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# Probabilistic Assessment of Well Production Capacity in the Dieng Geothermal Field Using Monte Carlo Simulation and Jiwa Flow Modeling

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## *ABSTRACT*

*The Dieng Geothermal Field, located in Central Java, Indonesia, is a high-temperature geothermal system with two primary reservoirs: Sileri and Sikidang. This study aims to estimate the electricity production capacity of the reservoir using a probabilistic approach and Monte Carlo simulation with Jiwa Flow software. The methodology involves modeling well trajectory, casing data, and feed zone characteristics, incorporating uncertainty in reservoir parameters to generate probability distribution curves. The simulation results indicate that at 50% probability (P50), the estimated electricity capacity is 8.47 MWe, increasing to 11.66 MWe at 90% probability (P90), which is classified as proven reserves. At 99% probability (P99), the estimated capacity reaches 14.06 MWe, representing possible maximum reserves. These findings suggest that the Dieng reservoir has significant geothermal energy potential, predominantly characterized as a steam-dominated system, which is optimal for power generation. The study highlights that electricity production can be enhanced through reservoir management optimization and additional well drilling. The results provide a scientific basis for planning geothermal development, particularly in the expansion of Dieng Unit-2. Future research should focus on improving the accuracy of capacity estimations through real-time reservoir monitoring and extended field studies.*

*Keywords: Dieng Geothermal Field, Monte Carlo Simulation, Jiwa Flow, Probabilistic Analysis*

## ABSTRAK

Lapangan Panas Bumi Dieng, yang terletak di Jawa Tengah, Indonesia, merupakan sistem panas bumi bertemperatur tinggi dengan dua reservoir utama: Sileri dan Sikidang. Penelitian ini bertujuan untuk memperkirakan kapasitas produksi listrik dari reservoir dengan menggunakan pendekatan probabilistik dan simulasi Monte Carlo melalui perangkat lunak Jiwa Flow. Metodologi yang digunakan melibatkan pemodelan trajektori sumur, data casing, dan zona pasokan fluida, serta mempertimbangkan ketidakpastian dalam parameter reservoir untuk menghasilkan distribusi probabilitas kapasitas produksi. Hasil simulasi menunjukkan bahwa pada probabilitas 50% (P50), kapasitas listrik yang dapat dihasilkan adalah 8,47 MWe, meningkat menjadi 11,66 MWe pada probabilitas 90% (P90) yang dikategorikan sebagai proven reserve. Pada probabilitas 99% (P99), kapasitas maksimum yang diestimasi mencapai 14,06 MWe, yang mencerminkan possible maximum reserves. Temuan ini menunjukkan bahwa reservoir Dieng memiliki potensi energi panas bumi yang signifikan, dengan dominasi sistem steam-dominated, yang lebih optimal untuk pembangkitan listrik berbasis uap.Penelitian ini menegaskan bahwa produksi listrik dapat ditingkatkan melalui optimalisasi manajemen reservoir dan pengeboran sumur tambahan. Hasil penelitian ini memberikan dasar ilmiah dalam perencanaan pengembangan panas bumi, khususnya dalam ekspansi Unit-2 Dieng. Penelitian lanjutan perlu dilakukan untuk meningkatkan akurasi estimasi kapasitas melalui pemantauan reservoir secara real-time dan studi lapangan yang lebih mendalam.

Kata Kunci: Lapangan Panas Bumi Dieng, Simulasi Monte Carlo, Jiwa Flow, Analisis Probabilistik

## I. INTRODUCTION

The Dieng Geothermal Field is located northwest of Yogyakarta City and 26 km north of Wonosobo Regency, in Central Java Province, Indonesia. Located within the Dieng Plateau, the geothermal field is characterized by its mountainous topography. At elevation between 1,950 to 2,150 meters above sea level, the area densely populated and extensively cultivated, especially for potatoes and vegetables. The Dieng Geothermal Field is located on the eastern side of the North Serayu Geo-anticline, which is influenced by the southern Java subduction zone. Dieng lies within a volcanic mountain range northwest-southeast (NW-SE) trending volcanic mountain range, characterized by notable features such as Pagarkendang, Merdada, Sikidang and Pakuwaja Craters. This geological trend These geological trends are believed to govern volcanic activity in the region, as evidenced by Mount Sindoro and Sumbing, which are located to the southeast of the field and also follow this trend.

