A, which relates to the cost of return on investment; Component B, which includes fixed operational and maintenance costs; Component C, which relates to fuel costs; and Component D, which includes variable operational and maintenance costs (Direktorat Jenderal EBTKE, 2021).

Component A depends on the initial capital investment of the plant and its rate of return. This cost component consists of depreciation expense, interest expense and/or pre-tax income. Component B consists of costs related to employee salaries, maintenance and repair services, insurance, research, consulting services, PNBP, and production bonuses. Component C consists of the cost of fuel, which is determined by the factor of power generation capacity as well as whether there is a purchase of steam. Geothermal power plants do not require fuel for their operation (Gonzalez-García et al., 2023). The D component consists of incentives, water use, chemicals, as well as overhaul costs .

Engineering Economics

The use of economic analysis is an important component in the decision-making process (Ahmed Khan, 2014). The study of engineering economics consists of several components, including problem identification, goal definition, cash flow estimation, financial analysis, and decision making. Adopting a method procedure is the optimal approach to determine the most suitable solution to a given problem. There are at least 7 (seven) steps in engineering economics (Blank & Tarquin, 2012), namely (1) the process of identifying and defining the problem, (2) the process of formulating alternative solutions to a problem, (3) providing realistic cash flow projections, (4) determining economic assessment criteria to facilitate decision making, (5) assessing each available option by considering non-financial factors, and using sensitivity analysis if necessary, (6) the optimal choice is determined by evaluating the results of the previous analysis phase, and (7) executing the proposed resolution and monitoring the results.

The cash inflows during the project operation period mainly come from the revenue generated, while the cash outflows are related to operation and maintenance (O&M) costs and tax costs [15]. Costs associated with issuing multiple securities, agency costs associated with different securities, and costs associated with unfavourable selection [16]. Weighted Average Cost of Capital (WACC) is a suitable metric to determine the overall cost of financing. It is important to note that the equity component of WACC can be calculated using the Capital Asset Pricing Model (CAPM), which takes into account a country's sovereign risk (represented by the risk-free interest rate or government bond yield, before and after taxes), market volatility, and market risk premium [17]. It is crucial for decision-makers to consider the potential tax risks associated with investments. This includes the recognition that tax policies that are currently favourable to investors may undergo modifications in the future, thus making tax protection less effective than previously anticipated [18]. Therefore, it can be concluded that factors outside financial considerations also have an impact on the composition of the company's capital structure. The formula to calculate WACC is as follows:

$$WACC = \left(\frac{E}{V} \, x \, Re\right) + \left(\frac{D}{V} \, x \, Rd \, x \, (1 - Tc)\right)$$

where:

D = Assessment of the company's outstanding debt in the market.

E = Valuation of the company's outstanding equity in the market

Tc = corporate tax rate

Re = Cost of equity

Rd = Cost of debt
V = amount between debt and equity (D+E)

The time value of money is a financial concept concerned with fluctuations in the value of a currency over time (Newnan et al., 2004). NPV is the result of calculations used to determine the present value of future payment and expenditure flows (Kamel et al., 2023). To calculate NPV, it is necessary to discount future cash flows in addition to investment costs, as shown in Equation:

$$NPV = -CI + \sum_{t=1}^{n} \frac{CF}{(1+i)^t}$$

where:
CI = capital investment
CF = cash flow
t = period
n = length of project
i = *discount rate*

The table below provides an explanation for determining investment feasibility based on NPV value.

