DOI : 10.22373/ijes.v1i2.4246
ISSN 3046-885X

IJES
Indonesian Journal of Environmental Sustainability

Published by : Center For Environmental Studies UIN Ar-Raniry Banda Aceh

INVESTMENT ANALYSIS OF A 5 MW GEOTHERMAL BINARY CYCLE POWER PLANT

Suardi Nur[1]*, Mulyadi Abdul Wahid[2]

[1]*Departement of Environmental Engineering Faculty of Sciences and Technology, University of Islamic State Ar-Raniry Banda Aceh, Indonesia*

[2]*Department of Physic Engineering, Faculty of Science and Technology, University of Islamic State Ar-Raniry Banda Aceh, Indonesia*

**Email Correspondence: suardinur.fst@ar-raniry.ac.id*

Received : 20 August 2023 Accepted : 21 September 2023 Published : 30 December 2023

ABSTRACT

Indonesia is blessed with around 27.510 MWe of geothermal resources. Amongst the numbers, some resources are identified as small-scale geothermal resources. The development of small-scale geothermal resources is quite challenging either to government or private developers due to their low selling price that varies from USD 6.50 cent/kWh to USD 9.76 cent/kWh depending on the location and capacity. The challenges can be multiplied in the case of the electricity produced from a geothermal power plant that located isolated grid, where the electricity is unable to be transmitted to another load areas. Therefore, the electricity production will be limited to only serve the demand in the island that consequently will limit the revenue from electricity sales. This study analyzes the financial aspect of a binary geothermal power plant with gross installed capacity of 5 MW located in isolated island. The analysis shows the power plant will be financially feasible when the electricity selling price is over USD 30 cent/kWh that will generate 12% of IRR which is assumed as feasible target for this project. Furthermore, if environmental benefit is included the project can be feasible at lower selling price of USD 25 cent/kWh.

Keywords : Geothermal Feasibility, Binary Cycle Power Plant, Environmental Benefit, Geothermal Investment Cost

ABSTRAK

Indonesia dikaruniai sumber daya panas bumi sekitar 27.510 MWe. Di antara jumlah tersebut, beberapa sumber daya diidentifikasi sebagai sumber daya panas bumi skala kecil. Pengembangan sumber daya panas bumi skala kecil cukup menantang baik bagi pemerintah maupun pengembang swasta karena rendahnya harga jual yang bervariasi dari USD 6,50 sen/kWh hingga USD 9,76 sen/kWh tergantung pada lokasi dan kapasitas. Tantangannya dapat berlipat ganda jika listrik dihasilkan dari pembangkit listrik tenaga panas bumi yang terletak di jaringan terisolasi, dimana listrik tidak dapat disalurkan ke area beban lain. Oleh karena itu, produksi listrik akan dibatasi hanya untuk melayani kebutuhan di pulau tersebut yang akibatnya akan membatasi pendapatan dari penjualan listrik. Studi ini menganalisis aspek finansial pembangkit listrik tenaga panas bumi biner dengan kapasitas terpasang 5 MW yang terletak di pulau terpencil. Analisis menunjukkan pembangkit listrik akan layak secara finansial ketika harga jual listrik melebihi USD 30 sen/kWh yang akan menghasilkan 12% IRR yang diasumsikan sebagai target yang layak untuk proyek ini. Selain itu, jika manfaat lingkungan juga disertakan, proyek ini akan layak secara finansial pada harga jual Listrik yang lebih rendah yaitu USD 25 sen/kWh.

Nur, S. & Wahid, M. A. (2023)
Vol. 1, No. 2 (December 2023), pp.146-154
DOI : 10.22373/ijes.v1i2.4246
ISSN 3046-885X

Kata kunci : *Kelayakan Panas Bumi, Pembangkit Listrik Siklus Biner, Manfaat Lingkungan, Biaya Investasi Panas Bumi*

Introduction

Rapid growth of electricity demand forces government to put all efforts to find the solution to supply the demand. As part of Indonesian NDC commitment to reduce GHG emission of 31.89% (unconditional) and 43.2% (conditional) by 2030, geothermal energy is expected as a promising source of renewable energy to cut the emission from energy sector in Indonesia. In addition, geothermal energy is also expected to contribute on the role to solve the power shortage and to replace the diesel-based power plant in remote areas and scattered islands in Indonesia.

