Available online: http://journal.uir.ac.id/index.php/JEEE/index

Journal of Earth Energy Engineering

Publisher: Universitas Islam Riau (UIR) Press

The development of geothermal energy as a renewable power plant

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Article History:

Received: May 20, 2023
Receive in Revised Form: May 31, 2023
Accepted: June 10, 2023

Keywords:

Geothermal energy, power plant, government policy, renewable energy.

Abstract

Geothermal energy is a sustainable and ecologically beneficial energy source, it is believed that Indonesia alone has 40% of the world's geothermal energy reserves of roughly 28.000 MW. The Indonesian government expects the geothermal power plant installed capacity to reach 10.000 MW by 2025. However, the installed capacity remained at 1.739 MW until 2014. Aside from that, the Indonesian government has made significant investments to expand the geothermal sector through different current rules. This research aims to determine the absorption of geothermal energy as an alternative to power generation and many elements of the associated hurdles, such as natural and human resources. In addition, this paper also creates new model parameters that significantly improve model performance. Analysis of system dynamics methods and modelling and simulation methods are used for fast and accurate results. According to a literature analysis done by collecting secondary data from journals and associated research publications, existing conditions are judged insufficient to meet the installed capacity of geothermal energy with a target of 3.458 MW in 2025 based on simulation results of forecasts through 2050. Factors impeding progress include the government's lack of coordination and implementation difficulties. Furthermore, because the financial sector was redirected to cope with the economic crisis, the pandemic scenario in 2020 was one of the impediments. Based on these criteria, the optimum solution was sought by expanding installed electricity capacity and raising the selling price of geothermal power with a target of 24.5% and electricity output of 13.263 GWh.

INTRODUCTION

Indonesia's population growth will raise energy demand. Similarly, energy, particularly electricity, is required to ensure the rate of economic expansion. With Indonesia's energy mix now dominated by fossil-based fuels, it is vital to generate power from renewable sources to ensure Indonesia's energy security. Geothermal energy is a renewable source of energy (Barbier, 2002). Unlike power plants that burn fossil fuels to generate electricity, geothermal power plants emit extremely minimal GHG emissions since there is no combustion process, making geothermal an ecologically beneficial energy source. Indonesia is currently building new power plants to accommodate rising electricity demand. However, fossil fuel-powered power generation, such as coal, oil, and gas, continues to dominate established power plants. Up to 2030, it is anticipated that fossil fuel-powered power plants will account for up to 78.32% of total power generation, with renewable energy accounting for the remaining 21.68% (Agung, 2019).

Geothermal Power Plant was designed to provide more ecologically friendly electrical energy in order to save the planet. Geothermal energy is the energy stored in the Earth's interior as heat. The source of this heat is tied to our planet's interior structure and the physical processes that occur there. Even though this heat exists in vast, nearly limitless quantities in the Earth's crust, not to mention the deeper sections of our

DOI: 10.25299/jeee.2023.13956
eISSN: 2540-9352 pISSN: 2301-8097

globe, it is irregularly distributed, seldom concentrated, and frequently at depths too large to be harnessed industrially (Pambudi, 2018). The energy in geothermal fluid is water, which can be vapour, liquid, or a mixture of both. The fluid is normally found at a depth of more than 1 kilometre below the earth's surface (Nasruddin et al., 2016) Geothermal energy is found in an area spanned by a fire ring (Ring of Fire), as seen in Figure 1.

