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Review of geothermal potential in Indonesia and the impact on climate change in the future

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ABSTRACT

Electricity is crucial at this time, but the challenge lies in reducing and replacing the use of fossil fuels, as continuous use will exacerbate climate change and harm the world. The best solution is to replace it with new renewable energy sources, such as geothermal energy, which has significant potential in Indonesia. The most considerable geothermal potential in the world is 29.038 MW. This paper uses the literature review method. The criteria for articles used as sources are research-type articles. The purpose of this article is to review the geothermal potential in Indonesia, which can be utilised and developed to reduce the use of fossil energy, which has negative impacts in the future, so that this potential can be used optimally.

Keywords: Electricity; climate change; fossil fuel; geothermal energy.

INTRODUCTION

Electricity is crucial in both industrial and household settings because an adequate electricity supply is essential for these activities (Ermawati, 2021). These conditions lead to dependence on the availability of electrical energy, which is increasing daily. Given that Indonesia remains dependent on fossil energy, its continued use will likely contribute to climate change in the future. Climate change is an important issue that poses a serious threat to all humans on Earth. Indonesia is blessed with abundant renewable energy potential, such as geothermal energy. The most considerable geothermal potential in the world is 29.038 MW. Geothermal energy is defined as the heat derived from below the Earth's surface, which can be harnessed for use as a renewable energy source. This heat is due to its geographical position, located in the Ring of Fire area, which generally has an enormous potential for exploiting geothermal energy for electricity generation (Sulkan, 2020).

To overcome the energy supply crisis and mitigate the impact of environmental damage caused by global warming, we can switch to alternative energy sources, specifically renewable energy, which is more environmentally friendly. Indonesia is blessed with abundant renewable energy potential, such as geothermal energy.

This geothermal energy originates from tectonic activity within the Earth that has been ongoing since the planet's formation. This heat also comes from solar heat, which is absorbed by the earth's surface Apart from that, this geothermal energy source is thought to originate from several phenomena.

The decay of radioactive elements beneath the Earth's surface, which are found and formed in the Earth's crust. The following table presents the distribution of geothermal potential on the main island of Indonesia.

Table 1. Geothermal Potential in the Main Islands of Indonesia

Island	Potency (MW)
Sumatera	9.517
Jawa	8.050
Nusa Tenggara	1.733,5
Kalimantan	175
Sulawesi	3.071
Papua	75

According to the potential listed in the newly developed potential table, only 9.8% of what is available (I., 2024). Therefore, the purpose of this literature review was to determine whether geothermal energy has the potential to be an alternative to fossil energy sources that are free from CO2 greenhouse gas emissions. However, when utilising geothermal energy, the first thing that needs to be remembered is that the costs of exploration and power plant production are expensive or high compared to other power plants that use fossil fuels.

MATERIAL AND METHODS

The research employs a qualitative literature study approach. The literature study was conducted by reviewing articles from previous research published between 2018 and 2023. The articles, written in Indonesian, were sourced from Google Scholar, Scopus, and other databases. The literature study begins by selecting several articles based on their relevance to the context. Each article selected is based on its grouping, and a conclusion is drawn with an overview explaining the potential, utilisation, and impact of thermal energy in Indonesia's future.

RESULT AND DISCUSSION

Based on the description of the method above, ten (10) scientific articles were selected as the primary articles in this paper to answer the research objectives. From this article, the authors found several things that led them to conclude: (1) What is the geothermal potential in Indonesia? (2) How is the utilisation of the geothermal potential? (3) What is the impact of geothermal potential on climate in the future, especially in Indonesia, as shown in Table 2?.

