The Application of Numerical Simulation Result for Geothermal Financial Model with Probabilistic Approach: A Comprehensive Study

To cite this article: Nevi Cahya Winofa et al 2020 IOP Conf. Ser.: Earth Environ. Sci. 417 012020

View the article online for updates and enhancements.
The Application of Numerical Simulation Result for Geothermal Financial Model with Probabilistic Approach: A Comprehensive Study

Nevi Cahya Winofa¹, Ade Lesmana², Heru Berian Pratama¹,², Nenny Miryani Saptadji¹,², Ali Ashat²,³

¹Petroleum Engineering Study Program, Institut Teknologi Bandung, Indonesia
²Geothermal Master Program, Institut Teknologi Bandung, Indonesia
Jl. Ganesha No.10, Bandung, West Java, Indonesia
³Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University., Fukuoka 819-0395, Japan

Email: nevicahyawinofa@gmail.com

Abstract. Feasibility of developing a geothermal project depends on the financial return generated from the investment. One of the strategies to achieve optimum return is formulating a financial model with a high level of confidence. Technical input parameters in the financial model are determined by the amount of available geothermal reserve in the form of a field development scenario. The best method for predicting geothermal reserve is a numerical simulation. The objective of this study is to determine the electricity tariff to generate 30 MW, 60 MW, and 110 MW which meet the 50% of the Rate of Return value will be equal or not exceed 16% (P50) for a specific geothermal field with a probabilistic approach. This study started with determining the technical input parameters: the number of production wells; make-up wells; and injection wells from each development scenarios based on numerical simulation result that has been studied by another researcher. The electricity tariff that meets the P50 of Rate of Return at 16% was calculated for those scenarios. Then, the tariffs were evaluated based on the Average Cost of Electricity Generation (BPP) on the relevant local grid. The result shows that the tariff or/and generation cost need to be negotiated. Moreover, total investment and economic indicators forecasting indicated that the investment was attractive. Lastly, sensitivity analysis shows that Rate of Return strongly affected by well drilling cost and power plant cost (EPCC).

1. Introduction
Feasibility of developing a new geothermal power project depends on the financial return that would result from the investment [1]. A financial model is developed to simulate the financial return of a geothermal project. One of the strategies to achieve optimum return is formulating a financial model with a high level of confidence. Technical input parameters in the financial model are determined by the amount of available geothermal reserve in the form of a field development scenario. There are several methods in the geothermal potential calculation, which are volumetric, analytical, and numerical [2]. Numerical simulation is the best method if there are detailed and comprehensive data. This method can be used to predict reservoir performance in a long period [3]. The numerical
simulation result is very suitable to be used as input parameters of the technical aspects to increase the level of confidence in the financial model. Investment feasibility analysis of numerical simulation result on the Kepahiang, Bengkulu geothermal field has been carried out by [4]. However, the investment feasibility analysis used a single flow calculation, simulating one fixed value for each parameter. However, the real conditions of the field are very dynamic, having high risk and uncertainty. This weakness can be overcome by a probabilistic approach.

The probabilistic approach in investment feasibility analysis is beneficial in investigating risks that arise in geothermal investment [5]. The probabilistic method is not something new in the financial model. [5] developed Monte Carlo Simulator to determine Internal Rate of Return (IRR) and cash flow of geothermal projects. Then [1] used a Monte Carlo simulator to make probabilistic distribution of electricity tariff that meet specific investment criteria (e.g., the target of the Internal Rate of Return (IRR) or Net Present Value (NPV) target). However, both studies did not use numerical simulation result as input parameters.

