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Techno-Economic and Social Analysis of Geothermal Development in Indonesia: A Case Study Approach

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Abstract— Indirect utilization of Geothermal resources in Indonesia is still very low compared to the existing potential, which is only around 2.36 GW (10.24%). In this research, the author conducted research using the Techno-Economic Analysis Method, which consists of several financial analysis tools, such as Net Present Value (NPV), Internal Rate of Return (IRR), and Discounted Payback Period (DPP), to determine the economic feasibility of geothermal development in the area under study. The author also looks at social aspects expected to provide an overview of the benefits for local communities around geothermal development projects. This research shows that if the developer only develops 55 MW, the project is considered unfeasible because the NPV shows negative results. However, if 110 MW is developed, it is feasible because the project provides positive results of USD 6,610,000 with a payback period of 25 years from the Commercial Operation Date (COD) and an IRR of 10.52%. From a social perspective, the positive benefit that will be directly received by the Government/community of producing regions is a production bonus with an average per year of USD 381,897 or around IDR 5.73 billion, assuming that 110 MW is developed.

Keywords – NPV, IRR, DPP, COD

I. INTRODUCTION

Energy utilization is still dominated by non-renewable energy, both on a national and global scale, which is still at ±80%. To begin transforming global energy production and infrastructure, the international community ratified the Paris Agreement to limit global warming to 1.5◦ Celsius, compared to pre-industrial levels [1]. This is a challenge for the energy transition towards a low-carbon energy system. Therefore, renewable energy development is a global trend that responds to the new paradigm of sustainable energy development.

Renewable energy is increasing yearly as more countries and organizations begin to recognize the importance of overcoming the negative impacts of greenhouse gases. In recent years, solar, wind, and geothermal energy have expanded worldwide as more and more countries and organizations commit to low-carbon targets to lower emissions [2]. Geothermal energy is one of the renewable energies that the Indonesian Government continues to encourage to develop. This is supported by the potential of Indonesia, one of the countries with large geothermal potential. If we look at the geothermal potential in Indonesia, which is 23 GW, the greatest potential is in West Java Province at 4.66 GW, North Sumatra at 2.03 GW and Lampung at 1.76 GW (see Figure 1). The lowest potential is in the Special Region of Yogyakarta and East Kalimantan Provinces, which are only 0.01 GW and 0.02 GW, respectively.

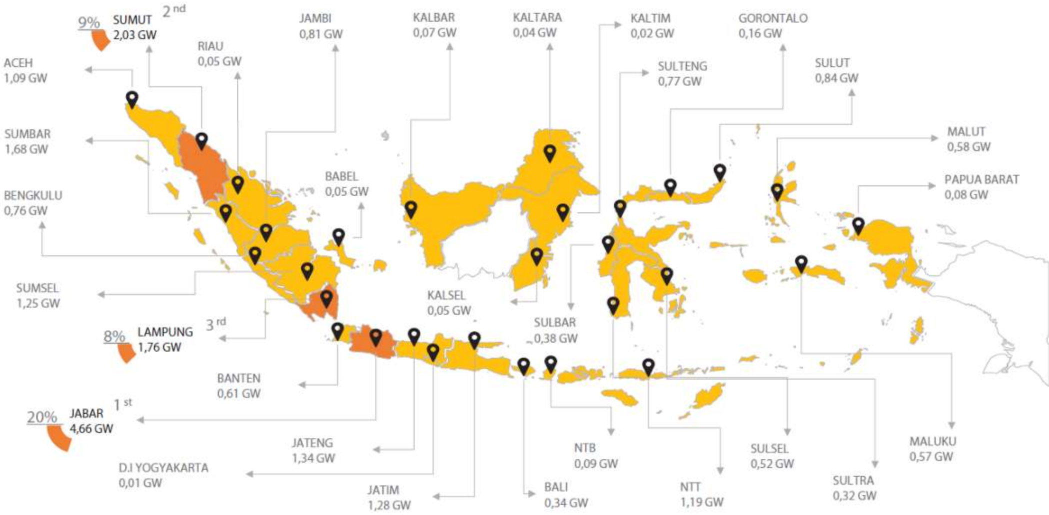

Figure 1. Distribution of geothermal potential in Indonesia (GW) [3]