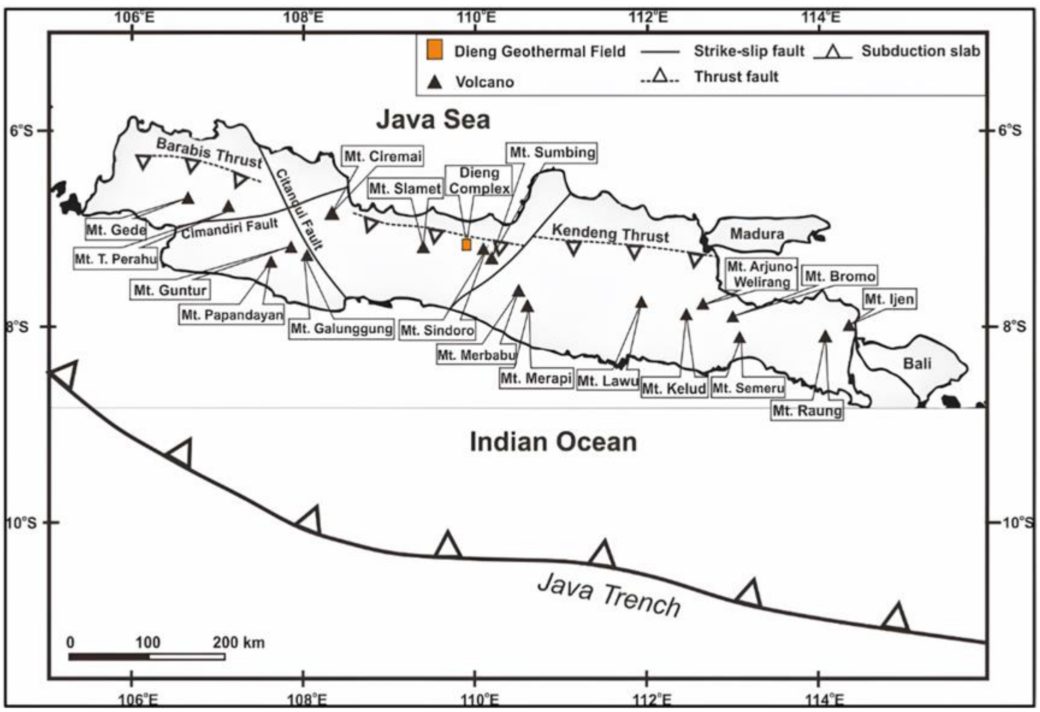


Figure 1.1 The Dieng Geothermal Field's location in relation to Java's main Quaternary volcanoes on a simplified tectonic map of the island (Simandjuntak & Barber, 1996)