Table 2 Investment Feasibility Based on NPV

NPV calculation	**Description**	**Decision**
NPV > 0	Investments have the potential to provide favorable returns for the company	feasible investment
NPV < 0	Investments made by the company can result in financial losses for the company.	investment is not feasible
NPV = 0	The investment made has a neutral impact on the company	Evaluate the potential impact on the company resulting from accepting or rejecting the proposed initiative

DCF analysis is typically used to estimate the potential for discounted cash flows over the life of a project to derive present value (Kamel et al., 2023). The notion that all investments are non-refundable is a fundamental weakness of most *discounted cash flow* (DCF) techniques. The project manager has the authority to influence the outcome of the project and may choose to terminate the project if the results are not satisfactory. Instead, they have the option to extend the project if the results exceed expectations. Conventional NPV methods do not place a high value on managerial flexibility. To determine the rate of return on investment, it is necessary to transform the various results from these investments into cash inflows and cash outflows. Next, the cash flow will be analyzed to determine the unknown value of the internal rate of return (IRR). IRR discounts all refunds in addition, resulting in NPV = zero over the life of the investment (Colantoni et al., 2021)

2. Materials and Methods

PT XYZ is a geothermal energy company operating in the XYZ Geothermal Working Area (WKP). WKP XYZ has a total geothermal reserve of 464 MW with details of Possible Reserve 224 MW, Proven Reserve 240 MW and has been operating at 55 MW. Therefore, in this study, experiments were carried out to maximize the utilization of the remaining geothermal reserves into geothermal power plants. The company was originally established as a collaboration between PT Pertamina (Persero) and PT Perusahaan Listrik Negara (Persero) to carry out integrated activities covering the entire geothermal energy production process, from the upstream side (steam field) to downstream (power plant). To obtain funding, the feasibility of the project must be evaluated through a feasibility study, which involves assessing the economic feasibility of the project and conducting a *Front End Engineering Design* (FEED) to determine technical feasibility. After determination of eligibility for development, the maintainer proceeds to seek funding. PT XYZ entered into a partnership with ADB (Asian Development Bank) on August 8, 2020, to obtain a credit facility under the *Ordinary Capital Resources* and *Clean Technology Fund* (The World Bank, 2019).

Cash flow projections are made for the next 30 years. This is based on the period of exploitation and the term of the electricity purchase agreement contract with PLN. In cash flow projections, there are several assumptions used, namely inflation which is calculated to project the magnitude of cost increases in future years. The cash flow that occurs during the construction phase is cash outflow, which is the initial investment in the project (Yang et al., 2023).

Cash flow in the *base scenario* (first scenario) uses PLTP investment guideline parameters (Direktorat Jenderal EBTKE, 2021) without taking into account the uncertainty of sales volume and operation and maintenance (O&M) costs. Figure 7 below shows cash flow in Unit-2 starting operations in 2024 without adding Unit-3 and Unit-4

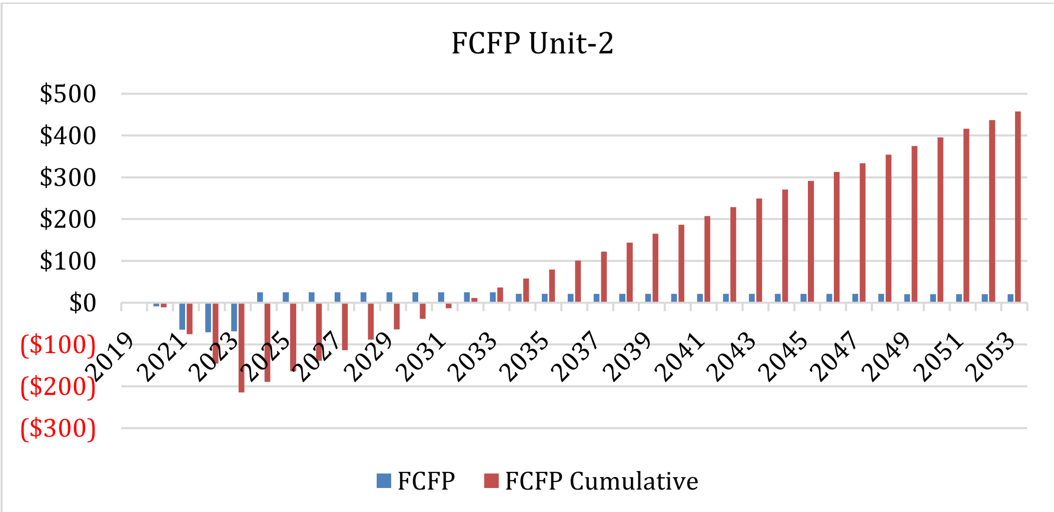

Figure 7 Free Cash Flow of Unit 2 Power Plant

Figure 8 shows cash flow in Unit-3 starting operations in 2029 without adding Unit-2 and Unit-4.