This potential has also been exploited in several provinces to be used as a power plant, such as those installed in North Sumatra at 0.50 GW, West Sumatra at 0.09 GW, South Sumatra at 0.16 GW, Lampung at 0.22 GW, West Java at 1.19 GW, Central Java 0.06 GW, North Sulawesi 0.12 GW, and East Nusa Tenggara 0.02 GW (See Figure 2). However, this shows that the utilization of geothermal potential for electricity generation is only around 2.36 GW or 10.24% compared to the existing potential. On the other hand, some targets must be achieved in supporting the national energy mix as stated in Presidential Regulation no. 22 of 2017 concerning the General National Energy Plan (RUEN) in 2025 the amount that must be installed is 7.24 GW and in 2050 it is 17.55 GW.

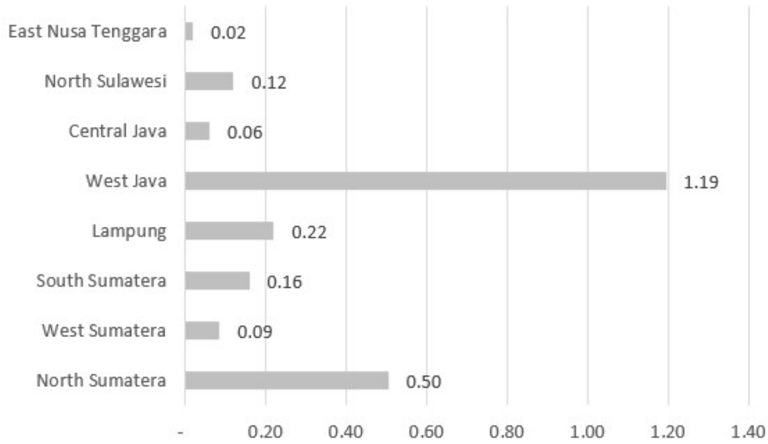

Figure 2. Installed capacity of geothermal power plant per province (GW) [4]

Utilization is still low and far from the RUEN target because there are still several fundamental challenges in geothermal development [5]. The exploration and development stage of geothermal energy resources has quite large financial risks because, at the drilling stage, there is often great uncertainty in predicting resource potential as well as challenges in optimizing well placement [6]. Apart from that, social challenges are also obstacles in developing new geothermal areas, which are often ignored. In fact, ensuring social acceptance of projects is important for investors and policymakers [7]. Therefore, this research was conducted to provide an overview of the potential of geothermal resources in one of the geothermal areas in Indonesia, the technology that is suitable for use in this geothermal area and also fulfills its economic feasibility. As well as the social benefits that arise from geothermal development, it is hoped that the results can be considered by developers and the surrounding community.

II. LITERATURE REVIEW & METHODOLOGY

2.1. Energy & Electricity Regulation in Indonesia

Every development program must always have a basis for it, whether in the form of laws, government/presidential regulations, or ministerial regulations. Law no. 30 of 2007 concerning energy is also a special basis for forming the National Energy Council (DEN), which is tasked with designing and formulating national energy policies to be determined by the Government with the approval of the House of People's Representatives (DPR). Apart from that, regarding more detailed policies regarding the primary energy mix, refer to Government Regulation (PP) no. 79 of 2014 concerning National Energy Policy (KEN), where in 2025, the role of Renewable Energy will be at least 23% and in 2050 at least 31% as long as the economy is met. However, currently the achievement is only at the level of 12.8%. Furthermore, it is detailed again in Presidential Regulation no. 22 of 2017 concerning the General National Energy Plan (RUEN), namely that to achieve the Renewable Energy mix target in KEN, the capacity to provide Renewable Energy power plants in 2025 must be around 45.2 GW and in 2050 around 167.7 GW. The legal basis for geothermal development in Indonesia was previously stated in Law no. 27 of 2003 concerning Geothermal Energy, which states that geothermal energy is a mining or mining activity so that geothermal potential in conservation forest areas cannot be utilized optimally and it is also considered that geothermal utilization has not been regulated comprehensively so it has been replaced with Law no. 21 of 2014 concerning geothermal energy.