A geothermal financial model was applied to three different development scenarios, 30 MW, 60 MW, and 110 MW in a specific field that has been studied by another researcher. The objectives of this study were first, to calculate and to evaluate electricity tariff based on Average Cost of Electricity Generation (in Indonesia, it known as Biaya Pokok Produksi or BPP) on the relevant local grid. Second, to calculate the amount of money needed and economic indicators (e.g., Net Present Value, Profitability Index and Pay Out Time), which meet 50% of Rate of Return value will be equal or less than 16% with probabilistic approach to build a new geothermal project for those scenarios. Lastly, to analyse sensitivity of financial parameters to Rate of Return. This model is the first geothermal financial model that used numerical simulation results and applied a probabilistic approach.

2. Karaha Talaga Bodas Field Overview and Development Scenarios
Karaha Talaga Bodas geothermal system is a partially vapor-dominated where there is a steam cap above the brine reservoir with temperatures ranging from 250°C to more than 350°C [6]. Four wells have been drilled in the Karaha area; two wells are productive wells and three wells in the Talaga area, one well is turned as a production well while two other wells cannot be produced because the fluids have a low pH [7]. Karaha-Talaga Bodas was developed by PT Pertamina Geothermal Energy which operates 1x30 MW commercially on April 6, 2018.

Numerical simulation in Karaha Talaga Bodas was studied by [8]. Probabilistic approach was applied to calculate geothermal reserve available. The results of P10, P50, P90 are 116 MWe, 120 MWe, and 125 MWe, respectively. The P10 is the basis for the development stage of the development plan. The production strategy for 30 years is made by utilizing the steam layer as a production zone and make-up well drilling zone to maintain the sustainability of production. [8] divided the development strategy of the Karaha-Talaga Bodas field into three scenarios which are 30 MW, 60 MW, and 110 MW. Table 1 shows the development strategies of the Karaha-Talaga Bodas field.

| Scenario       | 30 MW | 60 MW | 110 MW |
|---------------|------|------|-------|
| Production Well | 5    | 11   | 19    |
| Injection Well  | 3    | 3    | 3     |
| Make-up Well    | 3    | 4    | 22    |

3. Methodology
This study began by determining the technical input parameters in the financial model from 30 MW, 60 MW, and 110 MW scenarios in Karaha Talaha Bodas field. Technical input parameters were obtained from numerical simulation result. The number of production wells, make-up wells, and injection wells from each development scenario was selected as a technical input parameter for
financial model. Then probabilistic approach was applied on financial result (electricity tariff, total investment, and economic indicators). Lastly, sensitivity analysis of IRR was conducted to various financial parameters. Figure 1 shows the complete flow chart of this study.

![Figure 1. Working flowchart of this study.](image)

4. **Financial Model**
   A financial model is everything that is used to calculate, predict or estimate financial numbers [9]. In geothermal business activities, the financial model is built through a number of parameters. Those parameters are interconnected parameters in a financial model. The overall structure and interrelationships are shown in Figure 2.

4.1 **Geothermal Project Schedule**
   The activity schedule is made with a factorial approach or the percentage of project achievement per year. The project schedule is modified from geothermal development planning which made by [10]. Table 2 shows the geothermal project schedule Karaha Talaga Bodas field.

4.2 **Revenue**
   Geothermal income comes from the sale of geothermal electricity. The amount of revenue is influenced by the electricity tariff and geothermal capacity factor. The good performance of many geothermal plants around the world places the availability factor to be from 90-97% [11].

4.3 **Tangible and Intangible Capital Investment**
   A valuable financial geothermal model is one which integrates all the costs through all the phases of development and presents the resulting information in a manner to help various users make the appropriate decision [12]. Capital investment in the geothermal business is divided into two-part, namely upstream and downstream investment capital. Upstream capital investment concerns about steam availability and downstream investments related to electricity generation. The upstream capital investment consists of:
   1. Well Cost (Exploration Well, Production Well, and Injection Well)
   2. Land, Road Access and Site Work Cost
3. Steam Gathering System Cost
4. Piping and Production Facilities/ Steam Field Above Ground System (SAGS) Cost

![Diagram](image.png)

**Figure 2.** Financial model structure (modified from [13]).

Upstream capital investment is divided into two tangible and intangible capital investments. [14] assumed that intangible investment capital is 30% of wells, land, road access, and site work cost while the remainder is tangible investment capital. Downstream investment capital consists of:

1. Power Plant Detail Engineering Cost,
2. Power Plant Procurement/Construction Cost,
3. Commissioning Cost

Table 2 shows the capital investment cost assumption for Karaha Talaga Bodas field.

