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Preface

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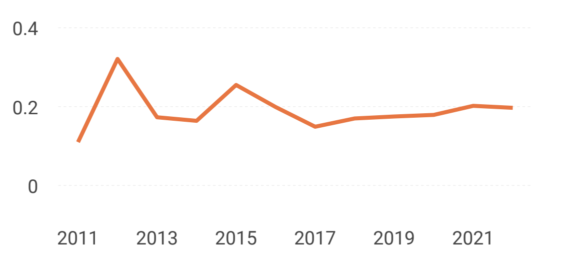

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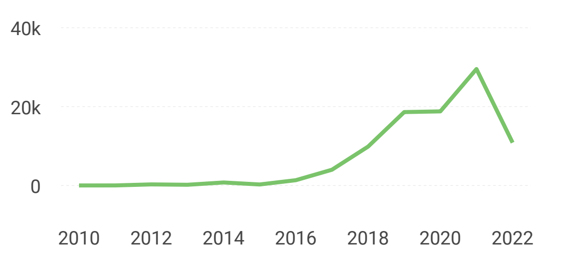

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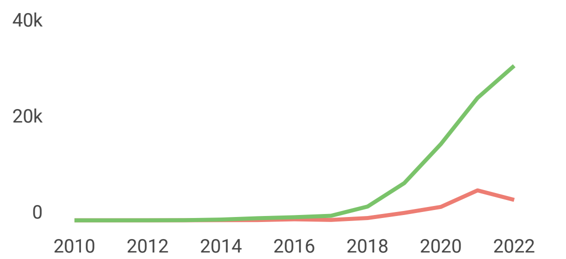

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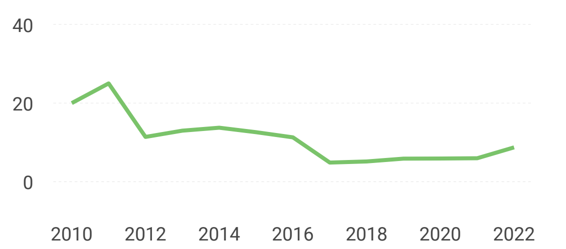

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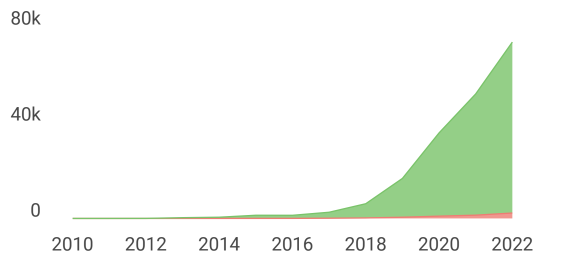

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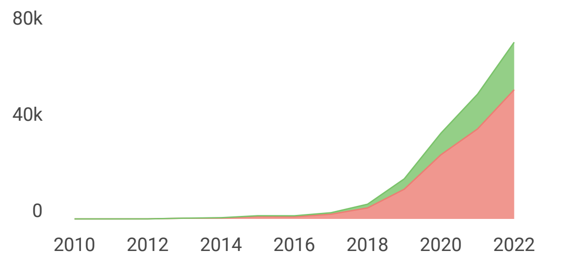

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Preface

The International Conference Research Collaboration 2023 (ICRC) aimed to promote cooperation and collaboration between The University of Kitakyushu and other universities, specifically in Indonesia and Malaysia. This conference marked the third event in a series, with the first held at Airlangga University on March 5, 2018, and the second conducted online on April 25-27, 2021. During the conference, the consortium presented and published the research findings of 147 articles in the areas of environmental management, education, and technology. Moreover, it provided an opportunity for The University of Kitakyushu to engage with community members and academics interested in research within these fields.

ICRC 2023 extended an invitation to scholars and researchers to actively participate and contribute their knowledge and experiences to promote understanding and progress in environmental and sustainability matters within their respective countries. The conference provided a hybrid format, allowing participants to choose between attending in person or joining online. It aimed to foster innovation and exploration within the overarching theme of "Development of Science and Technology for Solving Environmental Problems." The conference focused on several specific subtopics, which include:

1. Water and Wastewater Treatment and Recycling
2. Environmental Education
3. Energy Management and Air Pollution Control
4. Environmental Culture and Conservation
5. Environmental Health and Sciences
6. Waste Management and Treatment
7. Soil and Urban Environment

This year, The University of Kitakyushu, Japan, hosted the third ICRC from June 2-3, 2023, featuring a hybrid conference format, followed by a workshop and training session in Kitakyushu, Japan, from June 4-6, 2023. There were 46 participants joining the on-site conference during the first and second day while the rest, around 265 participants from 78 universities and institutions around the world joining the conference virtually. Almost all the plenary speakers were attending the virtual session on the first day, while half of the invited speakers, which also coming from the Japanese industries and practitioners were joining onsite. Zoom was used as the meeting platform for the online participants.

We have chosen 40 excellent manuscripts to be published in the Earth and Environmental Science IOP Proceedings. We would like to extend our sincere appreciation to the conference chairwoman, esteemed keynote speaker, reviewers, parallel session moderators, and all the participants. We would also like to express our gratitude to IOP for publishing our conference proceedings. It is our hope that readers will find valuable information and knowledge within our proceedings. We apologize for any errors identified during the conference or within the published papers.