In 2022, the Government will again issue Presidential Regulation No. 112 of 2022 concerning the Acceleration of Renewable Energy Development for the Supply of Electric Power, in which there are also guidelines regarding tariffs for purchasing electricity from renewable energy, one of which is related to geothermal power at each location and the amount it produces (see Table 1). This is done to ensure a high level of investment security and also to accelerate the achievement of the renewable energy mix target in the National Energy Mix by the KEN, as well as to reduce greenhouse gas emissions.

Table 1. Purchase price of electricity from geothermal power plant [8]

No.	Capacity	Highest Benchmark Price (cent USD/kWh) Years 1 - 10	Years 11 - 30	Figures are based on location factors (F)
Electric Power Purchase Prices				
1.	0 - 10 MW	(9,76 x F)*	8,30	Jawa, Madura, Bali = 1,00
				- small island = 1,10
2.	> 10 MW - 50 MW	(9,41 x F)*	8,00	Sumatera = 1,10
				- Riau islands = 1,20
3.	>50 MW - 100 MW	(8,64 x F)*	7,35	- Mentawai = 1,20
				- Bangka Belitung = 1,10
				- small island = 1,15
4.	> 100MW	(7,65 x F)*	6,50	Kalimantan = 1,10
				- small island = 1,15
Geothermal Steam Power Purchase Price Equivalent to Electricity				Sulawesi = 1,10
				- small island = 1,15
1.	0 - 10 MW	(6,60 x F)*	5,60	Nusa Tenggara = 1,20
				- small island = 1,25
2.	> 10 MW - 50 MW	(6,25 x F)*	5,31	North Maluku = 1,25
				- small island = 1,30
3.	>50 MW - 100 MW	(5,48 x F)*	4,65	Maluku = 1,25
				- small island = 1,30
				West Papua = 1,50
4.	> 100MW	(4,48 x F)*	3,81	Papua = 1,50

Note: * Note: *The highest benchmark price is the price after being multiplied by the F factor

2.2. Techno-Economic and Social Analysis

Techno-Economic Analysis is a method for evaluating the economic performance of a technology. This method assesses the overall value of a technology, allowing analysts to objectively weigh benefits versus costs [9]. Then, as in [10] that added one aspect of designing a new system is to look at the economic results. In principle, qualitatively a design must be calculated in terms of the price to be invested. The amount of investment required in a design will influence the company in making decisions. There are several types of strategies for analyzing economics when making investment estimates, namely payback period (PP), internal rate of return (IRR), and net present value (NPV).

NPV is the amount of current cash flow compared to the amount of future prices. NPV is used to determine the financial estimate of the return obtained, whether it will exceed or be less than the investment. This indicates whether a project is feasible or not. According to [11], the equation used to calculate NPV can be seen in the following equation:

$$\text{NPV} = \sum_{t=0}^{N} \frac{Revenue_t - Cos\ t}{(1+d)^t} \qquad (1)$$

Where Revenue is an income in year t, Cost is a cost in year t, t is the period (year), d is the discount rate, and N is the number of years from the start of the system operation.

IRR is a ratio or comparison used to calculate the rate of return on an investment. Therefore, the higher the IRR value, the better the investment. Furthermore, if the IRR value is lower, then the investment needs to be considered again. IRR is also the discount rate that makes the NPV equal to zero (the present value of the cash inflow is equal to the initial investment) [12]. The equation is as follows:

$$\text{IRR: NPV} = \sum_{t=0}^{N} \frac{Revenue_t - Co\ t}{(1+d)^t} = 0 \qquad (2)$$

Where Revenue is an income in year t, Cost is a cost in year t, t is the period (year), d is the discount rate, and N is the number of years from the start of the system operation.

The DPP means the time required for the total income to reach the total investment amount of the investment project after the investment project is put into operation. Currently, the DPP is the commonly used method for the financial assessment of various energy investments. [13]. Usually, DPP is calculated using the following equation:

$$\sum_{1}^{DPP} \frac{CF_n}{(1+\text{r})^n} = 0 \qquad (3)$$

Where CF_n is the cash flow in the year, r is the discount rate, and n is the number of years from the start of the system operation.

