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FINANCIAL RISK ANALYSIS OF GREEN-FIELD GEOTHERMAL PROJECTS IN INDONESIA: THE IMPACT OF INTEREST RATE SUBSIDY

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Abstract

Geothermal energy has continuously received a range of government incentives in the last decades. However, the research investigating the effectiveness of those incentives, particularly the interest rate subsidy, is relatively limited. Therefore, we are interested in exploring this gap at the project level by emphasizing green-field geothermal projects. This is relevant as green-field geothermal projects are carrying high financial risks during their early development stages that limit their access to a cheaper financing market. The study is carried out by employing Monte Carlo Simulation to examine the investment of a 55 MW green-field geothermal energy project and to analyze the extent of impact of interest rate subsidy on the project viability applied to a selected greenfield geothermal project as the case study. The simulation results show that, without an interest rate subsidy, the project's mean Internal Rate of Return (IRR) is 10.31%, a level generally considered too low for high-risk greenfield investments. Introducing a 50% interest rate subsidy raises the mean IRR to 11.27% and increases the probability of achieving an IRR ≥ 10% from 79% to 98.36%. These findings indicate that while interest rate subsidies improve project financial viability, the improvement is modest relative to the 14–16% IRR typically expected by private investors for greenfield geothermal projects, suggesting that interest rate subsidy alone may be insufficient without complementary policy instruments.

Keywords: *Financial viability; Geothermal projects; Interest subsidy; Monte Carlo simulation*

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1. Introduction

Geothermal projects inherit some risks that are associated with resource, financing, socio-environmental, policy and regulation. The main financial risks associated with geothermal projects relate to the high upfront costs and long lead times

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involved, both of which can impact severely on the cost of capital at an early stage when developers often rely on (more costly) equity capital with substantial credit risk premiums arising. Financial risk reflects the stability of a country's financial climate and is closely related to the challenges companies face in securing funding that is represented in the country credit rating (Lee et al. 2024).

Empirical evidence suggests that private lenders are particularly sensitive to credit risk with renewable energy project financing (Chen et al. 2023). In project finance, credit risk levels are relatively high at project inception, reflecting intensive capital upfront investment needs and the high leverage and non-recourse debts typical at this stage (Sorge 2004). The long-term commitment by lenders can expose the providers of capital to the risk of political changes in respective host governments; in such cases, the lenders may ask for guarantees from multilateral development banks or export credit guarantees to persuade them to commit for longer maturities, particularly in emerging countries (Pombo-Romero et al. 2024). More generally, credit enhancement with additional collateral or third-party guarantees is increasingly viewed as one of the most effective means of financing renewable energy projects with lower interest rates compared to commercial loans. However, at the early stage of the project, i.e., during the exploration stage in the case of geothermal projects, a commercial loan will likely not be available as the project is still not bankable.

In this case, the project sponsors must rely on equity which may be obtained from a much higher cost of debt financing sources. Consequently, many geothermal projects that have acquired the permit are unable to achieve financial closure. According to Quinlivan (2015), for a geothermal power plant with a capacity of 200 MW, an upfront cost in the range of US$ 120 to 320 million is required, which accounts for 20 to 40% of the overall investment cost. This upfront cost can only be met by very few developers, which leads many geothermal working areas that have been granted geothermal business permits, some of which have even signed PPAs, to fail to achieve financial close. Government participation to reduce the risk borne by the geothermal developers by providing incentives can be essential (Pambudi and Ulfa 2024). The availability of incentives, in this context, an interest rate subsidy, is required to ensure the financial viability of geothermal projects in Indonesia, particularly due to the tariff constraints of the geothermal energy in the current pricing policy (Nur et al. 2023).

Many studies on geothermal projects in Indonesia focus on tariff mechanisms to evaluate their financial viability. We found limited research that explores the introduction of a policy instrument, in this case an interest rate subsidy, in assessing a geothermal project's viability. Therefore, this study aims to explore this gap at the project level by emphasizing green-field geothermal projects by using stochastic modelling by examining the impact of interest rate subsidies on the project's Net Present Value (NPV) and Internal Rate of Return (IRR).