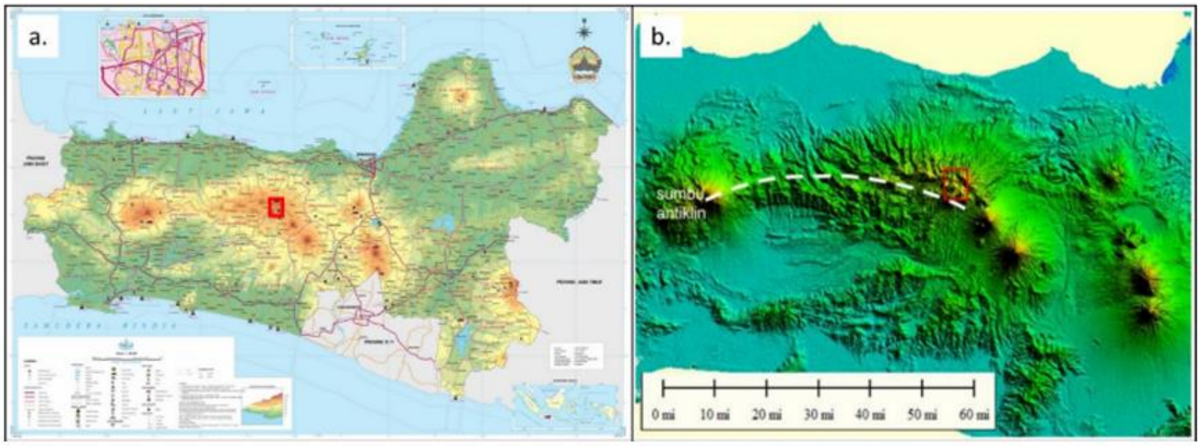


Figure 1. 2 a). Central Java Province, Indonesia, with Dieng Geothermal Fieldis remarked by red box.
b). North Serayu Gea-anticline (Alamsyah et al., 2024)

To begin with, the first investigation into the geothermal resources of Dieng was initiated in 1918 by the Dutch Colonial government. Subsequently, between 1964 and 1965, UNESCO recognized Dieng as one of Indonesia's most promising geothermal prospects. In 1970, the United States Geological Survey (USGS) conducted geophysical surveys and drilled six temperature core holes to a depth of 150 meters in 1973, where temperatures ranged from 73 to 92°C. Following this, in 1974, Pertamina carried out geological, geophysical, and geochemical surveys, eventually completing 27 wells between 1977 and 1994 On December 2, 1994, Himpurna California Energy (HCE) entered into a Joint Operation Contract (JOC) with Pertamina and an Energy Sales Contract (ESC) with PT (Persero) Perusahaan Listrik Negara (PLN). By 1998, HCE had completed its development program, which included five temperature core holes and 18 full-sized production wells, in addition to initiating geoscientific surveys. The core holes were drilled to depths of 600 to 900 meters, aiding in the determination of rock types, alteration zoning, and subsurface temperature distribution. One core hole uncovered an area of high temperature in the southern part of the field (Pakuwaja area), indicating potential for future development. In total, 18 full-sized wells were completed to depths ranging from 2,591 to 3,214 meters between September 1, 1995, and February 27, 1998, with three of these classified as non-commercial wells. However, in 1998, well HCE-10B was suspended during drilling due to economic uncertainty in Indonesia. All wells produced liquid steam, with output ranging from 2.3 to 23 MWe, leading to an estimated total of 192 Mwe (gross) available.

The development of geothermal resources in the Dieng region has entered the expansion stage with the construction of Unit 2, which aims to increase the production capacity of electrical energy from available geothermal resources. In an effort to support the optimization of resource utilization, this research focuses on the calculation of production well capacity with a probabilistic approach and Monte Carlo simulation method. This method is applied to accommodate the uncertainty in the estimation of well performance and the potential energy production that can be generated. In addition, this study also applies a production decline model based on the Hegerdous and Brown approach, which enables a more comprehensive analysis of long-term production behavior. All analyses in this study were conducted using Jiwa Flow software, which is a simulation tool designed to evaluate the performance of production wells in geothermal systems. The results of this approach produce more accurate well production capacity estimates and production performance projections that can be used as a basis for planning the development of geothermal resources in the Dieng region.

## II. METHODOLOGY

Monte Carlo methods are a broad class of computational algorithms, which rely on repeated random sampling to obtain numerical results (Gumati Puji,2013). repeated random sampling to obtain numerical results (Gumati Puji,2013). Monte Carlo simulation simulation is used to generate the probability distribution of a variable that depends on other parameters. other parameters. Invented by John Neumann and Stanislaw Ulam (1940) as a decision-making tool in uncertain conditions, Monte Carlo simulation is used to generate decision-making tool under uncertain conditions, this simulation performs risk analysis by build a model that allows by changing the range of values that have uncertainty. uncertainty. Then, the simulation calculates the results repeatedly using different random values of the probability function until it produces a distribution of possible values. distribution of possible values. In the geothermal context, the application of this method is done by using random probability distributions of potential parameters as input to generate probability distribution curves and confidence generate probability distribution curves and confidence levels in the calculation of potential (Hamidah, 2021).