Furthermore, to support the previous method, the author includes social aspects to convince the surrounding community that the geothermal development project will directly impact the surrounding area.

2.3. Methodology

This research is a quantitative literature study that goes through the stages of collecting data and then data analysis. Meanwhile, the research scope is related to geothermal development in Indonesia, especially one geothermal area that has good potential based on data from the Ministry of Energy and Mineral Resources. The types of data taken are primary data and secondary data. Table 2 explains the types and sources of research data.

Table 2. Types and sources of research data

Type	Data	Data Source
Secondary data	- Geology	Geothermal developer
	- Geochemistry	Geothermal developer
	- Geophysics	Geothermal developer
Primary data	- Other data for calculating economic feasibility	Vendor, Geothermal developer, & Journal

The analytical method used is techno-economic and social analysis, which aims to obtain an overview of the potential of geothermal resources in one of the geothermal areas in Indonesia and the technology that is economically feasible to develop, as well as the social benefits that arise from geothermal development in an area. There are several assumptions used in carrying out the analysis, as shown in Table 3.

Table 3. Key Assumption for Modeling

Assumption indicators		Remarks
Generation Plan		
Installed Capacity	Sc.1 = 55 MW & Sc.2 = 110 MW	
Capacity Factor	97% (MAX)	[14]
Shutdown Turn Around (SDTA)	every 4 years	*Geothermal developer*
	15 days/SDTA	*Geothermal developer*
	Cost: USD 2.1 Million/SDTA	Historical Data in Existing Plant
Electrical Price	Year 1-10 = 9.50 US¢ /kWh	Presidential Regulation 112 of.
	Year 11-30 = 9.09 US¢ /kWh	2022
Drilling		
Success Rate in Exploration Well	50%	*Geothermal developer*
Success Rate in Production Well	80%	*Geothermal developer*
Success Rate in Makeup Well	80%	*Geothermal developer*
Success Rate in Injection Well	90%	*Geothermal developer*
Decline Rate	4%	*Geothermal developer*
Production Capacity (Average/Well)	6 MW	*Geothermal developer*
Cost Estimation		
CAPEX	Sc.1 (55MW) = USD 332.7 Million	Accumulated costs
	Sc.2 (110MW) = USD 644.4 Million	
OPEX	Sc.1 (55MW) = USD 26.75 Million	Accumulated costs
	Sc.2 (110MW) = USD 50.40 Million	

Assumption indicators		Remarks
	Other Variable	
Tangible Cost	30%	[14]
Depreciation Period	8 years	Minister of Finance Regulation No. 21/ PMK.011/ 2010
Depreciation Rate	25%	Minister of Finance Regulation No. 21/ PMK.011/ 2010
Interest	7%	[15]
Interest During Construction	7%	[15]
Income Tax	25%	Law No. 36/2008
Discount Rate	10%	[15]
Investment Tax Allowance	5%	Minister of Finance Regulation No. 21/ PMK.011/ 2010
Production Bonus	0.5%	Gevernment Regulation No. 28/2016
Debt	70%	[14]
Debt Period	20 years	[14]

III. RESULTS & DISCUSSION

3.1. Technical Assessment

Determining the right technology for the research area requires considering several parameters, including Fluid Type, Enthalpy, Wellhead Pressure, Gas Content, and Temperature (see Table 4). Based on data from the 3G survey, the numerical value of potential reserve electric power is estimated at 495 MW, with the characteristics of the research area being that it has a liquid-dominated fluid type. Apart from that, Enthalpy is in the range of 1100-1500 kj/kg or estimated at 1300 kj/kg, which shows that it has a wet character.

Tabel 4. Geothermal reservoir characteristic parameters

Resevoir Parameter	Range	Remarks
Fluid Type	-	Liquid dominated fluid
Enthalphy	1100-1500 kj/kg (1300 kj/kg)	Wet
Wellhead Pressure	10-12 (10 bara)	Medium
Gas Content	NCG 1.5 – 2.0 %	Low
Temperature	High Temperature (> 225°C)	High

Meanwhile, for Wellhead Pressure it is around 10 bara as estimated by the predicted deliverability curve (see Figure 3). This curve represents the predicted production or deliverability of a well at various flow or pressure levels.