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The economic feasibility approach of the development of geothermal power plant 2 x 20 MW

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The economic feasibility approach of the development of geothermal power plant 2 x 20 MW

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Abstract. The development of a geothermal power plant project can be implemented if the project is feasible and can provide benefits from the economic side. In this study, the economic feasibility calculation for the development of a 2 x 20 MW power plant project was carried out based on economic indicators such as Net Present Value (NPV), Internal Rate of Return (IRR) and Pay Out Time (POT). The discounted cash flow method is used in determining the economic feasibility. The calculation results obtained for this power plant development project is not feasible because the NPV is US$ -31,336 million, IRR is 7.11% and POT is 0 year. Due to the uneconomical results obtained, a sensitivity analysis was carried out on the tariff price, drilling costs, and Engineering, Procurement, Construction, and Commissioning (EPCC) costs. With electricity tariffs regulated based on Presidential Regulation Number 112 of 2022, it is found that the resulting taxes in the area are not economical and there is needed for tariff adjustments, namely at a minimum price of 15 cents/kWh and 18 cents/kWh so that the project is economical. However, this price could not be realized because the price far exceeded the highest benchmark price set. Meanwhile, with these uneconomical and unfeasible results, a scenario of a loan was carried out to get better results with an NPV is US$ 528,000, IRR is 10.46% and POT is 28 years. Therefore, with a loan scenario, the project can be obtained as feasible.

1. Introduction

Geothermal is a renewable energy resource that has abundant potential in Indonesia, that is environmentally friendly. Geothermal potential in Indonesia is 24 GW or about 40% of the world's potential [4]. Until now, Indonesia is the second country with the largest geothermal potential in the world after the United States. However, many obstacles related to geothermal development in Indonesia are the cause of the minimum utilization of geothermal energy [1]. Geothermal potential which is spread in various regions in Indonesia provides distinct advantages for the development of electrical energy and has great potential to be utilized and developed into Geothermal Power Plants [8]. Geothermal energy also supports environmental protection because CO2 emissions from geothermal power plants are very low compared to power generation from fossil fuels. One of the factors that influence geothermal development is the economic factor [7]. Geothermal projects can be developed if the field is considered feasible and can provide benefits from an economic standpoint. This study aims to provide an overview of the economic feasibility of a power plant development project with a capacity of 2 X 20 MW.

The stages of geothermal activity consist of several stages, namely:

1. Preliminary Study, which is the stage of collecting and presenting data related to 3G condition information to determine whether or not geothermal resources exist.
2. Exploration is a stage that includes a 3G survey followed by the drilling of exploratory wells aimed at obtaining information on subsurface geological conditions and geothermal reserves.
3. Exploitation is a stage consisting of development infrastructure development activities, drilling of production wells and reinjection wells as well as EPCC.
4. Feasibility Study is a stage that is carried out when an exploration well has produced geothermal and is a stage to obtain detailed information on all aspects related to determining the feasibility of a geothermal business.
5. Production. This stage begins when the EPCC construction work has been completed and has gone through the Commercial Operation Date (COD), which is the time when the geothermal power plant begins to operate commercially to sell electricity to users [2].

In the development of geothermal energy in Indonesia, the price of electricity is very important. Currently, geothermal energy in Indonesia cannot be used as a reliable energy source because it cannot compete with fossil energy which is generally relatively cheap. Therefore, the thing that needs to be considered is the economic price of geothermal projects and also the efficiency of the development costs of geothermal power plant projects [6]. To maximize the utilization of new and renewable energy to accelerate the energy transition, it is necessary to know the price of electricity tariffs from geothermal power plants which are regulated in Presidential Regulation Number 112 of 2022 concerning the Acceleration of Development of Renewable Energy for the Provision of Electricity [7]

2. Methodology

In this study, the calculation is focused on calculating the economic feasibility of a project with a capacity of 2 X 20 MW using available data such as exploration costs, exploitation costs, EPCC costs, production costs, and other economic data. From the available data, it will be processed again to calculate the investment, production, and income parameters, Operating Expenditure (OPEX), and depreciation. Then proceed to calculate the final value, namely the economy by using the discounted cash flow method. The feasibility of a project is assessed based on the parameters NPV, IRR, and POT.

2.1 Discounted cash flow

Discounted cash flow is the method used to find out how much money will be generated in the future by looking at the present value of the investment [8].

$$\text{Discounted Cash Flow} = Net\ Cash\ Flow * \ Rate\ Discounted\ Cash\ Flow \quad (1)$$

2.2 Net present value (NPV)

NPV is the present value of the cash flow of an investment. NPV describes the feasibility of a project. If the NPV value is greater than zero or has a positive value, then it can be said that the project is feasible to develop and generate profits. However, if the NPV is negative, then the project is not feasible to develop because it causes losses [3].

$$\text{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0 \quad (2)$$

2.3 Internal rate of return (IRR)
IRR is the expected rate of return on the project [10]. IRR is the discount rate that gives the project's NPV equal to zero, which can be expressed by:

$$IRR = i_1 + \frac{NPV_1}{NPV_1 - NPV_2}\,(i_2 - i_1) \quad (3)$$

2.4 Pay out time (POT)
POT or payback period is the length of time required to return all the money invested in the project. A development project is feasible to develop if it gives a short POT value [9].

2.5 Sensitivity analysis
Sensitivity analysis is a method used for any variables or parameters that affect economic indicators. Sensitivity analysis in this study is displayed through the formation of a tornado chart.