Basically, this can be done with licensed software. However, in this case, the Monte Carlo stochastic simulation algorithm was applied using Jiwa Flow due to its advantages in geothermal fluid modeling. Jiwa Flow allows simulations to be performed locally as well as in web-based applications, and supports various operating system configurations such as Linux, Microsoft Windows, and MacOS. In addition, the software is designed to comprehensively model reservoir characteristics, including the estimation of well production capacity with a probabilistic approach.

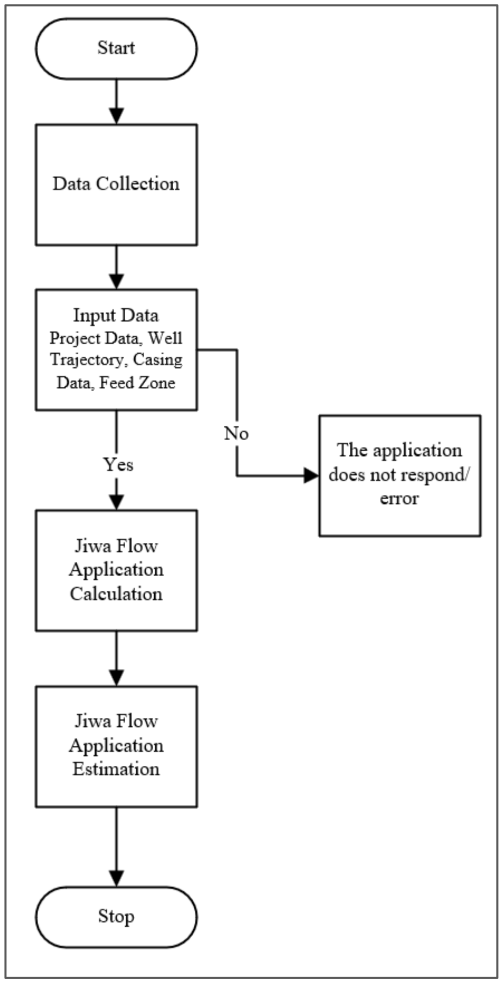


Figure 3 Flowchart of Geothermal Well Production Estimation Using Jiwa Flow

The steps to run the Monte Carlo stochastic simulation and process the results using Jiwa Flow begin with a data collection stage that includes project data, well trajectories, casing data, and geothermal fluid supply zones. This data is then entered into the Jiwa Flow application as the main input for the simulation. After the data is entered, the system will check if the application is running normally. If an error occurs or the application does not respond, then the process must be stopped and repairs made before continuing the simulation. If the application runs properly, then the next step is to perform simulation calculations using Jiwa Flow, where the parameters that have been entered will be processed using the Monte Carlo method to accommodate uncertainty in the calculation of well production capacity. After the calculation is complete, the next stage is the estimation of well production capacity, where the results of the probabilistic calculation are analyzed to obtain the distribution of output values. These results can be visualized in the form of probability distributions or histograms to understand the variation of production capacity based on the given input data. The process then ends with validation of the results and interpretation of the production estimates obtained. The detailed flow of well production capacity estimation using Jiwa Flow can be seen in Figure 2.