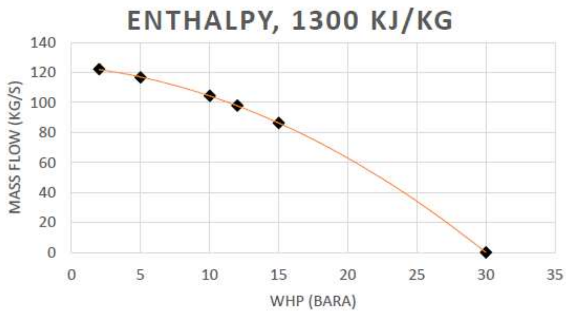

Figure 3. *Predicted deliverability curve*

Geochemical results show that the Non-Condensable Gas (NCG) content in the steam in the research area is estimated to be in the range of 1.5% - 2%. NCG is a type of gas that cannot be converted into a liquid at a certain temperature and pressure. This gas tends to remain in gaseous form even when subjected to pressure or cooled. Meanwhile, other results show that the research area has a temperature categorized as High Temperature, as indicated by previous experts (see Table 5).

Tabel 5. Types of Geothermal Systems: Based on Reservoir Temperature (°C)

Classification	**Muffler & Cataldi (1978)**	**Benderitter & Cormy (1990)**	**Hochstein (1990)**	**Nicholson (1993)**	**Axelsson & Gunnlaugsson (2000)**
Low temperature	< 90	< 100	< 125	≤ 150	≤ 190
Intermediate/moderate temperature	90-150	100-200	125-225	-	-
High temperature	> 150	> 200	> 225	> 150	> 190

Based on the explanation of each of these parameters, the technology estimated to be suitable for use in the research area is the condensing and hybrid steam turbine (see Figure 4). This is because the fluid type is liquid-dominated, Enthalpy is Wet, Wellhead pressure is in the medium range, NCG is estimated to be below 2.5% (low), and the temperature is categorized as high temperature.

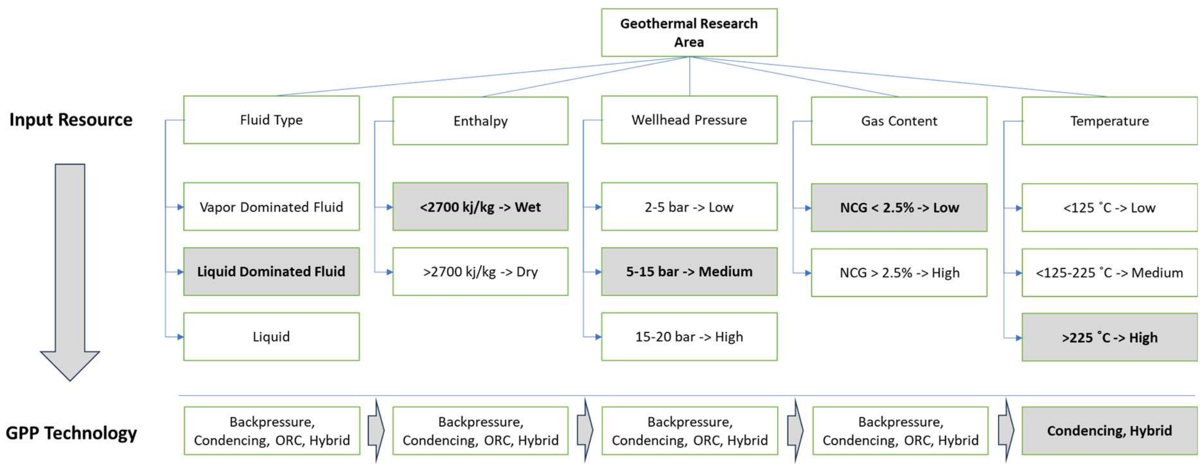

Figure 4. Geothermal power plant technology selection concept

Of the two options that have emerged based on the previous assessment, it is still necessary to determine in more detail which type of design or production process flow will be used. Table 6 provides a comparative overview of single flash condensing, double flash condensing, triple flash condensing, and hybrid (single + ORC). Considering the comparisons that have been made, the suggested power generation technology to be used for the geothermal research area at an early stage is a Double flash condensing steam turbine. This technology takes into consideration generation output and Power Conversion Efficiency.