2. Method

The impact of an interest rate subsidy on the financial viability of a green-field geothermal project is analyzed by using Monte Carlo simulation. Monte Carlo simulation involves mathematical modelling that predicts possible outcomes imposed by an

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uncertain input by employing random numbers in the simulation iterations with the aid of a computer program. To perform the simulation, the uncertainties imposed on the project by input variables such as drilling risk, i.e., unsuccessful wells, and uncertainty of drilling cost are modelled according to specific distribution functions. In this study, the Monte Carlo method will be employed to analyze the probability and impact of risks to the project value (i.e., IRR). The risky variables such as resource-based risks such as exploration risk variables will be modelled according to specific distributions to optimize the cash flow model using an iterative algorithm.

2.1 Data and Assumptions

The input data are random variables generated by a random number generator. In this study, the simulation is performed using Crystal Ball software with 10,000 iterations with the input values of the uncertain variables at each iteration determined from a random stochastic selection. The results are presented in the form of a probability density function.

The inputs are differentiated into deterministic inputs and uncertain inputs. The deterministic inputs applied in the model are outlined in Table 1:

Table 1. Deterministic Input Parameters used in Monte Carlo Model

Deterministic Input Parameters	Value	Justification
Power plant capacity	55 MW	Based on case configuration for Seulawah Agam Geothermal Project (Nur et al. 2023)
Electricity selling price	12.96 US cents/kWh (years 1 – 10) and 11.20 US cents/kWh (years 11-30)	Presidential Regulation No. 112/2022
Discount rate	10%	Typical value for geothermal projects (Hakam et al. 2025)
Production bonus	0.5% of EBITDA	Statutory; case configuration (Idianto et al. 2021; Nur et al. 2023)
Royalty	2.5% of net revenue	Statutory; case configuration (Idianto et al. 2021; Nur et al. 2023)
Loan tenor	10 years	Based on case configuration for Seulawah Agam Geothermal Project (Nur et al. 2023)
Interest rate	10%	OJK base rate of credit (OJK 2025)

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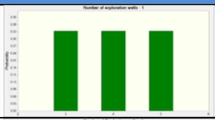
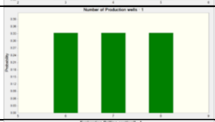
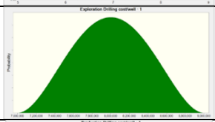
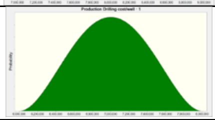
Meanwhile, as provided in Table 2, number of exploration wells, number of production wells, exploration drilling cost/well and production drilling cost/well that represent the resource and financial risks in this geothermal project.

Table 2. Uncertain input parameters

Name	Graph	Distribution Function	Min	Mean	Max
Number of exploration wells		Discrete Uniform	3	-	5
Number of production wells		Discrete Uniform	6	-	8
Exploration drilling cost/well		BetaPERT	7,000,000	8,000,000	9,000,000
Production drilling cost/well		BetaPERT	6,000,000	7,833,334	9,000,000

2.2 Model

The impact of an interest rate subsidy on the financial viability of a green-field geothermal project is analyzed by using Monte Carlo simulation. Monte Carlo simulation involves mathematical modelling that predicts possible outcomes imposed by an uncertain input by employing random numbers in the simulation iterations with the aid of a computer program. To perform the simulation, the uncertainties imposed on the project by input variables such as drilling risk, i.e., unsuccessful wells and uncertainty in drilling cost are modelled according to specific distribution functions. The input and output model of the Monte Carlo simulation is shown in Figure 1. In this study, the Monte Carlo method will be employed to analyze the probability and impact of risks to the project value (i.e., NPV and IRR). The risky variables such as resource-based risks such as exploration risk variables will be modelled according to specific distributions to optimize the cash flow model using an iterative algorithm.