## III. DISCUSSION

In the Dieng geothermal field there are two reservoirs, namely the Sileri and Sikidang reservoirs, the Sileri Reservoir is a two-phase liquid dominant system, with a temperature of 283 - 338°C. The reservoir fluid is neutral, with Cl content between 9,600 - 19,000 mg/kg and NCG < 1 wt%. Rock-water interaction is significant, with upflow zones at Sileri and Merdada, and outflow at Well-H, Well-12, Well-3, Well-I, Siglagah, and Bitingan. In contrast, the Sikidang reservoir has a two-phase system, with temperatures of 260 - 324°C. The fluid is acidic in some wells, with Cl content of 3,400 - 23,800 mg/kg and NCG of 2 - 21 wt%, indicating a stronger influence of magmatic gas. Rock-water interaction is also greater than at Sileri. The upflow zone is in Sikidang, while the outflow includes Well-L, Well-M, Pulosari, Pakuwaja, and Jojogan.

The first parameters that must be seen in calculating well capacity are well trajectory, casing data and feed zone. Table 1 is the input data to calculate well production capacity for several production wells in Dieng.

### Input Parameter

Table 1 Project Data Input in Jiwa Flow

| No. | Description | Case Name | Pressure Drop Correlation | Number of runs | WHP Specified (bar) | P Separator (bar) | SSC (kg/s)/MW) | SBC (kg/s)/MW) |
|---|---|---|---|---|---|---|---|---|
| 1 | Probabilistic Production Well Performance | Probabilistic Production Well Performance | Hagedorn and Brown Pressure Drop Correlation | 1000 | 15 | 2 | 1.85 | 0 |

Table 2 Well Trajectory Data Input in Jiwa Flow

| Wellhead Elevation Well | MD | TVD (m) | Elevation (masl) | Angle (deg) |
|---|---|---|---|---|
| 1250 | 500 | 500 | 750 | 0 |
| | 1500 | 1500 | -250 | 0 |
| | 2500 | 2500 | -1250 | 0 |

Table 3 Casing Data Input in Jiwa Flow

| MD (m) | TVD (m) | Eleavtion ( masl) | Code | Casing Size (inch) | Casing Grade | OD (m) | ID (m) | Rounghnes (mm) |
|---|---|---|---|---|---|---|---|---|
| 500 | 500 | 750 | Production Casing | 13 3/8 | 54.5 lb/ft J-55 | 0,34 | 0,32 | 0,045 |
| 1500 | 1500 | -250 | Perforated Linear | 10 3/4 | 40.5 lb/ft J-55 | 0,273 | 0,255 | 0 |
| 2500 | 2500 | -1250 | Perforated Linear | 8 5/8 | 24 lb/ft J-55 | 0,219 | 0,206 | 0 |

Table 4 Feed Zone Data Input in Jiwa Flow

| M.Depth (m) | Pressure (bar) | Entalpy | | PI | |
|---|---|---|---|---|---|
| | | min (kJ/kg) | max (kJ/kg) | min (kg/s.bar) | max (kg/s.bar) |
| 1650 | 100.76 | 1200 | 1400 | 0.1 | 0.5 |
| 2370 | 148.72 | 1100 | 1200 | 0.1 | 1 |

**Output Parameter**

Tabel 5. Production Well Output in Jiwa Flow

| Probability (n) | Mass (kg/s) | Enthalphy (kJ/kg) | MWe Steam | MWe Brine | MWe Total |
|---|---|---|---|---|---|
| 1 | 21.63 | 1114.57 | 3.59 | 0 | 3.59 |
| 10 | 32.83 | 1142.81 | 5.52 | 0 | 5.52 |
| 20 | 38.36 | 1155.22 | 6.37 | 0 | 6.37 |
| 30 | 42.3 | 1166.53 | 7 | 0 | 7 |
| 40 | 46.81 | 1175.88 | 7.84 | 0 | 7.84 |
| 50 | 51.22 | 1183.82 | 8.47 | 0 | 8.47 |
| 60 | 55.13 | 1192.52 | 9.14 | 0 | 9.14 |
| 70 | 59.35 | 1201.73 | 9.89 | 0 | 9.89 |
| 80 | 63.66 | 1213.74 | 10.64 | 0 | 10.64 |
| 90 | 69.51 | 1231.7 | 11.66 | 0 | 11.66 |
| 99 | 81.1 | 1285.31 | 14.06 | 0 | 14.06 |