### 4.4 Expense

Likewise, expenses are also divided into upstream and downstream expenses. Upstream expenses consist of:

1. Exploration Survey (Geology, Geochemistry, Geophysics)
2. Core Holes Cost
3. Resource Study and Modelling Cost
4. Operation and Maintenance cost
5. Feasibility Study
Table 2. Karaha Talaga Bodas Field Project Schedule (modified from [10]).

| Parameters                                                                 | Years 1 | Years 2 | Years 3 | Years 4 | Years 5 | Years 6 | Years 7 | Years 8 |
|----------------------------------------------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|
| **STEAM FIELD DEVELOPMENT**                                               |         |         |         |         |         |         |         |         |
| Capital                                                                    |         |         |         |         |         |         |         |         |
| Exploration drilling                                                       | 50%     | 50%     |         |         |         |         |         |         |
| Production Well                                                            | 50%     | 50%     |         |         |         |         |         |         |
| Injection well                                                             | 50%     | 50%     |         |         |         |         |         |         |
| Make-up Well                                                               |         |         |         |         |         |         |         |         |
| Land cost, access and site work (included Env. Study and Civil Work)       | 100%    |         |         |         |         |         |         |         |
| Steam Gathering System and Substation, Connection to Grid (transmission)   | 50%     | 50%     |         |         |         |         |         |         |
| SAGS (Piping and Production Facilities)                                    | 50%     | 50%     |         |         |         |         |         |         |
| **Expense**                                                                |         |         |         |         |         |         |         |         |
| Detailed G-G-G Survey                                                     | 50%     | 50%     |         |         |         |         |         |         |
| Core holes                                                                 | 100%    |         |         |         |         |         |         |         |
| Resource study & Modelling                                                | 100%    |         |         |         |         |         |         |         |
| Operating cost (Upstream)                                                 |         |         |         |         |         |         |         |         |
| Feasibility Study                                                         | 100%    |         |         |         |         |         |         |         |
| **PLANT DEVELOPMENT**                                                     |         |         |         |         |         |         |         |         |
| Capital                                                                    |         |         |         |         |         |         |         |         |
| Power Plant (Engineering, Procurement, Construction, Commissioning          | 33%     | 33%     | 33%     |         |         |         |         |         |
| (Condensing Turbine)                                                       |         |         |         |         |         |         |         |         |
| **Expense**                                                                |         |         |         |         |         |         |         |         |
| Operating cost (Downstream)                                               | 14%     | 14%     | 14%     | 14%     | 14%     | 14%     | 14%     | 14%     |
| Other Cost (Administration/Management)                                     |         |         |         |         |         |         |         |         |

While downstream expenses consist of:
1. Operation and Maintenance Cost
2. Others (Management/Administration Cost)

Table 3 shows the expense assumption for Karaha Talaga Bodas Field.

4.5 Incentive Tax
Incentive tax is regulated in the Minister of Finance Regulation No. 21/PMK.011/2010 [15] concerning the provision of tax and customs facilities for activities to utilize renewable energy sources. Incentive tax in the form of income tax reduction include:

4.5.1 Investment Tax Allowance. The reduction tariff in net income is 30% of the total investment, charged for six years each at 5% per year.