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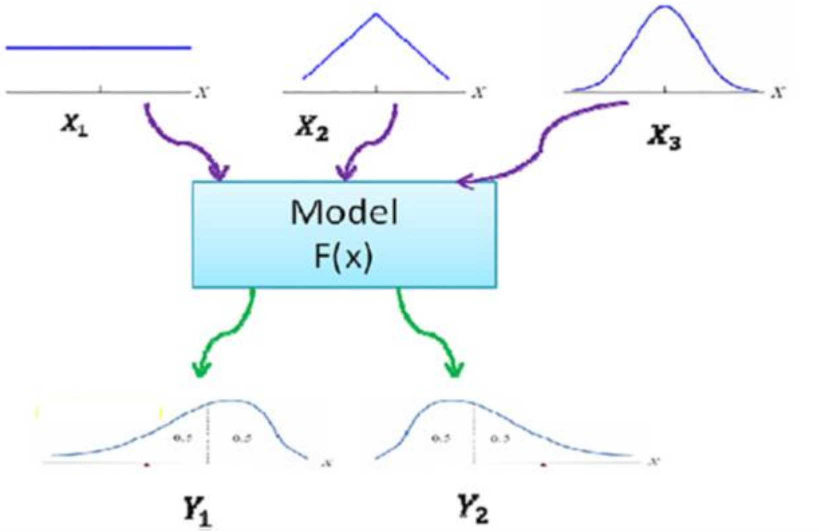

Figure 1. Stochastic model of Monte Carlo simulation (Platon and Constantinescu 2014)

The financial model used in this simulation is the NPV model of a power plant with an *N*-year lifetime:

$$NPV = -I + \frac{CF_1}{(1+\mathrm{r})} + \frac{CF_2}{(1+\mathrm{r})^2} \dots\dots.. \frac{CF_j}{(1+\mathrm{r})^j} \quad (1)$$

$$NPV = -I + \sum_{t=1}^{N} \frac{CF_t}{(1+\mathrm{r})^t} \quad (2)$$

For simplification purposes, the annual cash flow is modelled as follows:

$$CF = Rv - PB - D - L - T - R \quad (3)$$

where *CF* refers to annual net cash flow*; Rv* refers to annual revenue from electricity sales; *PB* is production bonus; $C_{o\&m}$ refers to annual operational and maintenance cost; *i* refers to the annual increment rate of O&M costs; *D* is depreciation; *L* is loan expenses; and *T* is corporate income tax; R is royalty.

Furthermore, to assess the impact of an interest rate subsidy, it is assumed that the investment *I* is financed with equity and loan financing, with equity used to finance all of the exploration stage amounting to $(1 - \lambda)I$ and the loan financing of λI is used to finance the rest of the activities. Hence, the amount of upfront investment *I* can be re-written as:

$$I = \lambda I + (1 - \lambda)I \quad (4)$$

The loan is assumed to have an *RP* repayment period with payment starting in year 7 with α annual interest rate. Therefore, the loan expenses (principal plus interest) as given by Mir-Artigues and del Río (2014) of the t^{th} period can be written as:

$$L_t = \lambda I \left[\frac{1}{RP} + (1 - \frac{t-1}{RP})\alpha\right], \text{ with } 0 < \alpha < 1 \quad (5)$$

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3. Results and Discussion

3.1 Results

The simulation results to examine the economic viability of a greenfield geothermal project are demonstrated in Figure 2. The results suggest that in the absence of an interest rate subsidy the mean IRR of the project is 10.31% (see Table 3). It also can be observed that there is a 79% probability that the project will yield an IRR ≥ 10%. The simulation results also suggested that the maximum IRR that can be achieved is 11.19% and the minimum is 9.43%. This value is relatively low for geothermal businesses, particularly for a greenfield project. The private investors may expect a much higher IRR of 14 to 16% for greenfield sites (Nur et al. 2023).