3. Results and discussion

In carrying out modeling scenarios, a series of data is needed, which will become the basis for calculating the economic feasibility analysis of a geothermal power plant development project with a capacity of 2 X 20 MW in Indonesia, to be precise in the province of North Sulawesi. The stipulation of Presidential Regulation Number 112 of 2022 was carried out with the aim of accelerating the development of renewable energy power plants in order to achieve the target of the renewable energy mix and reduce greenhouse gas emissions. The following table is the price of electricity based on Presidential Regulation Number 112 of 2022.

Table 1. Price of electricity [5]

No	Capacity	Highest Benchmark Price (cent US$/kWh)	
		Years 1 to 10	Years 11 to 30
1.	up to 10 MW	(9.76 x F) *	8.30
2.	>10 MW s.d. 50 MW	(9.41 x F) *	8.00
3.	>50 MW s.d. 100 MW	(8.64 x F) *	7.35
4.	>100 MW	(7.65 x F) *	6.50

Generally, the costs required to build a geothermal power plant include exploration, drilling, EPCC, and operations and maintenance (O&M) costs at the production stage. Before carrying out the operation, it is necessary to do a drilling planning calculation in advance to find the total number of wells to be opened. The wells include exploration, production, injection, and makeup wells. The wells are influenced by parameters such as the success ratio and the target deliverability capacity. In exploration wells, it is known that the success ratio is 58% with a target deliverability capacity of 10 MW/well. For production wells, it is known that the success ratio is 85% with a target deliverability capacity of production wells of 10 MW/well. Therefore, it is planned to drill 14 wells consisting of 2 exploration wells, 4 production wells, 4 injection wells, and 4 make-up wells, with a total of 14 wells. The total investment cost required starting from the exploration stage is US$ 286,073,000 as shown in Table 2.

Table 2. Total investment costs (equity)

Cost Element	Total (US$)
Survey 3G	1,010,000
Infrastructure	19,869,000
General & Administrative	3,475,000
Exploration Drilling	5,090,000
Production Drilling	34,379,000
Injection Drilling	34,897,000
Make Up Well Drilling	49,636,000
Well Testing	865,000
Steam Gathering System	33,591,000
Power Generation Facilities	103,262,000
Total Investment	286,073,000

After the total investment is obtained, it is followed by calculating production and revenue to be able to find out how much the amount of production and revenue is obtained from production each year by including the input data capacity factor of 95% and the selling price of electricity which has been set based on Presidential Regulation Number 112 the Year 2022, as seen on Table 3 below.

Table 3. Cumulative results of production and revenue

Year 1 to 10 (cents/kWh)	Year 11 to 30 (cents/kWh)	Production (MWh)	Revenue (US$)	Operation Days
10.35	8	9,986,400	883,068,000	10,950

In this development power plant project, costs for the OPEX are also required, which in this operational cost consist of O&M steam field and power generation costs of 0.57 cent/kWh and major overhaul costs of USD 2,700,000. So that from the calculation, the overall total OPEX cost is USD 207,890,000. With all the data that has been obtained, calculations are carried out to calculate the economic feasibility of this development project with the final results as shown in Table 4.

Table 4. Economic indicators calculation results (equity)

Parameter	Unit	Value
NPV	US$	- 31,336,000
IRR	%	7.11
POT	Year	0
Project Lifetime	Year	30

Economic analysis on the power plant development project with capacity of 2 X 20 MW, obtained an NPV value of USD - 31,336,000. Apart from looking at the NPV calculation, the feasibilityof a project can also be seen and determined from the IRR value, where from the cash flow calculation, the IRR value is 7.11%. Based on the calculation results of these economic indicators, it can be concluded that the power plant development project with a generating capacity of 2 X 20 MW is considered uneconomical because the NPV value shown is small or negative and the IRR value shows a value that is smaller than the Weighted Average Cost of Capital (WACC) value. which has been determined is 10.36%. Because the final result obtained is a negative NPV value and the IRR value has not reached the target, this development project can be said to be unfit for development because it does not generate profit for the developer until the contract ends. Based on the results obtained from the calculation of these economic indicators, an analysis was carried out using a tornado chart. The analysis using the tornado chart aims to find out which variables are the most sensitive on the economics of a project. The analysis was carried out by comparingseveral parameters, such as tariff prices, drilling costs, power generation facilities, OPEX, steam gathering systems, infrastructure, general and administrative, well testing and surveys using increasingand decreasing variables each by 20% so that to 80% and 120%.

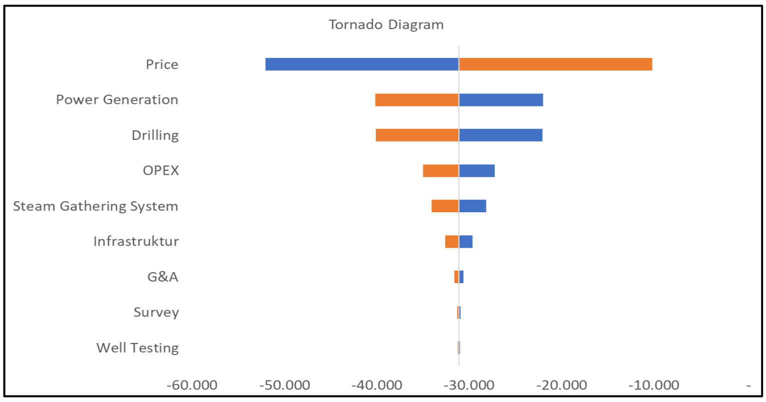

Figure 1. Tornado diagram

Based on Figure 2, it can be seen that the parameters that have the most influence on the development project with a capacity of 2 X 20 MW are tariffs, drilling costs and EPCC. These parameters will then be analyzed for sensitivity by trying to decrease to see and get the minimum value.