Table 6. Comparison of geothermal power plant technology

Condencing & Hybrid				
Parameter	**Single Flash Condencing**	**Double Flash Condencing**	**Triple Flash Condencing**	**Single Flash Condencing + ORC**
Separation Pressure	8.5 bar	HP 8.5 / LP 5.6 bara	HP 8.5 / IP 5.6 / LP 5.2 bara	8.6 bara
Turbine Inlet Pressure	7.5 bara	HP 7a.5 / LP 5 bara	HP 7.5 / IP 5 / LP 4.3 bara	7.6 bara
Isentropic efficiency	86%	86%	86%	-
Condencer Pressure	0.075 bara	0.075 bara	0.075 bara	0.075 bara
Brine Reinjection temperature	173 °C	173 °C	173 °C	150 °C
Gross Generation Output/Power Conversion Efficiency	55MW /11.6%	58.75MW /12.3%	58.75MW /12.3%	57.74MW /12.1%
ORC Conversion Efficiency	-	-	-	13%
Net Generation Output	50.88 MW	54.93 MW	54.93 MW	53.30 MW
Remarks	The energy from the Brine separated by the separator is not utilized as additional energy.	More complex than Single flash (adding a Low Pressure system) but still uses a single turbine with High Pressure and Low Pressure inlets.	Only able to operate at higher Wellhead Pressure	Complex system for operating a two-unit turbine, Steam turbine & ORC turbine.

3.2. Economic Assessment

The following mandatory step is to carry out an economic analysis because this is one of the determinants of whether a geothermal development project is economically feasible or not. In this research, there are two scenarios as illustrations for prospective developers regarding economic analysis that are expected to be considered in decision-making. Scenario 1 is for the development of 55 MW, and Scenario 2 is for the development of 110 MW. The calculation results show that scenario 1 is declared economically unfeasible because it has a negative NPV (USD -4,548,000), a payback period that exceeds 30 years from the time the plant starts operating (COD) and an IRR that is only 9.32% (see Table 7).

This indicates that scenario 1 is predicted not to produce adequate profits within the expected time period or will not provide sufficient added value for developers. In this case, further analysis must be conducted to evaluate whether there are ways to reduce project costs or increase income to change the NPV to positive. Meanwhile, scenario 2 is declared economically feasible because it has a positive NPV (USD 6,610,000), a payback period of 25 years from operation (COD), and an IRR value of 10.52%. This indicates that scenario 2 has the potential to be a profitable investment, provide good added value, and generate significant profits for stakeholders, especially developers. Therefore, geothermal development in this research area should not only be 55 MW but must be continued or maximized for its potential.

Table 7. Economic comparison of geothermal projects

Plan for Development	NPV	DPP (Project*)	IRR	Remarks
55MW	Negative (USD -4,548,000)	>36 years	9,32%	If you only develop 55MW, then the project is not economically viable (no added value)
110 MW	Positive (USD 6,610,000)	25 years since COD	10,52%	If 110 MW is developed, the project will be economically feasible, but the payback period will be quite long, around 25 years from COD.

3.3. Social Benefits

Based on Article 53 paragraph 2 of Law no. 2l of 20l4, geothermal development also pays attention to social aspects as indicated by the obligations of geothermal permit holders, geothermal resource concession holders, joint operation contract holders for geothermal resource exploitation, and geothermal resource concession holders must provide production bonus to the Producing Regional Government (district/city whose administrative area includes the relevant work area) for gross income from the sale of geothermal steam and/or electricity from geothermal power plants.

The aim of imposing a production bonus is so that the Government and the people of the Producing Region feel the benefits directly from geothermal business activities in the area where they live. Calculation of production bonuses from geothermal permit holders is carried out annually, with a recording period from January 1 to December 31. Production bonus calculations are carried out quarterly in accordance with the central Government's portion of the deposit period. The amount of the geothermal production bonus is 1% of gross income from the sale of geothermal steam and 0.5% of gross income from the sale of electricity.