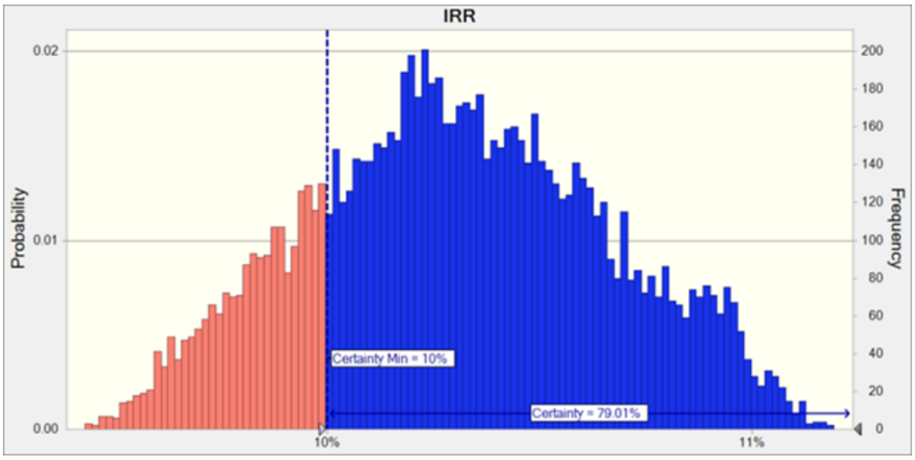

Figure 2. Project's IRR of a 55 MW geothermal project

Table 3. Statistics of project's IRR simulation

Statistics:	Forecast values
Trials	10,000
Base Case	10.89%
Mean	10.31%
Median	10.30%
Mode	---
Standard Deviation	0.35%
Variance	0.00%
Skewness	0.058
Kurtosis	2.38
Coeff. of Variation	0.03
Minimum	9.43%
Maximum	11.19%
Range	
Width	1.76%
Mean Std. Error	0.00%

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The impact of interest rate subsidy on the project viability can be seen in Figure 3. The introduction of a 50% interest rate discount that reduced the interest rate from 10% to 5% can increase project's mean IRR to 11.27%. The possibility of project IRR ≥ 10% is now increased to 98.36% (from previously 79%). The statistics in Table 4 also indicate that now the maximum IRR that can be achieved is 13.47%. Based on the results, it can be acknowledged that the introduction of interest rate subsidy for greenfield geothermal projects can increase the IRR to a more viable level.

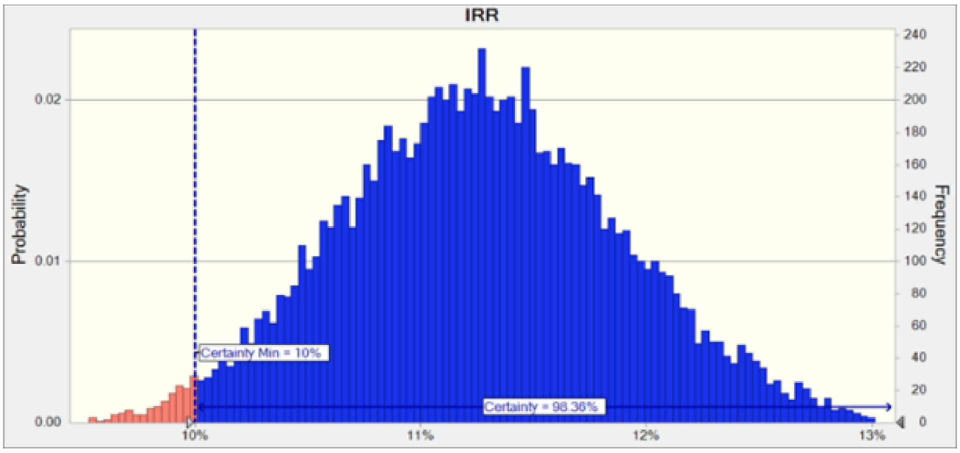

Figure 3. Project's IRR after the interest rate subsidy was introduced

Table 4. Statistics of project's IRR simulation after the interest rate subsidy was introduced

Statistics:	Forecast values
Trials	10,000
Base Case	10.89%
Mean	11.27%
Median	11.26%
Mode	---
Standard Deviation	0.62%
Variance	0.00%
Skewness	0.12
Kurtosis	2.92
Coeff. of Variation	0.05
Minimum	9.85%
Maximum	13.47%
Range Width	4.63%
Mean Std. Error	0.01%

3.2 Discussion

The investment cost of a geothermal project is influenced by several factors including the size of the power plant, technology used in the energy conversion process,

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and characteristics of the geothermal field (Stefánsson 2002). The total investment cost for a 55 MW project is estimated at US$ 210 million including the costs for exploration, field development and construction and pre-commercial operation date (COD) operational and maintenance.

The exploitation of greenfield geothermal fields is more complex and more expensive, leading to more risky investments (Nath et al. 2024). Furthermore, unlike brownfield projects, greenfield projects are often seen as higher risk due to uncertainties around factors such as site availability, complex regulations, investor confidence, and obtaining necessary approvals (Emodi et al. 2022). In addition, geothermal prospects are often located in remote areas that lack power infrastructure, such as transmission lines, making the business less attractive to risk-averse investors.