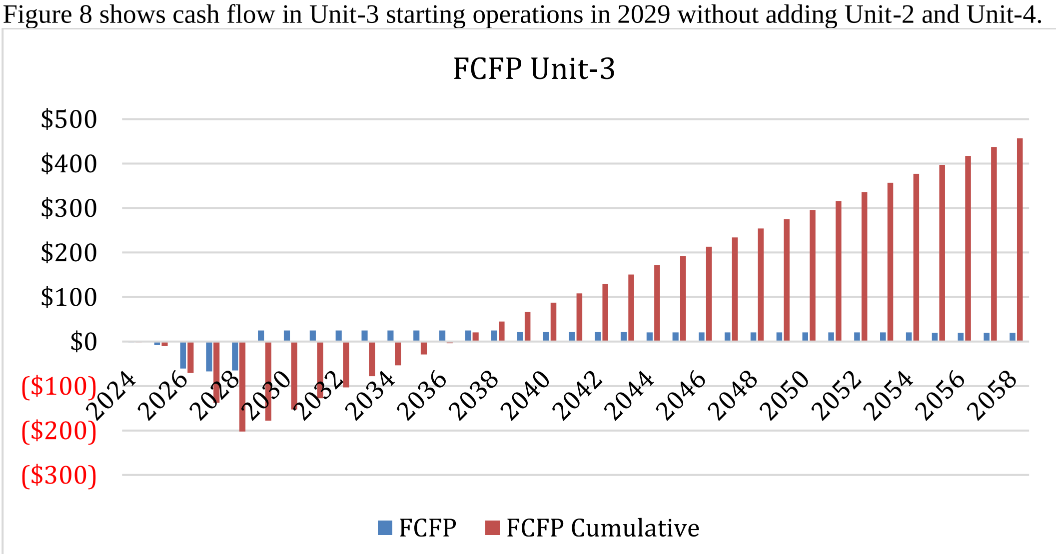

Figure 8 Free Cash Flow of Unit 3 Power Plant

Figure 9 shows cash flow in Unit-4 starting operations in 2034 without adding Unit-2 and Unit-3.