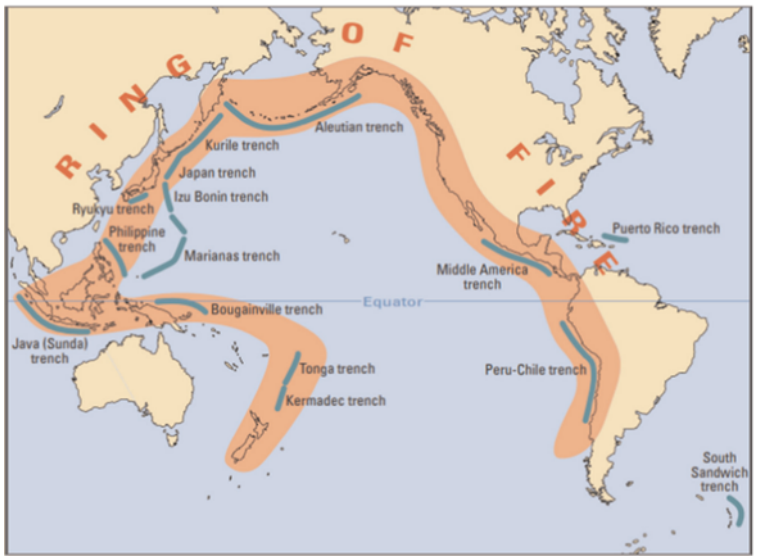

Figure 1. Ring of fire (National Geographic, 2023).

Geothermal energy originates as a result of three critical factors in a specific area inside the earth: a heat source, water, and a permeable layer. Geothermal energy has the potential to provide the world's energy needs for the next 100,000 years. In comparison to other prospective materials, Indonesia has considerable geothermal potential. Indonesia has 28,617 MW of geothermal potential but only 1343,5 MW of existing capacity. According to the National Energy Master Plan, Indonesia expects to reach 7.24 gigatonnes of geothermal energy by 2025 (at a cost of $15 billion, according to government authorities), and 9.3 gigatonnes by 2035 (Suharmanto et al., 2015).

Regardless of Indonesia's potential and aspirations in the field of geothermal, there are several hurdles to overcome while attempting to establish a geothermal power plant in Indonesia. As a result, the purpose of this research is to assess the development of geothermal power plants from a government regulatory standpoint, as well as the individuals impacted by geothermal power development and its impediments.

METHODS

This study takes a qualitative approach, evaluating the literature on the issue during the development stages. By corporate work reports and pertinent publications, the subjects of this research are residents affected by the existence of Geothermal Power Stations developed by Supreme Energy in West Sumatra. In Indonesia, there are various laws that may be applicable to geothermal activity, including geothermal legislation and environmental protection law. Geothermal legislation governs the scope, area, and licensing of geothermal activities. When geothermal operations occur within a forest, forestry legislation must be considered. Geothermal firms must additionally address water law rules to regulate their water consumption in geothermal cooling systems and water re-injection. The environmental protection legislation is crucial to examine since the use of geothermal resources requires an environmental license, which is governed by the environmental protection law.

RESULTS AND DISCUSSION

There are several energy solutions for meeting power consumption from the standpoint of energy supply. However, the average utilized thus far is still fossil-based, while renewable energy, which is more ecologically benign, has a lesser percentage of the national energy mix. In 2020, coal will account for 38.04% of Indonesia's national energy mix, followed by petroleum (33.58%), and natural gas (19.16%). Meanwhile, renewable energy (wind, sun, bioenergy, geothermal, and water) accounted for 11.2% of total energy consumption (Alison et al., 2012) (Table 1). This demonstrates that the use of renewable energy is still not dominated by fossil fuels.

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Table 1. The national energy mix based on new and renewable energy information and investment services and energy conservation 2020.

Num.	Types of energy	Years (%)				
		2016	2017	2018	2019	2020
1	Coals	29.85	30.53	32.97	37.15	38.04
2	Renewable energy	6.47	6.34	8.55	9.15	11.2
3	Gas	21.75	20.61	19.67	20.12	19.16
4	Oils	41.93	42.52	38.81	33.58	33.58