4.5.2 Depreciation and Amortization. The depreciation period and rate are divided into four groups based on the type of assets. Group three has a depreciation period of 8 years and a depreciation rate of 25% (decline balance).
Table 3. Summary of Karaha Talaga Bodas Field Cost Components.

| Parameters                                                                 | Unit       | Price per unit (Million USD) | References |
|---------------------------------------------------------------------------|------------|------------------------------|------------|
|                                                                           |            | Minimum | Most-likely | Maximum |
| STEAM FIELD DEVELOPMENT                                                  | Capital    |          |             |          |
| Exploration drilling                                                      | Well       | $4.00   | $6.00       | $8.00    | [16]      |
| Production drilling                                                       | Well       | $4.00   | $6.00       | $8.00    | [16]      |
| Development makeup                                                        | Well       | $4.00   | $6.00       | $8.00    | [16]      |
| Injection well                                                            | Well       | $4.00   | $6.00       | $8.00    | [16]      |
| Land cost, access and site work (included env. Study and civil work)      | Activity /MW | $1.00   |             | $5.00    | [17]      |
| Steam Gathering System and Substation, Connection to Grid (transmission)  | Activity /MW | $0.24   | $0.32       | $0.44    | [10]      |
| SAGS (Piping and Production Facilities)                                   | Activity   | $0.33   | $0.35       | $0.40    | [18]      |
| EXPENSE                                                                  |            |          |             |          |
| Detailed G-G-G Survey                                                     | Activity   | $1.00   | $2.00       | $3.00    | [17]      |
| Core holes                                                                | Activity   | $1.00   |             |          | [17]      |
| Resource study                                                            | Activity   | $0.1    |             |          | [19]      |
| Operating cost (Upstream)                                                 | Activity /MW | $0.03   |             |          | [20]      |
| Feasibility Study                                                         | Activity /MW | $0.10   | $0.14       | $0.20    | [17]      |
| PLANT DEVELOPMENT                                                         | Capital    |          |             |          |
| Plant equipment construction & Install. (Include Design Engineering, Power Plant procurement/Constructions, Testing/Commissioning) | /MW        | $1.30   | $1.50       | $1.90    | [10]; [19] |
| EXPENSE                                                                  |            |          |             |          |
| Operating cost (Downstream)                                               | /MW        | $0.05   |             |          | [20]      |
| Other Cost (Administration and Management)                                 | Activity /MW | $0.25   |             |          | [19]      |

4.5.3 Production Bonus. Geothermal permit owner must expend production bonus to the regional government on the relevant work area. Production bonus is regulated in Law No. 21/2014 [21] concerning geothermal energy. The production bonus is charged with a certain percentage of gross revenues since the first unit commercially produced. The rate of production bonus is regulated in government regulation No. 28/2016 [22]. The production bonus is charged at 0.05% of the gross sales revenue of electricity with the provisions is not yet produced at the time Law No. 21/2014 [21] be in force, starting from the first unit is produced commercially.

4.6 Taxable Income
The corporate income tax rate in Indonesia is regulated in Law No. 36/2008 [23] concerning the fourth amendment to Law No.7/1983 concerning income tax. The compatible tariffs for a geothermal
corporation are 25% of gross income (after incentive tax reduction), which be in force since the 2010 tax year.

4.7 Loan
Debt: Equity can be adjusted by the user, which typical value is 70:30 [1]. In loans, several things need to be considered, namely the repayment period, Interest During Construction (IDC) and interest. The length of the repayment period will affect the amount of annual payment. The length of the repayment period, IDC and interest depend on the type of bank that provides the loan.

The Interest Rate “Commercial banks (e.g. HSBC, SCB) may offer interest rates in the range 8%-12%, but they have limited funds and frequently they syndicate together to provide the required debt. Even so, when the total funding requirements for a greenfield geothermal project are in the range US$500 Million - US$1 Billion even a commercial syndicate may not be able to cover the total debt and, in the case of projects in developing countries, bilateral or multilateral international development investment banks may need to be involved. These banks (such as JBIC, ADB, IADB, etc) have higher funds available that commercial banks and can offer lower interest rates in the range 4%-8%. Additionally, in certain circumstances in developing countries, “government to government” cooperation can offer lower interest rates even less than 4% such as World Bank, JICA, KfW, etc., with grace periods and much longer repayment periods than commercial or international development banks can offer” [1]. In this study, it is assumed that the development of the Karaha Talaga Bodas field owes from international development banks with an IDC and interest are same, which are 4%, a grace period of 7 years and a repayment period of 20 years.