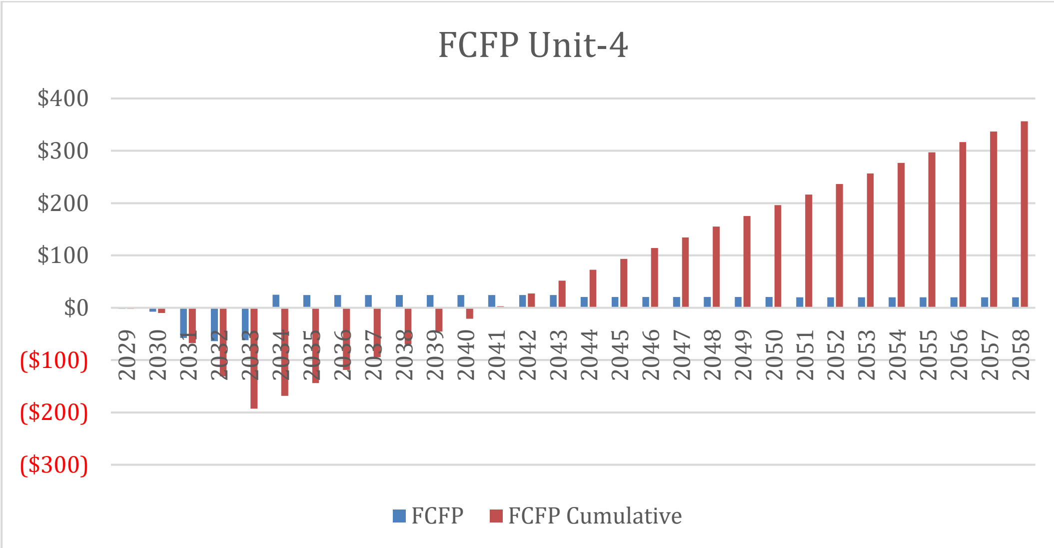

Figure 9 Free Cash Flow of Unit 4 Power Plant

The next cash flow if the geothermal development company decides to build a unit 4 plant in 2029, combined into the total cash flow of unit 2-3-4 plants, it will only get accumulated positive cash flow in 2037 as shown in the figure below.

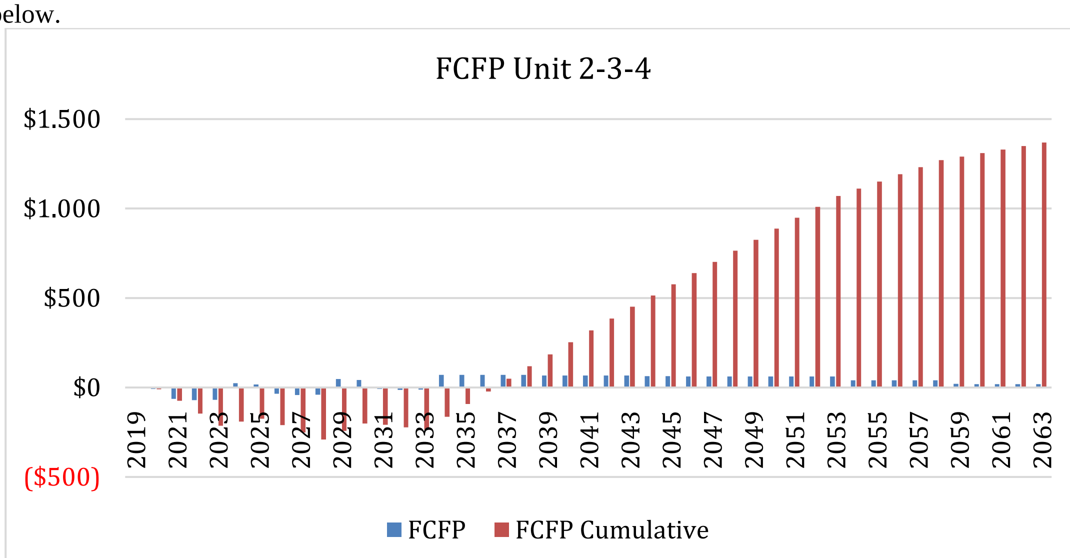

Figure 10 Free Cash Flow of Unit 2-3-4 Power Plant

Monte Carlo simulation is a quantitative risk assessment methodology that can be used by various organizations in their risk management procedures, especially in the risk analysis and/or risk evaluation stages involving stochastic variables. The use of risk analysis and evaluation techniques involving stochastic variables, such as market risk, credit risk, and operational risk events, is widely used in the banking and oil and gas sectors (Guedes & Santos, 2016). Monte Carlo simulation methodology involves mathematical models in multiple simulations using computer programs (Nur et al., 2023). This study uses the Palisade Decision Tools @Risk program for the implementation of Monte Carlo simulation in simulating project investment risk analysis.

Inputs have been classified into two categories: 'known' variables and 'uncertain' variables. The variables considered are predetermined values, which include power generation capacity, capacity factor, corporate tax, interest rate, and discount rate. Uncertain variables include risk variables associated with resource drilling/exploration (such as number of wells and cost per well), as well as the base price of electricity tariffs. The accuracy of risk analysis using Monte Carlo simulations depends largely on the use of precise distribution functions to represent uncertainty and variability, as shown in the table below.