Resource wise, Indonesia has been blessed to own around 27.510 MWe of geothermal potential which is claimed as largest in the world with 40 % of the world total potential. However, by 2022, only 2.138 MW has been utilized which far behind the target set up by the government to utilize 9.500 MW of geothermal resources by 2025 (Harsoprayitno, 2009). Even tough, the Indonesian government has issued some policies that includes tax incentives, offering new framework of exploration right based on the Geothermal Law of 21/2014 and regulating new feed in tariff to accelerate the development, the target set up in the roadmap cannot be achieved by 2025 as depicted in Figure 1.

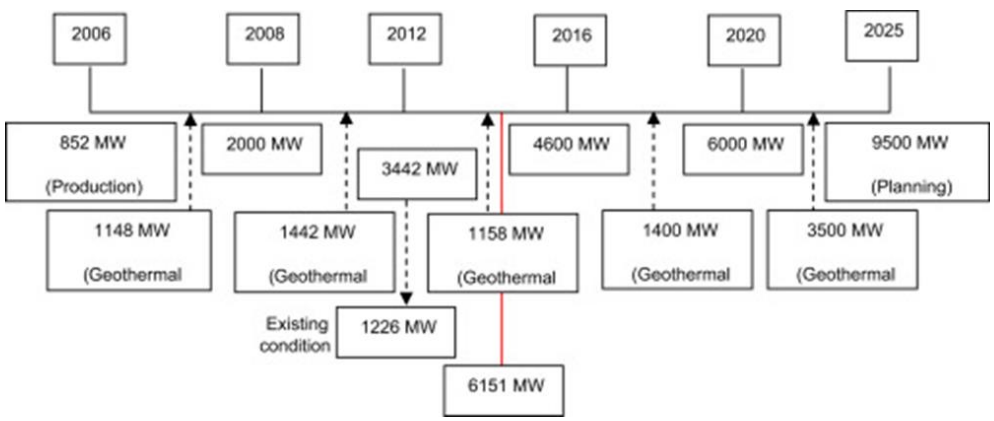

Figure 1. Road Map of Indonesia's Geothermal Energy Development
(Nasruddin et al., 2016)

In technological aspect, technology developments such as exploration techniques, reservoir engineering and power plant technologies are also expected to play a vital role in accelerating and reducing the cost of geothermal energy the deployments. The development of technologies may increase the viability of previous unfeasible resources such low to intermediate enthalpy resources which classify as resources with temperature lower than 225 °C. One of the technologies is known as Organic Rankine Cycle (ORC) geothermal power plant or binary cycle power plant which is suitable for small scale geothermal deployment in the remote areas. It is estimated there are more than 200 geothermal resources is classified as low to medium enthalpy geothermal resources (Saragih, 1995).

DOI : 10.22373/ijes.v1i2.4246
ISSN 3046-885X

However, the implementation of binary cycle technology has its own challenges due to the difficulties achieve its commercial scale as the technology and its operational is still considered not competitive compared to conventional geothermal power plant technologies such as flash or double flash geothermal systems. Therefore, this study is trying to analyze the investment of a 5 MW binary cycle power plant by assessing its economic and environmental benefits.

Binary cycle power plant basically converts the heat into the power from geothermal fluid by using secondary working fluid, usually organic working fluid. The working fluid works in closed cycle. In certain boiling point, the working fluid will evaporate, expands trough an expansion machine and releases enthalpy. The first geothermal binary power plant was installed at Kamchatka peninsula, Russia in 1967 with capacity 670 kW and served small village and some farms with both electricity and heat (DiPippo, 2008). The basic model of a geothermal binary cycle power plant is presented in Figure 2.