4.8 Economic Indicators
Net Present Value is the discounted net value (present value) of expenditure and income over the project life using a nominated discount rate. If the NPV is greater than zero, then the investment is more attractive than the discount rate. Discount rates for geothermal projects are usually set at 10% [1].

The discount rate at which the net present is zero is the Internal Rate of Return (IRR). If the IRR is greater than the Required Rate of Return (RRR), then the proposed project is feasible to implement. The ideal IRR desired by the company is 16% regarding the statement of the previous Chairman of the Indonesian Geothermal Association (API), Abadi Poernomo [24].

PI is the ratio of the amount of present value cash flow in the future to the sum of the present value of the initial investment. If the PI is higher than one, then the investment is more attractive than the discount rate. PI higher than 1.2 is more sought in geothermal business [1].

POT is the length of time needed to recover all costs incurred in a project. POT can be a consideration in investing because a longer period usually is not too desirable in geothermal investment. All variable affecting financial modeling are summarized in Table 4.

5. Result
A probabilistic approach is applied with Monte Carlo simulation. Monte Carlo simulation is programmed using Excel® (Microsoft Corporation) spreadsheet. Monte Carlo simulation is implemented to calculate 90%, 50% and 10% of total investment and economic indicators (e.g., NPV, PI, and POT) estimate for 30 MW, 60 MW, and 110 MW scenarios in Karaha Talaga Bodas field.

5.1 Electricity Tariff and Average Cost of Electricity Generation (BPP)
Electricity tariff that meets 50% of Rate of Return value will be equal or not exceed 16%. Table 5 summarized electricity tariff calculation result for those scenarios. The 30 MW scenario’s electricity tariff result supports price renegotiation request from the developer, PT. Pertamina Geothermal Energy (PGE) to the buyers, PT Perusahaan Listrik Negara (PLN). PGE submits price increases from 8.6 cents / kWh to 11.6 cents / kWh [25].
**Table 4. Variables Affecting Financial Modelling.**

| Parameters                        | Value   | References   |
|-----------------------------------|---------|--------------|
| **Technical Factors**             |         |              |
| Capacity Factor                   | 90%     | [11]         |
| Production Well DSR               | 80%     | [18]         |
| Additional Production Factor      | 25%     | Expert Judgement |
| **Financial Factors**             |         |              |
| Tangible Cost                     | 30%     | [14]         |
| Depreciation Period              | 8 Years | [15]         |
| Depreciation Rate (Decline Balance) | 25%   | [15]         |
| Equity : Debt                     | 30 : 70 | [1]          |
| Loan Period                       | 20 Years | [1]          |
| Interest                          | 4%      | [1]          |
| Interest During Construction      | 4%      | [1]          |
| Production Bonus                  | 0.5%    | [22]         |
| Tax Rate                          | 25%     | [23]         |
| Investment Tax Allowance (for 6 years) | 5%  | [15]         |
| Discount Rate                     | 10%     | [1]          |

**Table 5. Electricity tariff calculation result for each scenario.**

| Scenario | 30 MW | 60 MW | 110 MW |
|----------|-------|-------|--------|
| Electricity Tariff (cents/kWh) | 13.90 | 11.75 | 11.85 |

The average cost of electricity generation (BPP) is calculated by summating the total generation, transmission, and distribution costs for PLN divided by the total sales of electricity produced for each island/(sub) grid (Van B, 2017). According to Ministry of Energy and Mineral Resources Regulation No. 12/2017, renewable energy tariff (including geothermal) negotiated in Power Purchase Agreement (PPA) between developer and buyer must not exceed the existing Average Generation Cost (BPP) on the relevant local grid. If the average local grid generation cost is lower than the average national generation cost, the tariff needs to be negotiated between the developer and the buyer. Geothermal ceiling price in Indonesia in 2019 are regulated in MEMR Regulation No.55 K/20/MEM/2019 [26].