Table 3 Probability Distribution Functions

Distribution Function	Criteria	Type of Use
Discrete	A value that is discrete and comes with an assigned probability.	For variables that only contain discrete values
Uniform	Minimum and maximum potential values.	where the mode does not exist and/or the shape of the distribution is uncertain or debatable, with respect to the variables in question.
Triangle	Minimum possible value, most likely value, and maximum possible value.	It is used in situations where the central tendency is obvious, but the slope of the distribution is unnoticeable.
Normal Continuous,	Mean, Standard deviation	is used to denote a value that indicates a balanced distribution. There are various empirical bases for establishing the parameters associated with this concept.
Log-normal	Mean, Standarddeviation dari variabel naturallogarithm	is used to denote a value that indicates a lack of symmetry, and there are various empirical methods to estimate the associated parameters
PERT or Beta PERT	Minimum possible value, most likely value, and maximum possible value	It is used in situations where the most likely value is obvious, and the distribution shows a significant degree of asymmetry.
Binomial	Binary systems are characterised by two distinct values, namely zero and one, and the possible value is one.	is used to indicate the likelihood of a potential hazard occurring, regardless of the outcome.
Cumulative	Generates a replica of an existing distribution by entering its lower and upper bounds, along with a set of discrete value/probability pairs.	It can be used in conjunction with historical data or in cases where the results of probabilistic analyses serve as input for subsequent analyses.

3. Results and Discussions

Cash flow projections will use Monte Carlo simulation analysis, which involves obtaining the *mean* or average of data from 1,000 iterations of random numbers. These simulations have been run to produce significant amounts of data, which are considered reliable representations of results close to the normal distribution.

In this study, the feasibility analysis of investment in the geothermal power plants capacity development project of PT. "XYZ", using project feasibility analysis using Monte Carlo simulation. Where takes into account the uncertainty variable by giving the probability risk distribution function in Monte Carlo simulation, with the value of the uncertainty variable as follows:

Table 4 Monte Carlo Simulation Uncertainty Variable Values

Variabel	Value	Probability Distribution Function
Inflation	4,16%	Distribusi Triangle
Capacity Factor	90,00%	Distribusi Normal
Period of construction	5 Years	Distribusi Triangle
Financing Structure	70 % Debt 30 % Equity	Distribusi Normal

Interest Rate	10,47%	Distribusi Triangle
Corporate Tax	34%	Distribusi Triangle
WACC	9,06%	Distribusi Triangle

This study uses Monte Carlo Simulation with 2 (two) investment scenarios, namely:

- Investment Scenario First, where the development of PLTP Unit 2 capacity of 1x55 MW was built first in 2019, after the generation of unit 2 *commercial date* in 2024, continued with the development of unit 3 generating capacity of 1x55 MW in 2024 until the *commercial date* in 2029, and continued with the development of unit 4 development capacity of 1x55 MW in 2029 until the *commercial date* year 2034.

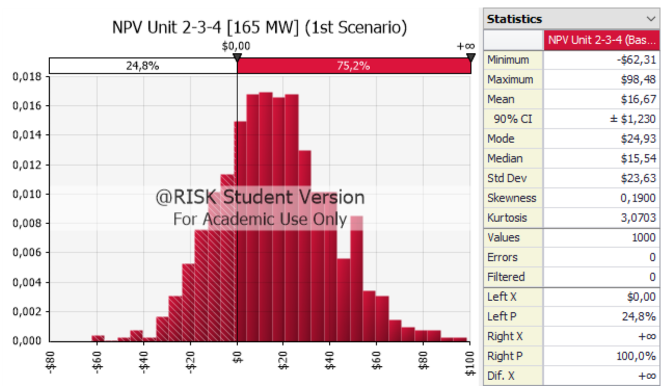

Figure 11 NPV Value Simulation with First Ivestment Scenario

Figure 11 is the result of a Monte Carlo simulation with the First Investment Scenario showing that the average NPV value is $16.67 million and the probability of NPV value is ≥ 0 or positive at 75.2%. Figure 12 is a tornado diagram showing the sensitivity of variables to NPV values. Variable *capacity factor* is the variable that most sensitively affects changes in NPV value.