- Price Sensitivity Analysis based on Presidential Regulation Number 112 of 2022

In the analysis of tariffs based on the price of Presidential Regulation Number 112 of 2022, the highest benchmark price is obtained for the Sulawesi region starting from the first year to the 10th year of 10.35 cents/kWh and for the 11th year to the 30th year of 8.00 cents/kWh. The tariff sensitivity analysis is calculated in stages to obtain a tariff price that shows the NPV and IRR values that allow the field to beconsidered feasible for development which can be seen in Table 5.

Table 5. Tariff sensitivity results year 1-10

Price (cents/kWh)	IRR (%)	NPV (US$)
9.0	6.09	- 41.465,000
10.0	6.84	- 33,968,000
10.35	7.11	- 31,336,000
11.0	7.61	- 26,470,000
12.0	8.38	- 18,973,000
13.0	9.16	- 11,475,000
14	9.94	- 3,978,000
14.53	10.36	0
15	10.73	3,520,000

Table 6. Tariff sensitivity results year 11-30

Price (cents/kWh)	IRR (%)	NPV (US$)
5.00	5.18	- 41,456,000
6.0	5.93	-38,083,000
7.0	6.56	-34,709,000
8.0	7.11	-31,336,000
9.00	7.59	-27,963,000
10.0	8.03	-24,590,000
11.0	8.43	-21,217,000
12.0	8.79	-17,844,000
13	9.13	- 14,470,000
14	9.45	-11,097,000
15	9.74	-7,724,000
16	10.02	-4,351,000
17	10.29	-978,000
17.29	10.36	0
18	10.54	2,395,000

Based on the sensitivity results in Table 5 and Table 6, the minimum tariff for years 1 to 10 isat a minimum price of 15 cents/kWh. At this price, the NPV calculation results obtained were US$ 3,520,000 and the IRR value was 10.73%. And the minimum tariff price for years 11 to 30 is at a minimum price of 18 cents/kWh with an NPV of US$ 2,395,000 and an IRR value of 10.54%. A positiveNPV value and an IRR value that is above the WACC value indicate that the geothermal power plant development project is feasible to develop. However, these two prices could not be realized because these prices far exceeded the highest benchmark price that had been set.

- Sensitivity analysis of drilling cost

In the cost sensitivity analysis of this drilling cost, the initial cost of drilling cost was marked down, with the initial price of drilling cost consisting of exploration drilling costs of US$ 2,422,000, productiondrilling costs of US$ 7,900,000, reinjection drilling costs of US$ 7,980,000 and the cost of drilling make-up was US$ 7,900,000.

Table 7. Sensitivity results of drilling cost

Percent (%)	Exploration Well (US$)	Production Well (US$)	Injection Well (US$)	Make Up Well (US$)	IRR (%)	NPV (US$)
100	2,422,000	7,900,000	7,980,000	7,900,000	7.11	- 31,336,000
90	4,360,000	7,110,000	7,182,000	7,110,000	7.50	- 26,827,000
80	3,875,000	6,320,000	6,384,000	6,320,000	7.90	- 22,317,000
70	3,391,000	5,530,000	5,586,000	5,530,000	8.34	- 17,807,000
60	2,906,000	4,740,000	4,788,000	4,740,000	8.80	- 13,297,000
50	2,422,000	3,950,000	3,990,000	3,950,000	9.29	- 8,787,000
40	1,938,000	3,160,000	3,192,000	3,160,000	9.82	- 4,727,000
30	1,453,000	2,370,000	2,394,000	2,370,000	10.39	229,000

Based on Table 7, from the results of the sensitivity analysis of drilling costs, costs were reduced to obtain minimum prices for exploration, production, injection and makeup drilling costs of US$ 1,453,000, US$ 2,370,000, US$ 2,394,000 respectively, and US$ 2,370,000. With this minimum price, the NPV and IRR values were US$ 229,000 and 10.39%, respectively.

- Sensitivity analysis of EPCC

In the EPCC cost sensitivity analysis, the initial cost of the power generation facilities and steam gathering system was marked down, with the initial cost of the power generation facilities being US$ 29,725,000 and the cost of the steam gathering system being US$ 91,745,000.

Table 8. Sensitivity results of EPCC

Percent (%)	Exploration Well (US$)	Production Well (US$)	Injection Well (US$)	IRR (%)	NPV (US$)
100	29,725,000	91,745,000	121,470,000	7.11	- 31,336,000
90	26,753,000	82,571,000	109,323,000	7.63	- 25,316,000
80	23,780,000	73,396,000	97,176,000	8.19	- 19,296,000
70	20,808,000	64,222,000	85,029,000	8.80	- 13,816,000
60	17,835,000	55,047,000	72,882,000	9.47	- 7,257,000
50	14,863,000	45,873,000	60,735,000	10.20	- 1,237,000
40	11,890,000	36,698,000	48,588,000	11.00	4,775,000
30	8,918,000	27,524,000	36,441,000	11.89	10,802,000

Based on Table 8, from the results of the EPCC sensitivity analysis, costs were reduced to obtain a minimum price from the initial cost of US$ 121,470,000 to only US$ 48,588,000. This minimum price shows that the NPV and IRR values are US$ 4,775,000 and 11.00%, respectively. Because the results of the economic feasibility calculation show results that not feasible to develop, a scenario with loan is carried out to increase the investment cost of this project. The total cost of investment with borrowing is shown in Table 9.