Therefore, the availability of a subsidy can encourage investment in greenfield geothermal prospects. The potential incentives to reduce the levelized cost of geothermal energy can be in the form of an exploration grant, co-investment funding, tax incentives, interest rate subsidy and accelerated depreciation (Emodi et al. 2022; Lin and Xie 2024). The emergence of the green finance concept also provides the opportunity for renewable energy projects to access favourable financing terms such as preferential interest rates, thereby reducing the financial cost of the projects (Lee et al. 2024). In this context, the introduction of dual credit policy where lenders offered lower interest rates (green loan) for green technologies can be an alternative (Wang et al. 2020; Che et al. 2021).

Incentives are important to motivate the risk-averse agent (Miller and Whitford 2002). However, according to Klein (1997), the rationale of government in providing support for private projects should be based on three reasons: (1) The project offers high social benefits; (2) To provide protection against political risk for investors; and (3) As a risk premium for high-risk projects. Furthermore, according to Klein (1997), the types of government support can be in the form of a guarantee, an interest subsidy, a cash subsidy or equity contribution.

In this context, from the perspective of lenders, geothermal projects are inherently financially risky, particularly in the early stage. In the earlier stage of development, the capital and insurance markets perceive resource risk as natural-inherited uncertainty due to: 1) The risk of not finding sufficient heat arising because of drilling zonation design and lack of data or data analysis errors; 2) The risk of being unable to find an economically viable reserve; 3) The risk of drilling in geologically dangerous zones such as volcanic eruption exposures; and 4) other geological risks due to the excessive contents of dangerous elements in a geotherwmal field such as very high H_2S gas (Hasan et al. 2013). Therefore, financing at an early stage is an issue for geothermal developers, including in developed countries that have wider access to capital markets like in the US (Robertson-Tait et al. 2008).

To address this financing constraint, Indonesia needs to encourage the private sector to finance geothermal projects by providing compatible incentives, particularly in reducing the private cost of equity (ESMAP 2012). According to Dewar (2011), equity capital is the highest financial risk in the capital structure. Therefore, in this case, the availability of an incentive mechanism is essential in the early stage of project development. For example, the Market Incentive Program (MAP) was introduced by the

German government, which included deep geothermal projects in Germany in 1999. In this program, the German Government aimed to provide long-term loans with a subsidised interest rate for exploration drilling (Hasan et al. 2013). This loan covers up to 80% of exploration drilling costs with a fixed low-interest loan for a 10-year period under the KfW program with different interest rates accounting for different exploration risks (Schachtschneider 2013). In the case of project failure (e.g., dry hole), the loan does not need to be repaid by developers (Sander 2016).

4. Conclusion

This study examined the effect of interest rate subsidies on the financial viability of greenfield geothermal projects using Monte Carlo simulation, addressing a gap in project-level analysis of this specific policy instrument. As an indirect mechanism for encouraging private investment, interest rate subsidies reduce financing costs and, in principle, allow developers to improve project returns. The simulation results confirm that introducing a 50% interest rate subsidy increases the project's mean IRR from 10.31% to 11.27% and raises the probability of achieving an IRR ≥ 10% from 79% to 98.36%. However, this improvement remains modest, and the resulting IRR stays below the 14–16% return typically required by private investors for greenfield geothermal projects, indicating that interest rate subsidy alone is unlikely to fully close the viability gap for high-risk, early-stage projects. This suggests that interest rate subsidies alone are not effective and therefore need to be combined with complementary instruments such as exploration grants, tax incentives, accelerated depreciation, or co-investment funding. Future research could extend this analysis through sensitivity testing across a range of subsidy levels to identify the optimal subsidy extent relative to the levelized cost of geothermal energy, and through comparative modelling of combined incentive packages to determine the most cost-effective policy mix for accelerating greenfield geothermal investment in Indonesia.

AI Writing Statement

During the preparation of this manuscript, the authors used Claude (Anthropic, 2026) for English language editing. The authors have reviewed, verified, and edited all AI-assisted content and accept full responsibility for the integrity and accuracy of the manuscript.

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