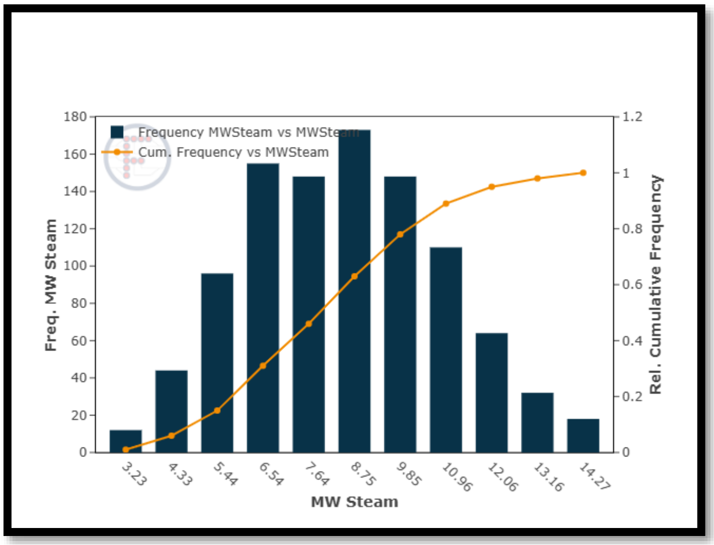


Figure 4 MW Steam  Output Chart in Jiwa low

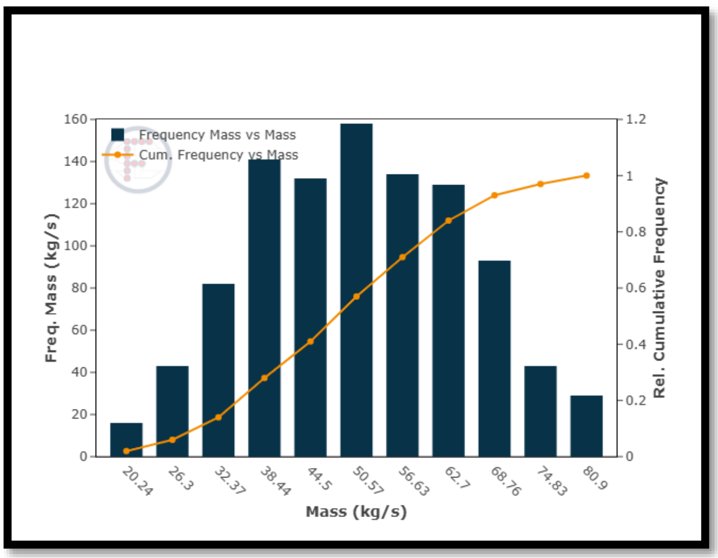


Figure 5 Mass Output chart in Jiwa Flow

The figure above shows the relationship between the production probability and the parameters of fluid mass, enthalpy, and generated electrical power (MWe). At 50% probability (P50), the estimated electrical power that can be generated is 8.47 MWe, with a mass flow rate of 51.22 kg/s and an enthalpy of 1183.82 kJ/kg. When the probability increases to 90% (P90), the power generated rises to 11.66 MWe, indicating that this value can be considered a proven reserve based on the probabilistic approach. Meanwhile, at 99% probability (P99), the estimated production capacity reaches 14.06 MWe, which can be categorized as possible maximum reserves. These results show that the potential electric power that can be generated varies between 3.59 MWe and 14.06 MWe, depending on the probability level applied in the simulation. The initial estimate at P50 shows a stable capacity of 8.47 MWe, which can be used as a reference in the development of geothermal-based power generation projects. In addition, the absence of brine production in this estimate indicates that the geothermal system studied is more oriented towards steam-dominated reservoirs, which are more optimal for steam-based power production. This capacity estimate can be improved with further exploration, drilling of additional wells, and optimization in reservoir management to maximize the production and sustainability of geothermal power plants.