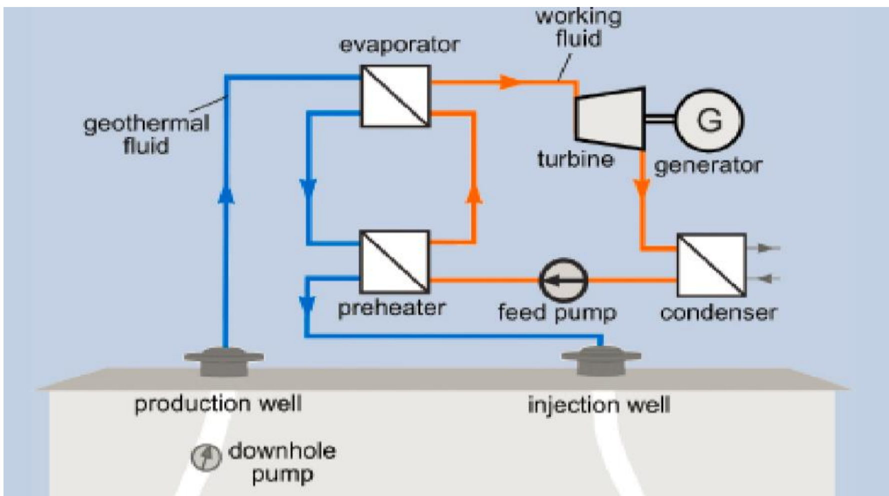

Figure 2. Basic Model of Binary Cycle Geothermal Power Plant Technology
(Source: Huenges, 2011)

Methods

Project viability is analyzed by using NPV and IRR indicators. The NPV model is presented for the lifetime of power plant of N years is determined as:

$$NPV = -I + \frac{CF_1}{(1+r)} + \frac{CF_2}{(1+r)^2} \dots\dots\dots \frac{CF_N}{(1+r)^N} \qquad \text{Eq (2.1)}$$

$$NPV = -I + \sum_{t=1}^{N} \frac{CF_j}{(1+r)^t} \qquad \text{Eq (2.2)}$$

where; I refers to total investment I (US$), CF_j is annual cash flow (US$) and r is the discount rate (%). The investment cost is estimated based on cost information estimated by Castlerock Consulting (2010) for Cibuni geothermal. Assumption used in this model are detailed below:

Net power plant output : 3000 kW

Capacity Factor : 90%

DOI : 10.22373/ijes.v1i2.4246
ISSN 3046-885X

Discount rate :10%

Geothermal Feed in Tariff (FIT) is assumed based on Presidential Regulation No. 112/2022 that specifies the electrify sales from geothermal between USD cent 6.50/kWh and 9.76/kWh. We assumed the electricity sales from this power will be at US$ 9.7 cent /kWh. The tax incentive scenario only applies income tax allowance as specified in Regulation of Ministry of Finance No. 21/PMK.011/2010. It is assumed the project will be eligible for income tax reduction of 30% in the first 6 years since project commercial operation date (COD).

The levelized cost of electricity and emission produced from diesel power plant operational is calculated based on assumption provided by Nusiaputra, et al. (2011). The assumption in listed Table 1.

Table 1. Assumption for Diesel Generating Cost and CO_2 Emission Calculation

Diesel power plant capacity (net output)	3000 kW
Investment @ US$ 500/kWnet	US$ 1.500.000
Capacity factor	0.8
Annual electricity production	21.02 GWh
Fuel consumption	0.269 liter/kWh
Annual fuel cost @ US$ 0.72/liter	US$ 4.071.928
Annual Operational and maintenance cost @ US$ 0.198/kWh	US$ 4.160.000
Annual CO_2 emission @760 kg/MWh	15.978 ton
Estimated annual CER price @ US$ 15/ton	US$ 239.673

Source : Nusiaputra,et al. (2011)

In this study only CO_2 emission is considered. CO_2 Emission calculation is based on IPPC Tier 1 approach. Tier 1 approach is emphasized on estimating the emissions from the carbon content of fuels or to the main fuel combustion activities (IPCC, 1996).