Karaha Talaga Bodas field is located in West Java. Average West Java generation cost is 6.91 cents/kWh while the average national generation cost is 7.86 cents/kWh. The average West Java generation cost is lower than the average national generation cost that means the tariff need to negotiate between developer and buyer. The financial model result shows that electricity tariff of 30 MW, 60 MW, and 110 MW scenario in Karaha Talaga Bodas field is higher than the average generation cost of national and West Java. Therefore, electricity tariff or/and generation cost of 30 MW, 60 MW, and 110 MW scenario need to be negotiated.

5.2 Total Investment, and Economic Indicators

5.2.1 Total Investment. Table 6 depicts Monte Carlo simulation result of total investment per MW for 30 MW, 60 MW, 110 MW scenarios, respectively. Those investment is reasonable because the global
cost of development ranges from 3 to 6 million USD/MW [19]. For geothermal development in Indonesia, the average investment cost is estimated at around 4 million USD per installed MW [27].

Table 6. Monte Carlo simulation result of total investment/MW calculation result.

| Probability | Scenario | 30 MW | 60 MW | 110 MW |
|-------------|----------|-------|-------|--------|
| P10         |          | 4.98  | 4.44  | 4.10   |
| P50         |          | 5.34  | 4.74  | 4.37   |
| P90         |          | 5.72  | 5.04  | 4.66   |

5.2.2 Net Present Value (NPV). Table 7 illustrates Monte Carlo simulation result of Net Present Value (NPV) for 30 MW, 60 MW, 110 MW scenarios, respectively. Those development scenarios were feasible to be developed based on NPV because P10, P50, and P90 of NPV are positive.

Table 7. Monte Carlo simulation result of NPV calculation result.

| Probability | Scenario | 30 MW | 60 MW | 110 MW |
|-------------|----------|-------|-------|--------|
| P10         |          | 33.07 | 55.40 | 96.39  |
| P50         |          | 37.63 | 62.35 | 109.85 |
| P90         |          | 42.12 | 69.06 | 123.02 |

5.2.3 Profitability Index (PI). Table 8 illustrates Monte Carlo simulation result of Profitability Index (PI) for 30 MW, 60 MW, 110 MW scenarios, respectively. The investment in those development scenarios were attractive because the P10, P50, and P90 of PI were greater than 1.2.

Table 8. Monte Carlo simulation result of PI calculation result.

| Probability | Scenario | 30 MW | 60 MW | 110 MW |
|-------------|----------|-------|-------|--------|
| P10         |          | 1.30  | 1.30  | 1.29   |
| P50         |          | 1.37  | 1.37  | 1.35   |
| P90         |          | 1.45  | 1.44  | 1.42   |

5.2.4 Pay Out Time (POT). Figure 3 shows the cumulative cash flow for 30, 60, 110 MW generation. Based on the results of the geothermal cumulative cash flow projection for both 30 MW, and 60 MW scenarios, the developer will gain profit five years after commercial date while for 110 MW scenario was taken a year longer than both scenarios.
6. Sensitivity Analysis
Sensitivity analysis was conducted to see how the IRR could vary with regards to financial parameters. Figure 4-6 show sensitivity result of financial parameters for 30, 60, 110 MW, respectively in Karaha Talaga Bodas Field.