## IV. CONCLUSION

This study uses the probabilistic method and Jiwa Flow software-based Monte Carlo simulation to estimate the electricity production capacity of the Dieng geothermal reservoir. The simulation results show that at 50% probability (P50), the electricity capacity that can be generated reaches 8.47 MWe, while at 90% probability (P90), the capacity increases to 11.66 MWe, which can be categorized as proven reserve. Estimates at 99% probability (P99) show a maximum capacity of 14.06 MWe, reflecting possible maximum reserves. This study confirms that the Dieng reservoir has significant electricity production potential, with the possibility of increasing capacity through reservoir management optimization and drilling additional wells.

## V. REFERENCES

Alamsyah, R. R., et al. (2024). Project development update of the Dieng Unit-2 geothermal power plant, Dieng geothermal field, Indonesia. *Proceedings of the Workshop on Geothermal Reservoir Engineering*. California: Stanford University.

Alamsyah, R., et al. (2023). Individual feed zone characterization in two-phase geothermal reservoir for preliminary indication while drilling: A case study Dieng field, Indonesia. *Proceedings of the Stanford Geothermal Workshop*.

Allahvirdizadeh, P. (2020). A review on geothermal wells: Well integrity issues. *Journal of Cleaner Production, 275*, 124009. https://doi.org/10.1016/j.jclepro.2020.124009

Ashat, A., et al. (2019). Numerical simulation update of Dieng geothermal field, Central Java, Indonesia. *Proceedings of the 41st New Zealand Geothermal Workshop 2019*.

Asian Development Bank & The World Bank. (2015). Unlocking Indonesia's geothermal potential. *Philippines: Author*.

Gumati, N. P. (2013). Aplikasi metode Monte Carlo pada penentuan harga opsi Amerika (*Undergraduate thesis*). Universitas Pendidikan Indonesia. Retrieved from repository.upi.edu

Hamidah, A. T. (2021). Perbandingan perhitungan metode pengkajian potensi panas bumi antara volumetrik dan mass-in-place (MIP) dengan simulasi Monte Carlo: Studi kasus lapangan panas bumi Ulumbu (*Master's thesis*)

Hasan, A. R., & Kabir, C. S. (2010). Modeling two-phase fluid and heat flows in geothermal wells. *Journal of Petroleum Science and Engineering, 71*(1-2), 77-86.

Kencana, A. Y., et al. (2024). Initial state fluid geochemistry of the Dieng geothermal field, Indonesia: New constraints for conceptual model. In *Proceedings of the 49th Workshop on Geothermal Reservoir Engineering*. Stanford, CA: Stanford University.

Prabata, W., Situmorang, J., & Nainggolan, T. (2021). JIWAFlow: A cloud computing wellbore simulator. In *Proceedings of the 46th [Conference/Workshop Name, if available]* (Vol. 1963, pp. 1–5).

Quinao, J. J., & Zarrouk, S. J. (2014, February). Applications of experimental design and response surface method in probabilistic geothermal resource assessment–preliminary results. In *Proceedings of the 39th Workshop on Geothermal Reservoir Engineering*. Stanford, CA: Stanford University.

Simandjuntak, T. O., & Barber, A. J. (1996). Contrasting tectonic styles in the Neogene orogenic belts of Indonesia. *Geological Society, London, Special Publications*, *106*(1), 185-201.

Sirait, P., Ridwan, R. H., & Battistelli, A. (2015). Reservoir modeling for development capacity of Dieng geothermal field, Indonesia. In *Proceedings of the 40th Workshop on Geothermal Reservoir Engineering*. Stanford, CA: Stanford University.

Supriyadi, S., Srigutomo, W., & Munandar, A. (2014, March). Application analysis of Monte Carlo to estimate the capacity of geothermal resources in Lawu Mount. In *AIP Conference Proceedings* (Vol. 1589, No. 1, pp. 108-111). American Institute of Physics.