Results and Discussion

Investment Cost

Cost for small geothermal project depends significantly on the power plant type, drilling cost, resource quality and cost of financing. The development of a small geothermal field with capacity of 5 MW is assumed to require only a production well with another well as reinjection well (double system). It is also assumed the make up well will be drilled after 4 or 5 year operations, depends on decline rate of reservoir.

Therefore, the typical time frame needed to complete the power plant development is estimated in 6 years with the following stages:

- Geology and geosciences (G & G) 1 year
- Exploration and appraisal (E & A) 2 years
- Site development 2 years
- Power plant construction 1 year

Geological and Geosciences (G&G) Costs Estimation

Geology and geosciences (G&G) stage is a phase where geological, geochemical, and geophysics surveys are conducted. In this phase, the collected data and integrated analysis are aimed to develop a preliminary conceptual model of a geothermal reservoir

DOI : 10.22373/ijes.v1i2.4246
ISSN 3046-885X

that provides information to proceed to the next phase. The expenditure for this phase is presented in Table 2.

Table 2. Geological and Geosciences Cost Estimation

No	G&G activities	Costs Estimation (USD mil.)
1	Legal cost	0.05
2	PPA negotiation	0.10
3	Permitting	0.15
4	MT geophysics survey (estimate prospect area 6 km^2)	0.15
5	MT data interpretation	0.05
6	Detailed geological survey with petrology and reporting	0.06
7	Detail geochemistry survey with analysis and reporting	0.06
8	Environmental/social baseline survey	0.14
9	Market and tariff assessment	0.13
10	Land access (right)	0.01
11	Owner/developers' cost (project management)	0.25
	Total G&G costs	**1.60**

Exploration and appraisal (E&A) cost estimation

Main activity of this phase is to drill exploration wells which provide important information to validate and revise the preliminary conceptual model of geothermal reservoir. If in phase, positive results are found, the project will proceed to the development stage. The activities and costs required for exploration phase are presented in the Table 3.

Table 3. Exploration and Appraisal Cost

No	Exploration and Appraisal	Cost Estimation (USD mil.)
1	Legal cost	0.10
2	Site survey	0.10
3	Land acquisition	0.25
4	Access road	0.60
5	Base camp	0.24
6	Geotechnical (foundation and seismics evaluation)	0.18
7	Prepare spec, tender doc, bid out, evaluate and award contracts for drilling-rig, services, material and personnel	0.20
8	Rig mobilization and demobilization	1.4
9	Drill exploration well	7
10	Well surveys	0.05
11	Design of portable well testing equipment	0.35
12	Fabrication of portable well testing equipment	0.12
13	Well testing-output testing, geochemistry analysis and reporting	0.36
14	Site operation (supervision and project management)	0.17
15	Asset insurance (incl. well)	0.09
16	Resource Assessment and Feasibility Study	0.40

DOI : 10.22373/ijes.v1i2.4246
ISSN 3046-885X

	Total E&A costs	**11.61**

Field development cost estimation

The injection well is drilled at this development phase as well as to develop the steam field facilities. The activities and cost associated in this stage are listed in the Table 4.

Table 4. Field Development Cost Estimation

No	Field Development Activities	Cost Estimation (USD mil.)
1	Legal cost	0.10
2	Injection well drilling + prod. well	10
3	Steam Field-Detailed Engineering	0.36
4	Steam Field-Procurement & Construction	2.10
5	Grid connection study	0.07
6	Project management	0.12
	Total field development cost	**12.75**

Power Plant Construction cost estimation

Power plant unit costs highly depend on power plant design (i.e size and specification) and the components of power plant. DiPippo (1999) describes that a basic binary power plant will be equipped by major equipments such as vaporizers and preheaters, condensers, organic vapor turbine, downhole pump, plant pumps and cooling tower. Castle Rock Consulting (2010) estimates cost for equipment purchasing and power plant construction of a binary type of power plant will cost US$ 1.944/ kW_{gross}. This estimation will be used in this study as the detailed is presented in Table 5.