Table 9. Total investment costs (loan)

Cost Element	Total (US$)
Survey 3G	1,010,000
Infrastructure	19,869,000
General & Administrative	3,475,000
Exploration Drilling	5,090,000
Production Drilling	34,379,000
Injection Drilling	34,897,000
Make Up Well Drilling	49,636,000
Well Testing	865,000
Interest During Construction	4,245,000
Steam Gathering System	33,591,000
Power Generation Facilities	103,262,000
Total Investment	290,318,000

Total loan funds are taken based on the total cost of building the EPCC, which is USD 135,833,000 with an annual interest of 3.125% based on World Bank Data and a loan period of 15 years. With all the data that has been obtained and the additional funds available, calculations are carried out to calculate the economic feasibility of borrowing with the final results as shown in Table 10.

Table 10. Economic indicators calculation results (loan)

Parameter	Unit	Value
NPV	US$	528,000
IRR	%	10.46
POT	Year	28
Project Lifetime	Year	30

Based on Table 10, the NPV value is US$ 528,000 with an IRR of 10.46% and a POT of 28 years. From these results, it can be said that this project is more economical than the scenario without a loan.

- Discussion

The results of an economic analysis with equity in the 'GT' field with a generating capacity of 2X20 MW show that this project is not feasible to develop. Therefore, the next step was using loan scenario. With loan scenario, the NPV value is USD 528,000 and the IRR value is 10.46% with a POT of 28 years. Based on the calculation results of these economic indicators, it can be said that the development of geothermal power plant in the 'GT' field is more economical, because the NPV value shown is positive and the IRR value shows a value greater than the predetermined discount rate, 10.36%.

4. Conclusion

Based on the modeling of economic calculations that have been carried out, the economic parameter NPV is US$ - 31,336,000 with an IRR value of 7.11% and POT is 0 year, so it can be stated that a power plant development project with a capacity of 2 x 20 MW using the discounted cash flow method is not feasible to develop, for not making a profit. The selling price of electricity based on Presidential Regulation Number 112 of 2022 shows that the project is not feasible to develop with the selling price of electricity from the 1st to the 10th year of 10.35 cents/kWh and the 11th to the 10th year 30 of 8.00 cents/kWh, so an analysis of the tariff price was carried out and a selling price was obtained that could be considered feasible to develop, namely from the 1st year to the 10th year of 15 cents/kWh and the 11th to 30th year of 18 cents/kWh. However, the prices could not be realized because these prices far exceeded the highest benchmark price that had been set. With these uneconomical and unfeasible results, a scenario of loan was carried out to get better results with an NPV value of US$ 528,000 with an IRR value of 10.46% and POT is 28 years.

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The economic feasibility approach of the development of geothermal power plant 2 x 20 MW

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The economic feasibility approach of the development of geothermal power plant 2 x 20 MW

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Abstract. The development of a geothermal power plant project can be implemented if the project is feasible and can provide benefits from the economic side. In this study, the economic feasibility calculation for the development of a 2 x 20 MW power plant project was carried out based on economic indicators such as Net Present Value (NPV), Internal Rate of Return (IRR) and Pay Out Time (POT). The discounted cash flow method is used in determining the economic feasibility. The calculation results obtained for this power plant development project is not feasible because the NPV is US$ -31,336 million, IRR is 7.11% and POT is 0 year. Due to the uneconomical results obtained, a sensitivity analysis was carried out on the tariff price, drilling costs, and Engineering, Procurement, Construction, and Commissioning (EPCC) costs. With electricity tariffs regulated based on Presidential Regulation Number 112 of 2022, it is found that the resulting taxes in the area are not economical and there is needed for tariff adjustments, namely at a minimum price of 15 cents/kWh and 18 cents/kWh so that the project is economical. However, this price could not be realized because the price far exceeded the highest benchmark price set. Meanwhile, with these uneconomical and unfeasible results, a scenario of a loan was carried out to get better results with an NPV is US$ 528,000, IRR is 10.46% and POT is 28 years. Therefore, with a loan scenario, the project can be obtained as feasible.

Introduction

Geothermal is a renewable energy resource that has abundant potential in Indonesia, that is environmentally friendly. Geothermal potential in Indonesia is 24 GW or about 40% of the world's potential [4]. Until now, Indonesia is the second country with the largest geothermal potential in the world after the United States. However, many obstacles related to geothermal development in Indonesia are the cause of the minimum utilization of geothermal energy [1]. Geothermal potential which is spread in various regions in Indonesia provides distinct advantages for the development of electrical energy and has great potential to be utilized and developed into Geothermal Power Plants [8]. Geothermal energy also supports environmental protection because CO_2 emissions from geothermal power plants are very low compared to power generation from fossil fuels. One of the factors that influence geothermal development is the economic factor [7]. Geothermal projects can be developed if the field is considered feasible and can provide benefits from an economic standpoint. This

study aims to provide an overview of the economic feasibility of a power plant development project with a capacity of 2 X 20 MW.