**Figure 3.** Cumulative cash flow for 30, 60, 110 MW generation.

**Figure 4.** Sensitivity result of financial parameters for 30 MW in Karaha Talaga Bodas Field.

**Figure 5.** Sensitivity result of financial parameters for 60 MW in Karaha Talaga Bodas Field.
7. Conclusion
According to the financial model, the following main conclusions can be made:
1. Electricity tariff or/and generation cost of 30 MW, 60 MW, and 110 MW scenarios in Karaha Talaga Bodas field are needed to be negotiated based on BPP.
2. The investment on those scenarios are attractive based on total investment and economic indicators forecasting.
3. Sensitivity results show that Rate of Return was strongly affected by exploration well drilling cost, development drilling cost and power plant (EPCC) cost.

8. Recommendation
Further improvements are required to make the model better, such improvements include:
1. Investigate detailed and updated data, especially for numerical simulation result and cost components because every field is unique.
2. Explore more tariff and non-tariff policy options and their updates, especially for income tax, incentive tax, and BPP values. Ministry of Energy and Mineral Resources (MEMR) sets the geothermal ceiling tariff based on annual BPP by referring to PLN’s proposal.
3. Generate scenario with lower IRR varied to represent the real condition (based on personal communication with an expert, IRR of geothermal in Indonesia is ranged from 12% to 14%).

9. Disclaimer
The financial model in this paper is based on numerical simulation results in the form of 30 MW, 60 MW, and 110 MW in Karaha Talaga Bodas field that have been studied by Prabata (2017). This financial model can be changed according to the amount of available data and the assumptions used.

References
[1] Quinlivan P, Batten A, Wibowo M, Hinchliffe S, Rahayu D, Doria I, Yahmadi A and Tondang H Y T 2015 Assessing Geothermal Tariffs in the Face of Uncertainty , a Probabilistic Approach Proceedings World Geothermal Congress 2015
[2] Ketilsson J, Axelsson G, Jonsson M T and Palsson H 2008 Production Capacity Assessment : Numerical Modeling of Geothermal Resources Proceedings Thirty-Third Workshop on Geothermal Reservoir Engineering Stanford University Stanford California
[3] Axelsson G 2016 Nature and Assessment of Geothermal Resources Presented at SDG Short Course I on Sustainability and Environmental Management of Geothermal Resource Utilization and the Role of Geothermal in Combating Climate Change organized by UNU-GTP and LaGeo
[4] Pane I A 2015 Analisis Kelayakan Investasi Pengembangan dengan Variasi Model Numerik Hasil Eksperimental Desain Plackett-Burman pada Lapangan Geothermal Kepahiang,
Bengkulu Institut Teknologi Bandung in preparation

[5] Fatony M G, K J P and A A F S 2010 Application of Monte Carlo Simulation for Determining IRR and Cash Flow of a Geothermal Project *Proceedings World Geothermal Congress 2010*

[6] Allis R, Moore J N, Mcculloch J, Petty S and Derocher T 2000 Karaha-Telaga Bodas, Indonesia: A partially vapor-dominated geothermal system *Geotherm. Resour. Counc. Trans.* 24

[7] GeothermEx I 1998 *Assessment of the Geothermal Resource in Karaha Talaga Bodas Area, Indonesia* Richmond California

[8] Prabata W 2017 *Aplikasi Permodelan Numerik Reservoir pada Studi Skenario Pengembangan Lapangan Geothermal Karaha-Talaga Bodas, Jawa Barat, Indonesia* Institut Teknologi Bandung

[9] Avadhut 2019 *Financial Modeling in 2019 The Definitive Guide* https://www.financewalk.com/financial-modeling-2/#what-is-financial-modeling

[10] Gehringer M and Loksha V 2002 *Geothermal Handbook: Planning and Financing Power Generation* World Bank Technical Report Energy Sector Management Assistance Program (ESMAP)

[11] Sarmiento Z F, Steingrimsson B and Axelsson G 2013 Volumetric Resource Assessment Presented at Short course V on Conceptual Modelling of Geothermal Systems organized by UNU-GTP and LaGeo