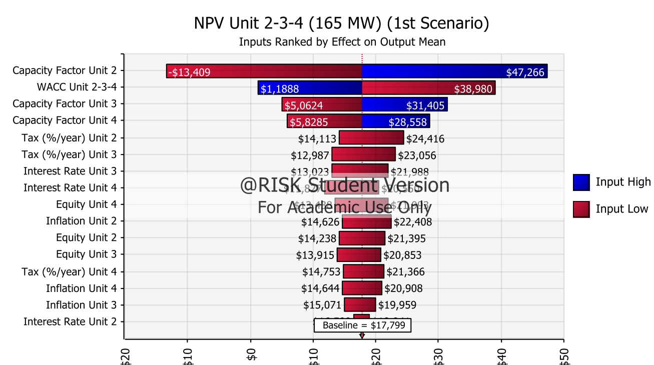

Figure 12 Sensitivity of Uncertainty Variable to NPV in First Investment Scenario

- Investment Scenario Second, the development of PLTP Unit 2 capacity of 1x55 MW was built in 2019 until the commercial date stage in 2024, then in 2024 continued with the development of unit 3 generating capacity of 2x55 MW until *the commercial date* in 2029.

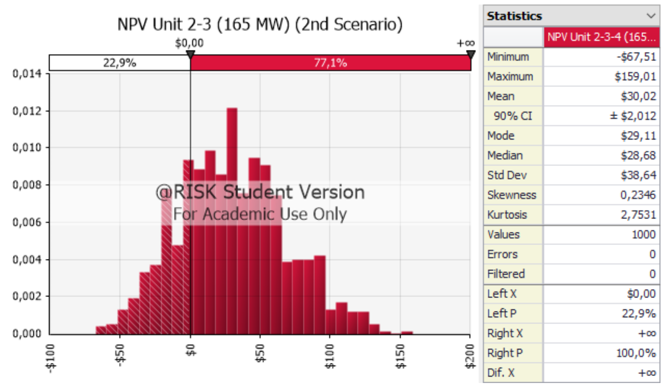

Figure 63 NPV Value Simulation with Second Investment Scenario

Figure 13 is the result of a Monte Carlo simulation with the Second Investment Scenario showing that the average NPV value is $30.02 million and the probability of NPV value is ≥ 0 or positive of 77.11%. Figure 14 is a tornado diagram showing the sensitivity of variables to NPV values. Variable *capacity factor* is the variable that most sensitively affects changes in NPV value.

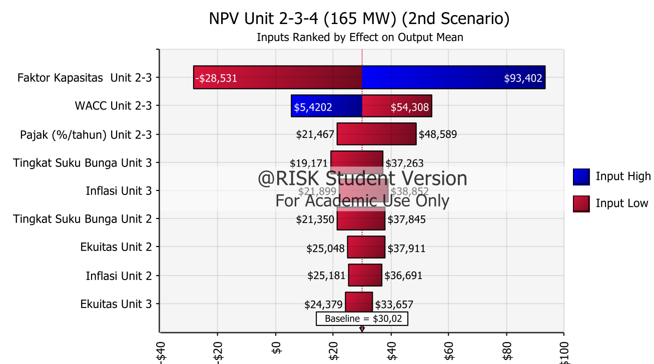

Figure 14 Sensitivity of Uncertainty Variable to NPV in the Second Investment Scenario

For capacity development, PLTP XYZ with the second investment scenario provides better return on investment than the first investment scenario. This is because the greater the generating capacity and the smaller the "*lead time*" of a project will provide large and earlier revenues for the company.

4. Conclusion

When evaluating investment in the development of "XYZ" PLTP plant capacity, there are several factors that influence decision making, so as to reduce investment risk, namely uncertainty variables such as generation capacity, WACC, inflation, and implementation period. The probability value of NPV describes the distribution of possible NPV to be obtained, so it can be used for analysis of the decision-making process to invest even though the resulting NPV is positive.

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