The stages of geothermal activity consist of several stages, namely:
1. Preliminary Study, which is the stage of collecting and presenting data related to 3G condition information to determine whether or not geothermal resources exist.
2. Exploration is a stage that includes a 3G survey followed by the drilling of exploratory wells aimed at obtaining information on subsurface geological conditions and geothermal reserves.
3. Exploitation is a stage consisting of development infrastructure development activities, drilling of production wells and reinjection wells as well as EPCC.
4. Feasibility Study is a stage that is carried out when an exploration well has produced geothermal and is a stage to obtain detailed information on all aspects related to determining the feasibility of a geothermal business.
5. Production. This stage begins when the EPCC construction work has been completed and has gone through the Commercial Operation Date (COD), which is the time when the geothermal power plant begins to operate commercially to sell electricity to users [2].

In the development of geothermal energy in Indonesia, the price of electricity is very important. Currently, geothermal energy in Indonesia cannot be used as a reliable energy source because it cannot compete with fossil energy which is generally relatively cheap. Therefore, the thing that needs to be considered is the economic price of geothermal projects and also the efficiency of the development costs of geothermal power plant projects [6]. To maximize the utilization of new and renewable energy to accelerate the energy transition, it necessary to know the price of electricity tariffs from geothermal power plants which are regulated in Presidential Regulation Number 112 of 2022 concerning the Acceleration of Development of Renewable Energy for the Provision of Electricity [7]

2. Methodology

In this study, the calculation is focused on calculating the economic feasibility of a project with a capacity of 2 X 20 MW using available data such as exploration costs, exploitation costs, EPCC costs, production costs, and other economic data. From the available data, it will be processed again to calculate the investment, production, and income parameters, Operating Expenditure (OPEX), and depreciation. Then proceed to calculate the final value, namely the economy by using the discounted cash flow method. The feasibility of a project is assessed based on the parameters NPV, IRR, and POT.

2.1 Discounted cash flow

Discounted cash flow is the method used to find out how much money will be generated in the future by looking at the present value of the investment [8].

$$\text{Discounted Cash Flow} = Net\ Cash\ Flow * Rate\ Discounted\ Cash\ Flow \quad (1)$$

2.2 Net present value (NPV)

NPV is the present value of the cash flow of an investment. NPV describes the feasibility of a project. If the NPV value is greater than zero or has a positive value, then it can be said that the project is feasible to develop and generate profits. However, if the NPV is negative, then the project is not feasible to develop because it causes losses [3].

$$\text{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0 \quad (2)$$

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2.3 Internal rate of return (IRR)

IRR is the expected rate of return on the project [10]. IRR is the discount rate that gives the project's NPV equal to zero, which can be expressed by:

$$IRR = i_1 + \frac{NPV_1}{NPV_1 - NPV_2}(i_2 - i_1) \quad (3)$$

2.4 Pay out time (POT)

POT or payback period is the length of time required to return all the money invested in the project. A development project is feasible to develop if it gives a short POT value [9].

2.5 Sensitivity analysis

Sensitivity analysis is a method used for any variables or parameters that affect economic indicators. Sensitivity analysis in this study is displayed through the formation of a tornado chart.

3. Results and discussion

In carrying out modeling scenarios, a series of data is needed, which will become the basis for calculating the economic feasibility analysis of a geothermal power plant development project with a capacity of 2 X 20 MW in Indonesia, to be precise in the province of North Sulawesi. The stipulation of Presidential Regulation Number 112 of 2022 was carried out with the aim of accelerating the development of renewable energy power plants in order to achieve the target of the renewable energy mix and reduce greenhouse gas emissions. The following table is the price of electricity based on Presidential Regulation Number 112 of 2022.

Table 1. Price of electricity [5]

No	Capacity	Highest Benchmark Price (cent US$/kWh)	
		Years 1 to 10	Years 11 to 30
1.	up to 10 MW	(9.76 x F) *	8.30
2.	>10 MW s.d. 50 MW	(9.41 x F) *	8.00
3.	>50 MW s.d. 100 MW	(8.64 x F) *	7.35
4.	>100 MW	(7.65 x F) *	6.50

Generally, the costs required to build a geothermal power plant include exploration, drilling, EPCC, and operations and maintenance (O&M) costs at the production stage. Before carrying out the operation, it is necessary to do a drilling planning calculation in advance to find the total number of wells to be opened. The wells include exploration, production, injection, and makeup wells. The wells are influenced by parameters such as the success ratio and the target deliverability capacity. In exploration wells, it is known that the success ratio is 58% with a target deliverability capacity of 10 MW/well. For production wells, it is known that the success ratio is 85% with a target deliverability capacity of production wells of 10 MW/well. Therefore, it is planned to drill 14 wells consisting of 2 exploration wells, 4 production wells, 4 injection wells, and 4 make-up wells, with a total of 14 wells. The total investment cost required starting from the exploration stage is US$ 286,073,000 as shown in Table 2.

Table 2. Total investment costs (equity)

Cost Element	Total (US$)
Survey 3G	1,010,000
Infrastructure	19,869,000
General & Administrative	3,475,000
Exploration Drilling	5,090,000
Production Drilling	34,379,000
Injection Drilling	34,897,000
Make Up Well Drilling	49,636,000
Well Testing	865,000
Steam Gathering System	33,591,000
Power Generation Facilities	103,262,000
Total Investment	286,073,000

After the total investment is obtained, it is followed by calculating production and revenue to be able to find out how much the amount of production and revenue is obtained from production each year by including the input data capacity factor of 95% and the selling price of electricity which has been set based on Presidential Regulation Number 112 the Year 2022, as seen on Table 3 below.