[12] Ngugi P K 2014 *Financial Modeling of Geothermal Power Projects Presented at Short Course VI on Utilization of Low- and Medium-Enthalpy Geothermal Resources and Financial Aspects of Utilization* organized by UNU-GTP

[13] Ashat A 2019 *Geothermal for Everyone* Institut Teknologi Bandung in preparation

[14] Danar A and Sukyar R 2010 *Energi Panas Bumi di Indonesia: Kebijakan Pengembangan dan Keputusan Investasi* Jakarta: Geological Agency of the Ministry of Energy and Mineral Resources

[15] Ministry of Finance Regulation 2010 *Pemberian Fasilitas Perpajakan dan Kepabeanan untuk Kegiatan Pemanfaatan Sumber Energi Terbarukan* (Republic of Indonesia) Law 21/PMK.011/ 2010

[16] Purwanto E H, Suwarno E, Lukman R F and Herdiyanto B 2018 Geothermal Drilling in Indonesia: a Review of Drilling Operation, Evaluation of Well Cost and Well Capacity *The 6th Indonesia International Geothermal Convention & Exhibition 2018 Jakarta*

[17] Antonaria, Rustandi D, Armstrong J, Brophy J, Sikumbang I, Nugroho H, Primana J R, Sunandar, Marizi N, Nugroho H T, Sinamora W P, Sinaga D V C R, Widayastuti N L, Hendrawijaya P and Mathieu T 2014 *Geothermal Handbook for Indonesia* ed M Girianna Directorate for Energy Resources, Mineral and Mining Ministry of National Development Planning / National Development Planning Agency (BAPPENAS) Jakarta

[18] Wahjosoedibjo A S and Hasan M 2018 Indonesia’s Geothermal Development: Where is it Going? *Proceedings, 43rd Workshop Geothermal Reservoir Engineering Stanford University*

[19] Henneberger R 2013 *Costs and Financial Risks of Geothermal Projects* Geothermal Exploration Best Practices Launch Event Istanbul Turkey

[20] South Pole Carbon Asset Management Ltd. and PT. Pertamina Geothermal Energy 2012 *Project Design Document: Project Karaha Unit 1 PT. Pertamina Geothermal Energy* UNFCCC/CCNUCC

[21] Ministry of Energy and Mineral Resources Regulation 2014 *Panas Bumi* (Republic of Indonesia) Law No.21/2014

[22] Ministry of Energy and Mineral Resources Regulation 2016 *Besaran dan Tata Cara Pemberian Bonus Produksi Panas Bumi* (Republic of Indonesia) Government Regulation No. 28/2016

[23] Ministry of Energy and Mineral Resources Regulation 2008 *Perubahan Keempat atas Undang-Undang Nomor 7 Tahun 1983 Tentang Pajak Penghasilan* (Republic of Indonesia) Law No. 36/2008
[24] Berita Satu Team 2012 23 Proyek Panas Bumi Terancam Mangkrak
https://www.beritasatu.com/ekonomi/60932/23-proyek-panas-bumi-terancam-mangkrak

[25] Dunia Energi Team 2018 Resmi Beroperasi, Harga Jual Listrik PLTP Karaha Unit I Belum Sesuai Keekonomian
https://www.dunia-energi.com/resmi-beroperasi-harga-jual-listrik-pltp-karaha-unit-i-belum-sesuai-keekonomian/

[26] Ministry of Energy and Mineral Resources 2019 Besaran Biaya Pokok Pembangkitan PT Perusahaan Listrik Negara Persero (Republic Indonesia) Regulation No. 55 K/20/MEM/2019

[27] Richter A 2017 Indonesia plans auction for geothermal projects valued at $1 billion
http://www.thinkgeoenergy.com/indonesia-plans-auction-for-geothermal-projects-valued-at-1-billion/