Table 5. Power Plant Cost Estimation

No	**Field Development Activities**	**Cost Estimation (USD mil.)**
1	Engineering specs, design	0.50
2	Equipment purchasing & const.	13.61
3	Transformers (3.5% of utilization cost)	0.48
4	Project management	0.42
5	Insurance	0.28
	Total field development cost	**15.29**

Operational and Maintenance cost estimation

Operation and maintenance costs are estimated Table 6.

Table 6. Operational and Maintenance Cost per Year

Fixed O&M cost	**$/MW**	**Capacity (MW)**	**Cost (US$)**
Power plant	50.000	5	250.000
Steam field	20.000	5	100.000
Variable cost			
Power plant	5000	5	25.000
Steam field	5000	5	25.000
	26000	5	130.000

DOI : 10.22373/ijes.v1i2.4246
ISSN 3046-885X

Overhaul per year (performed in interval of 3 year, expecting power factor 90%)			
Total O&M cost			**530.000**
O&M Cost per kW			**106**

A total cost of US$ 530.000 per year or US$ 106 per kW is estimated as operational and maintenance cost for a 5 MW geothermal binary cycle power plant. By assuming power factor 90 %, this O&M cost is calculated as US$ 2.8 cent/ kWh. As comparison, Sanyal (2004) estimated operational and maintenance cost of US$ 2.0 cent/kWh for a 5 MW power plant (the type of power plant is not specified).

Economic and Environmental Benefits Analysis

Table 7 highlights the project feasibility level based on a specific scenario based on current geothermal Feed in Tariff (FIT) based on Presidential Regulation No. 112/2022 that specifies the electrify sales from geothermal between USD cent 6.50/kWh and 9.76/kWh. It shows that the project is only feasible, in this case the project IRR at least 12%, if the tax obligation is excluded. The tax incentive provided is still insufficient to take the project to be financially viable.

Table 7. IRR and NPV of The Project Based on Specific Scenario

Scenario	IRR	NPV (US$ mil.)
After tax (without tax incentive)	4%	-10.46
After tax (tax incentive applied)	6%	-6.55
After tax (including revenue from CER)	8%	-3.54
Before tax	10%	1.83

To assess the environmental benefit, it is required to calculate levelized cost of electricity generated from a diesel power plant. It is expected to produce a kWh electricity from diesel power plant will cost USD 39.5 cent/kWh. It is also assumed the geothermal power plant will replace a 3 MW diesel power plant. The substitution of this 3 MW diesel power plant is calculated to mitigate 16.000 tonCO_2 emission per year. If the global carbon price is estimated at USD 15/ton, then the revenue from carbon credit is estimated to be around USD 240.000/year. By considering the income from environmental benefit, the project viability can be reached at lower electricity selling price of USD 25 cent/kWh.