Currently, Indonesia's geothermal energy utilization in 2020 remains unchanged from the previous year at 2,130.7 MW, or around 8.9% of its capacity - the breakout of the COVID-19 epidemic in early March 2020 prompted renewable energy facilities to endure a delay in COD time. "Commercial Operation Date" is the date when a power plant begins running to deliver electrical energy to PT PLN Persero's electricity network due to the existence of the Large-Scale Social Restriction Policy so that there is no extra installed capacity (State Electricity Company. 2021). The case study of the development of the Geothermal Power Plant by Supreme Energy, which has been inaugurated by The Ministry of Energy and Mineral Resources created the Development of Geothermal Resources by Supreme Energy Muara Laboh (SEML) Geothermal Mining Working Area in West Sumatra Province on March 30, 2009. Supreme Energy Muara Laboh (SEML) was also granted a Geothermal Mining Business License by the South Solok Regent on April 26, 2010. Supreme Energy Muara Laboh (SEML) commenced exploratory efforts in 2010, including Micro Earth Quake (MEQ) surveys, topographical surveys, infrastructure development/civil works, and land acquisition activities. Drilling construction at the exploratory stage commences following the signing of the Power Purchase Agreement with the State Electricity Company (PLN). In September 2012, the first exploratory well was dug. The goal of the exploration is to discover enough potential geothermal energy to build a 250-Megawatt power station. This facility will be supplied with steam by a network of steam flow pipes emanating from 13 (thirteen) or more well pads, with a total of 24 - 27 output wells (Stimac, 2019). Based on the Supreme Energy website and P.E. Indonesia, The development and construction phase of the Geothermal Power Plant (GPP) began in March 2017, and the generated electricity is channelled through the 150 KV High Voltage Transmission Line and connected to the Sumatra electricity toll road network owned by PT PLN (Persero) based on a 30-year Power Purchase Agreement. To develop this GPP project, PT SEML appointed a consortium of Sumitomo Corporation and *Rekayasa Industri (Rekind)* as EPC contractors. The main equipment of the turbine and generator is produced by Fuji Electric. After a long journey since 2008, starting from the preliminary survey process, and exploration, to the development stage, on December 16th, 2019, PT. Supreme Energy Muara Laboh (SEML) announced the commercial operation of Unit I Muara Laboh Geothermal Power Generation located in West Sumatra Province. The power generation has a capacity of 85 MW net.

Meanwhile, according to Darma et al. (2021), geothermal development can preserve forests because geothermal systems maintain the necessary balance of protection forest that serves as a catchment area, reliability of electric power generated from geothermal energy can be sustained over a long period of time (more than 30 years), utilization of geothermal energy does not require large tracts of land, and The Muara Laboh field, which has 300 MW of geothermal potential, features a 70 MW institution. The Muara Laboh Geothermal Field, according to the Geothermal Mining Business Permit, is located between 450 and 1,500 meters above sea level (asl), has an area of approximately 62,300 hectares (ha), and is adjacent to the Kerinci Seblat National Park (Kerinci National Park) on the west and south sides. Nevertheless, developing a geothermal power plant in Indonesia, like at the Muara Laboh Geothermal Field, is lengthy.

Problems in developing geothermal power plants in Indonesia are caused by several factors including the stigma of the local community over the construction and development of geothermal power plants. According to Malau et al. (2020), the main factors of the un-favourable public stigma towards the construction and development of Geothermal Power Plants especially in Muara Laboh Geothermal Power Plant are caused by the limited knowledge of geothermal energy for them, the existence of geothermal energy was not seen as renewable and sustainable energy. The global level of geothermal energy uses sustainable alternative energy and reduces our dependence on fossil energy, which is considered harmful to the environment. But such stories, whether the narrative is true or false, are underrepresented by the masses. Local or affected communities said they would not benefit from using geothermal energy in their area. Furthermore, community involvement in the planning process is also low, as evidenced by only a small