Table 3. Cumulative results of production and revenue

Year 1 to 10 (cents/kWh)	Year 11 to 30 (cents/kWh)	Production (MWh)	Revenue (US$)	Operation Days
10.35	8	9,986,400	883,068,000	10,950

In this development power plant project, costs for the OPEX are also required, which in this operational cost consist of O&M steam field and power generation costs of 0.57 cent/kWh and major overhaul costs of USD 2,700,000. So that from the calculation, the overall total OPEX cost is USD 207,890,000. With all the data that has been obtained, calculations are carried out to calculate the economic feasibility of this development project with the final results as shown in Table 4.

Table 4. Economic indicators calculation results (equity)

Parameter	Unit	Value
NPV	US$	- 31,336,000
IRR	%	7.11
POT	Year	0
Project Lifetime	Year	30

Economic analysis on the power plant development project with capacity of 2 X 20 MW, obtained an NPV value of USD - 31,336,000. Apart from looking at the NPV calculation, the feasibility of a project can also be seen and determined from the IRR value, where from the cash flow calculation, the IRR value is 7.11%. Based on the calculation results of these economic indicators, it can be concluded that the power plant development project with a generating capacity of 2 X 20 MW is considered uneconomical because the NPV value shown is small or negative and the IRR value shows a value that is smaller than the Weighted Average Cost of Capital (WACC) value. which has been determined is 10.36%. Because the final result obtained is a negative NPV value and the IRR value has not reached the target, this development project can be said to be unfit for development because it does not generate profit for the developer until the contract ends. Based on the results obtained from the calculation of these economic indicators, an analysis was carried out using a tornado chart. The analysis using the tornado chart aims to find out which variables are the most sensitive on the economics of a project. The analysis was carried out by comparingseveral parameters, such as tariff prices, drilling costs, power generation facilities, OPEX, steam gathering systems, infrastructure, general and administrative, well testing and surveys using increasingand decreasing variables each by 20% so that to 80% and 120%.

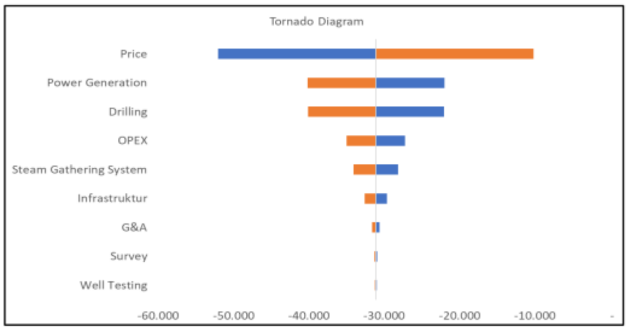

Figure 1. Tornado diagram

Based on Figure 2, it can be seen that the parameters that have the most influence on the development project with a capacity of 2 X 20 MW are tariffs, drilling costs and EPCC. These parameterswill then be analyzed for sensitivity by trying to decrease to see and get the minimum value.

- Price Sensitivity Analysis based on Presidential Regulation Number 112 of 2022

In the analysis of tariffs based on the price of Presidential Regulation Number 112 of 2022, the highestbenchmark price is obtained for the Sulawesi region starting from the first year to the 10th year of 10.35 cents/kWh and for the 11th year to the 30th year of 8.00 cents/kWh. The tariff sensitivity analysis is calculated in stages to obtain a tariff price that shows the NPV and IRR values that allow the field to beconsidered feasible for development which can be seen in Table 5.

Table 5. Tariff sensitivity results year 1-10

Price (cents/kWh)	IRR (%)	NPV (US$)
9.0	6.09	- 41.465,000
10.0	6.84	- 33,968,000
10.35	7.11	- 31,336,000
11.0	7.61	- 26,470,000
12.0	8.38	- 18,973,000
13.0	9.16	- 11,475,000
14	9.94	- 3,978,000
14.53	10.36	0
15	10.73	3,520,000

Table 6. Tariff sensitivity results year 11-30

Price (cents/kWh)	IRR (%)	NPV (US$)
5.00	5.18	- 41,456,000
6.0	5.93	-38,083,000
7.0	6.56	-34,709,000
8.0	7.11	-31,336,000
9.00	7.59	-27,963,000
10.0	8.03	-24,590,000
11.0	8.43	-21,217,000
12.0	8.79	-17,844,000
13	9.13	- 14,470,000
14	9.45	-11,097,000
15	9.74	-7,724,000
16	10.02	-4,351,000
17	10.29	-978,000
17.29	10.36	0
18	10.54	2,395,000

Based on the sensitivity results in Table 5 and Table 6, the minimum tariff for years 1 to 10 isat a minimum price of 15 cents/kWh. At this price, the NPV calculation results obtained were US$ 3,520,000 and the IRR value was 10.73%. And the minimum tariff price for years 11 to 30 is at a minimum price of 18 cents/kWh with an NPV of US$ 2,395,000 and an IRR value of 10.54%. A positive NPV value and an IRR value that is above the WACC value indicate that the geothermal power plant development project is feasible to develop. However, these two prices could not be realized because these prices far exceeded the highest benchmark price that had been set.

- Sensitivity analysis of drilling cost

In the cost sensitivity analysis of this drilling cost, the initial cost of drilling cost was marked down, with the initial price of drilling cost consisting of exploration drilling costs of US$ 2,422,000, productiondrilling costs of US$ 7,900,000, reinjection drilling costs of US$ 7,980,000 and the cost of drilling make-up was US$ 7,900,000.