DOI : 10.22373/ijes.v1i2.4246
ISSN 3046-885X

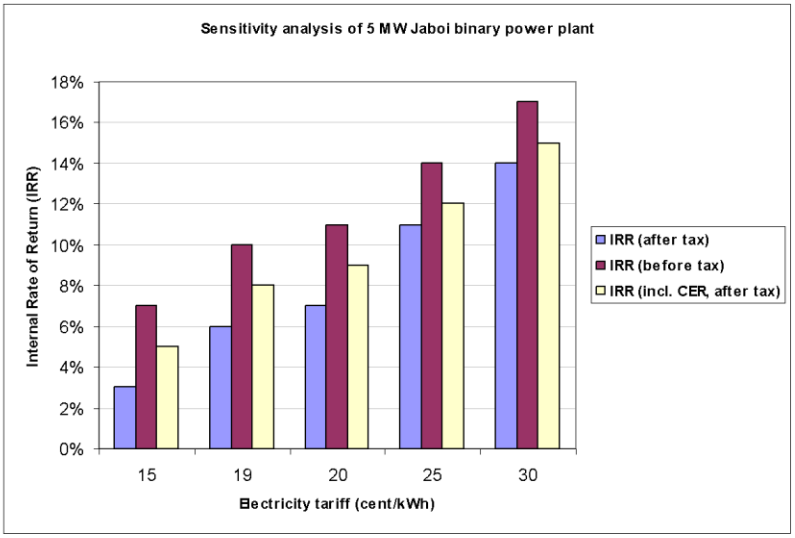

Figure 3. Sensitivity of IRR to the Electricity Selling Price

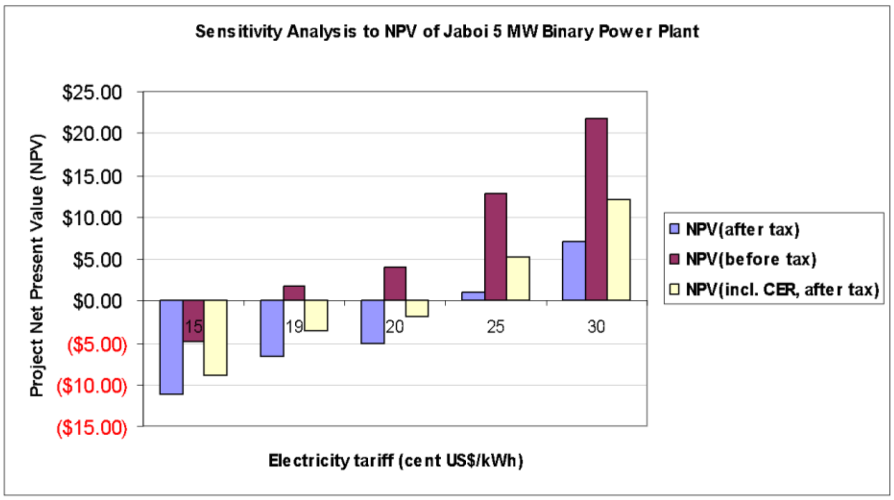

Figure 4. Sensitivity of NPV to the Electricity Selling Price

Conclusion

Current geothermal Feed in Tariff (FIT) based on Presidential Regulation No. 112/2022 that specifies the electrify sales from geothermal between USD cent 6.50/kWh and 9.76/kWh is not yet sufficient to make unfeasible geothermal resources to be viable particularly small-scale low to medium geothermal resources. Based on financial analysis of a 5 MW binary cycle geothermal power plant, the project will be feasible if the selling price is at least USD 30 cent/kWh where the IRR of 12% is achieved. Even when environmental benefit obtained from avoidance of 16.000 ton CO2 emission per year is considered the power plant is still not feasible within the tariff framework stated in the Regulation No. 112/2022.

 DOI : 10.22373/ijes.v1i2.4246
ISSN 3046-885X

References

DiPippo, R., (1999), "Small geothermal power plant. Design, performance and economics", *GHC Bulletin*.

DiPippo, R. (2008), "Geothermal power plants, principles, applications, case studies and environmental impact" *Oxford: Butterworth-Heinemann*

Harsoprayitno, Sugiharto (2009): Geothermal energy in Indonesia. Jakarta, Indonesia: *Directorate General of Mineral, Coal and Geothermal*.

Huenges, E (2011), "Conception for deployment of small-scale binary power plant in remote geothermal areas in Indonesia" *Proceeding thirty-sixth workshop on geothermal reservoir engineering Stanford University, California*

IPCC. (1996). *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*.

PT. Castlerock Consulting (2010): Review and analysis of prevailing geothermal policies regulation and cost. *Consulting Report*.

Nasruddin, Idrus Alhamid, M., Daud, Y., Surachman, A., Sugiyono, A., Aditya, H. B., & Mahlia, T. M. I. (2016). Potential of geothermal energy for electricity generation in Indonesia: A review. Renewable and Sustainable Energy Reviews, Vol. 53, pp. 733–740.

Nusiaputra, Yodha Yudhistira; Dwi, Agus; Bimo, Ibrahim (2011): Aplikasi pembangkit listrik tenaga panas bumi (PLTP)-Biner mengganti pembangkit diesel di daerah" *PT. PLN (Persero).*

Radja, Saragih (1995) "Utilization of small-scale geothermal power plant for rural electrification in Indonesia" *PT. PLN (Persero),* Indonesia.

Vimmerstedt, L (1999), "Opportunities for small geothermal power project" *GHC Bulletin*