fraction of those communities who know about corporate and government socialization. So, this is certainly a concern about future rejection from the community, and it could turn into a dispute. Not only that, but there are also challenges that might impact the process's sustainability during the creation of a geothermal power plant, which includes exploration, feasibility studies, extraction, and utilization. One of the barriers to the development of geothermal energy as a source of power generation during the exploration stage is the unpredictability of identifying and calculating geothermal reserves in a geothermal operating region. Because the stages of geothermal extraction cannot be paralleled, the development of geothermal power plants takes longer than that of conventional power plants. Because geothermal resources cannot be relocated, the building of the power plant must follow the position of the source, and the plant will only be developed if the existing resources are confirmed (Greencap NAA Indonesia, 2015). Before starting the development stage, the manager or holder of a Mine Business Permission or Geothermal Permit must get an Environmental Permit from the local government and the Ministry of Environment and Forestry if the project is in a forest area. Community uncertainty influences land purchases in addition to environmental licenses. The subsurface system, which includes heat sources, reservoirs, fluid flow mechanisms, and so on, and the surface system, which includes steam field facilities known as SAGS or Steam-field Above Ground System; however, rights to the working area do not include rights to surface land. If the population surrounding the geothermal source is unwilling to give their property, the surface system (above-ground system) will not be built, but geothermal power plants cannot be built far from the source. In comparison to other power plants, the development of geothermal energy utilization for indirect utilization necessitates a significant investment of around US$ 4.7 million/MW (Sofyan, 2012).

From the law implementation, the Geothermal Law in Indonesia is governed by Law No. 21 of 2014 on Geothermal Resources. The purpose of this law is to encourage the development of geothermal energy as a vital source of renewable energy for the country. It declares geothermal energy a national asset and directs the government to develop, administer, and use it for the benefit of the Indonesian people. The legislation establishes a legal framework for geothermal resource exploration, development, production, and consumption in Indonesia. Before engaging in any geothermal resource-related activity, enterprises must seek government licenses and permissions. The legislation also requires that geothermal exploration and development be done in an ecologically friendly way and that local populations' rights be maintained. In addition, the Indonesian Geothermal Law stipulates a revenue-sharing system between the government and geothermal developers. The government obtains a portion of the cash generated by geothermal projects, which is subsequently distributed to local communities and used to assist the geothermal sector's development (President of the Republic of Indonesia, 2014; Sahdarani et al., 2020).

From that several factors, Prior to the construction and development of a geothermal power plant, thorough knowledge is given to the local community on the impacts and risks if a geothermal power plant is built in the area. If development is carried out in the village area, the developer should adapt to the customs of the community in the area. Indonesia's Geothermal Law establishes a legislative framework that encourages the development of geothermal energy in a sustainable and responsible manner. It promotes private sector investment while ensuring that the advantages of geothermal resources are shared by all stakeholders, including local people and the Indonesian government. Not only that, from the implementation of regional autonomy through Law No. 22 of 1999, which gives authority to the regions to formulate regional energy plans and policies; The objective of Law No. 30/2009 on electricity is to promote the use of local and renewable energy; worldwide environmental pressure supports the development of new and renewable energy, including geothermal, through incentive incentives; legal clarity can restore investor trust (President of the Republic of Indonesia, 2014; Sahdarani et al., 2020).

CONCLUSION

The stigma of the local community over the construction and development of geothermal power plants in Indonesia is caused by limited knowledge of geothermal energy. The development of geothermal energy as a source of power generation is hindered by the unpredictability of identifying and calculating geothermal reserves in a geothermal operating region. Before starting the development stage, the manager or holder of a Mine Business Permission or Geothermal Permit must get an Environmental Permit from the local government and the Ministry of Environment and Forestry if the project is in a forest area. Community uncertainty influences land purchases in addition to environmental licenses. The Geothermal Law in Indonesia is governed by Law No. 21 of 2014 on Geothermal Resources, it declares geothermal energy a national asset and directs the government to develop, administer, and use it for the benefit of the Indonesian people. It establishes a legal framework for geothermal resource exploration, development, production, and consumption, and requires that enterprises seek government licenses and permissions. Indonesia's Geothermal Law encourages private sector investment while ensuring that the advantages of geothermal resources are shared by all stakeholders. Law No. 22 of 1999 gives authority to the regions to formulate regional energy plans and policies; Law No. 30/2009 on electricity promotes the use of local and renewable

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energy; worldwide environmental pressure supports the development of new and renewable energy through incentive incentives; and legal clarity can restore investor trust.

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