Table 7. Sensitivity results of drilling cost

Percent (%)	Exploration Well (US$)	Production Well (US$)	Injection Well (US$)	Make Up Well (US$)	IRR (%)	NPV (US$)
100	2,422,000	7,900,000	7,980,000	7,900,000	7.11	- 31,336,000
90	4,360,000	7,110,000	7,182,000	7,110,000	7.50	- 26,827,000
80	3,875,000	6,320,000	6,384,000	6,320,000	7.90	- 22,317,000
70	3,391,000	5,530,000	5,586,000	5,530,000	8.34	- 17,807,000
60	2,906,000	4,740,000	4,788,000	4,740,000	8.80	- 13,297,000
50	2,422,000	3,950,000	3,990,000	3,950,000	9.29	- 8,787,000
40	1,938,000	3,160,000	3,192,000	3,160,000	9.82	- 4,727,000
30	1,453,000	2,370,000	2,394,000	2,370,000	10.39	229,000

Based on Table 7, from the results of the sensitivity analysis of drilling costs, costs were reduced to obtain minimum prices for exploration, production, injection and makeup drilling costs of US$ 1,453,000, US$ 2,370,000, US$ 2,394,000 respectively, and US$ 2,370,000. With this minimum price, the NPV and IRR values were US$ 229,000 and 10.39%, respectively.

- Sensitivity analysis of EPCC

In the EPCC cost sensitivity analysis, the initial cost of the power generation facilities and steam gathering system was marked down, with the initial cost of the power generation facilities being US$ 29,725,000 and the cost of the steam gathering system being US$ 91,745,000.

Table 8. Sensitivity results of EPCC

Percent (%)	Exploration Well (US$)	Production Well (US$)	Injection Well (US$)	IRR (%)	NPV (US$)
100	29,725,000	91,745,000	121,470,000	7.11	- 31,336,000
90	26,753,000	82,571,000	109,323,000	7.63	- 25,316,000
80	23,780,000	73,396,000	97,176,000	8.19	- 19,296,000
70	20,808,000	64,222,000	85,029,000	8.80	- 13,816,000
60	17,835,000	55,047,000	72,882,000	9.47	- 7,257,000
50	14,863,000	45,873,000	60,735,000	10.20	- 1,237,000
40	11,890,000	36,698,000	48,588,000	11.00	4,775,000
30	8,918,000	27,524,000	36,441,000	11.89	10,802,000

Based on Table 8, from the results of the EPCC sensitivity analysis, costs were reduced to obtain a minimum price from the initial cost of US$ 121,470,000 to only US$ 48,588,000. This minimum price shows that the NPV and IRR values are US$ 4,775,000 and 11.00%, respectively. Because the results of the economic feasibility calculation show results that not feasible to develop, a scenario with loan is carried out to increase the investment cost of this project. The total cost of investment with borrowing is shown in Table 9.

Table 9. Total investment costs (loan)

Cost Element	Total (US$)
Survey 3G	1,010,000
Infrastructure	19,869,000
General & Administrative	3,475,000
Exploration Drilling	5,090,000
Production Drilling	34,379,000
Injection Drilling	34,897,000
Make Up Well Drilling	49,636,000
Well Testing	865,000
Interest During Construction	4,245,000
Steam Gathering System	33,591,000
Power Generation Facilities	103,262,000
Total Investment	290,318,000

Total loan funds are taken based on the total cost of building the EPCC, which is USD 135,833,000 with an annual interest of 3.125% based on World Bank Data and a loan period of 15 years. With all the data that has been obtained and the additional funds available, calculations are carried out to calculate the economic feasibility of borrowing with the final results as shown in Table 10.

Table 10. Economic indicators calculation results (loan)

Parameter	Unit	Value
NPV	US$	528,000
IRR	%	10.46
POT	Year	28
Project Lifetime	Year	30

Based on Table 10, the NPV value is US$ 528,000 with an IRR of 10.46% and a POT of 28 years. From these results, it can be said that this project is more economical than the scenario without a loan.

- Discussion

The results of an economic analysis with equity in the 'GT' field with a generating capacity of 2X20 MW show that this project is not feasible to develop. Therefore, the next step was using loan scenario. With loan scenario, the NPV value is USD 528,000 and the IRR value is 10.46% with a POT of 28 years. Based on the calculation results of these economic indicators, it can be said that the development of geothermal power plant in the 'GT' field is more economical, because the NPV value shown is positive and the IRR value shows a value greater than the predetermined discount rate, 10.36%.

4. Conclusion

Based on the modeling of economic calculations that have been carried out, the economic parameter NPV is US$ - 31,336,000 with an IRR value of 7.11% and POT is 0 year, so it can be stated that a power plant development project with a capacity of 2 x 20 MW using the discounted cash flow method is not feasible to develop, for not making a profit. The selling price of electricity based on Presidential Regulation Number 112 of 2022 shows that the project is not feasible to develop with the selling price of electricity from the 1st to the 10th year of 10.35 cents/kWh and the 11^{th} to the 10^{th} year 30 of 8.00 cents/kWh, so an analysis of the tariff price was carried out and a selling price was obtained that could be considered feasible to develop, namely from the 1st year to the 10th year of 15 cents/kWh and the 11^{th} to 30^{th} year of 18 cents/kWh. However, the prices could not be realized because these prices far exceeded the highest benchmark price that had been set. With these uneconomical and unfeasible results, a scenario of loan was carried out to get better results with an NPV value of US$ 528,000 with an IRR value of 10.46% and POT is 28 years.

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