Figure 5 provides an overview of production bonuses if the research area is successfully developed, either at 55 MW or 110 MW. In this simulation, several assumptions have also been taken into consideration, such as a capacity factor of 97%, the Shutdown Turn Around (SDTA) program every four years with each duration of 15 days, the selling price of electricity in years 1-10 is 9.50 US¢ /kWh and in years 11-30 it was 9.09 US¢ /kWh. With these assumptions, the estimated average production bonus if the research area is developed into a geothermal power plant with a capacity of 55 MW, the average per year is USD 190,948 or around 2.86 billion rupiah. Meanwhile, if it is developed at 110 MW, the annual average is USD 381,897 or around 5.73 billion rupiah, which is given to the Regional Government/Producing Region.

Therefore, from a social perspective, geothermal development is very necessary because it is predicted that it will have a positive impact on improving the standard of living of the surrounding community, which is expected to foster a sense of ownership by the community in geothermal business activities, thereby creating partnerships between communities and geothermal development business entities.

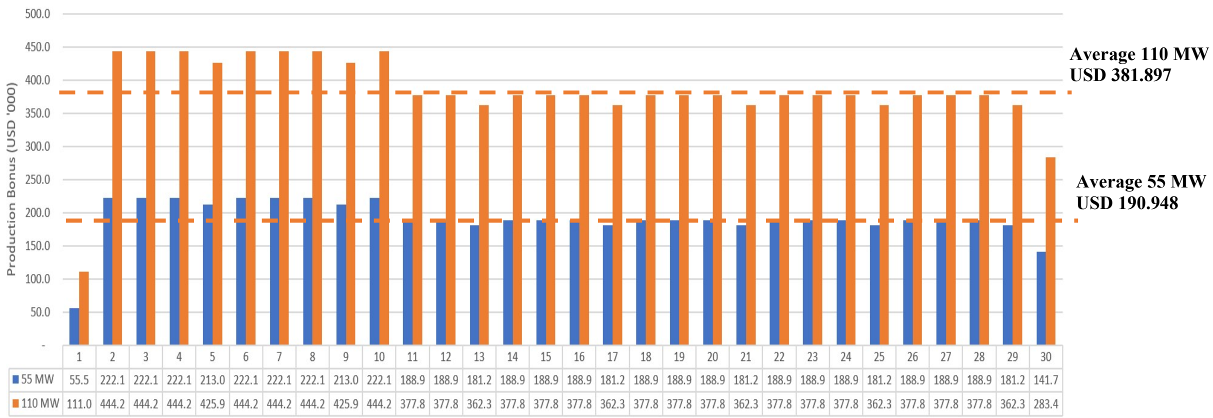

Figure 5. Research area production bonus simulation

IV. CONLUSIONS & RECOMMENDATIONS

Based on the results of the 3G survey, the numerical value of potential electric power reserves is estimated at 495 MW, with the characteristics of the research area being that the fluid type is liquid-dominated fluid. The double flash condensing steam turbine is the technology that suits the reservoir characteristics in the research area. This technology has better generation output and power conversion efficiency than other technologies.

The choice of technology and determination of the amount of generation output was also confirmed again through an economic feasibility study, and the results showed that if the developer only developed 55 MW, then the project was considered unfeasible because the NPV showed negative results. USD -4,548,000 with a payback period exceeding 30 years (exceeding the operating contract) and a payback period of only 9.32%. However, if 110 MW is developed, it is considered feasible because the project provides positive results of USD 6,610,000 with a payback period of 25 years from the Commercial Operation Date (COD) and an IRR of 10.52%.

From a social perspective, the positive benefit received directly by the Government/community of producing regions is a production bonus of an average of USD 381,897 or around IDR 5.73 billion per year, assuming development of 110 MW. Thus, it is hoped that there will be support from the regional Government and local community so that geothermal development in the research area can be developed.

For geothermal development with a capacity of 55MW to be carried out and economically feasible, the government through state-owned banks needs to provide support in the form of policies related to easy access to initial capital assistance with an amount greater than 70% (minimum 73%) and providing interest which was lower during the construction period, namely around 5.5%.

V. ACKNOWLEDGMENT

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