Table 2. Research on the potential, use, and impact of geothermal energy

Article title and publisher	Author, Year	Paper Description
Geothermal potential as an alternative energy in realising a carbon emission-free Indonesia	Ermawati Yuli, et al., 2022	The target of increasing the use of new and renewable energy by 23 per cent by 2025 is expected to be achieved. Utilising geothermal power plants and other renewable energy must continue to be maximised. In addition to meeting the demand for electrical energy, it is also part of a program aimed at reducing CO_2 gas emissions (Ermawati et al., 2022).
Climate change due to the increasing concentration of carbon dioxide and	Kabir Muhammad et al., 2023	The climate is an important environmental factor of an area, any country and the globe. The changes in environmental factors of an area over a long period

its impact on the environment in the 21st century		of time constitute climatic change. It includes quantities of light, temperature, humidity, wind, gases, air, water, and soil, which are averaged over about 30 years. These changes impact the agricultural sector, animals, the hydrological cycle, wind patterns, rainfall distribution, plant growth and development, and even the entire food chain, as plants are primary producers on the Earth's crust (Kabir et al., 2023).
Potential and utilisation of geothermal energy in Indonesia	Hakim et al., 2022	Indonesia ranks first among countries with the most extensive geothermal potential in the world, with this energy potential spread across 285 locations in the country's volcanic areas. The potential for geothermal energy, which is substantial in Indonesia, can be developed and utilised as a power plant (Hakim et al., 2022).
Review and feasibility study of geothermal energy in Indonesia	SBA Kashem et al., 2021	Currently, many people in Indonesia lack access to electricity. Indonesia's energy consumption growth is 7% per year, which needs to be balanced with the energy supply. The dependence on fossil fuel energy remains high, despite limited energy reserves, as fossil fuel subsidies continue to increase annually. One recommendation for this phenomenon is that the Indonesian government fund energy development. They should consider increasing subsidies for renewable energy development, particularly geothermal energy, by reducing subsidies for fossil fuels (Kashem et al., 2021).
Grounding ecology citizenship through knowledge about environmental issues	Deni Gunawati., 2020	Noble intentions and community motivation should drive the management and protection of natural resources. Knowledge of natural resources in the context of utilisation must refer to ethics and morals that are upheld together as the rule of the game in an effort to realise the need to form an awareness within oneself of responsibility for using natural resources (Gunawati et al., 2020).
Utilization and Policy Direction of Geothermal Energy Planning in Indonesia as a Sustainability of Maximizing New and Renewable Energy	Nurwahyudin et al., 2020	Geothermal utilisation nationally is only 8% or around 2,130.7 MW. The utilisation of geothermal energy is currently equivalent to the use of domestic fuel, equivalent to 32,000* BOE per day (92,000 BOE per day of crude oil) or around 81,200 BOE* per day of domestic fuel in 2025. Meanwhile, the direction of energy policy is directed towards electricity according to (PP No. 79, 2014) (Nurwahyudin et al., 2020).
Challenges of developing geothermal energy in its role in energy security in Indonesia	Mukhamad Faehsol et al., 2018	Through Presidential Regulation of the Republic of Indonesia No. 5 of 2006, the Indonesian government has set a target for achieving an optimal energy mix by 2025, with the role of renewable energy in national energy consumption reaching 17%. In the composition of renewable energy, geothermal energy sources account for a more significant 5%. This energy mix target aims to

		realise energy supply security domestically (Umam & Purba, 2018).
Geothermal Potential and Its Relation to Energy Development in Indonesia	Ahmad F 2021	The Indonesian government aims to increase the installed capacity of geothermal power plants to 10,000 MW by 2025. However, in reality, the installed capacity remained at 1,739 MW until 2014. With a target of 4,000 MW in 2015, 4,600 MW in 2016, and 10,000 MW in 2025, it is natural that some people are starting to doubt that the 2025 target will be achieved (Ahmad, 2021).
Enhanced geothermal systems: A critical review of recent advancements and future potential for clean energy production	Nath F 2024	Geothermal energy serves multiple purposes, including commercial power production, agricultural applications like greenhouse climate control, residential heating and cooling, and industrial processes like oil and chemical recovery. High-temperature resources (>150 °C) are utilised for consistent base-load electricity generation, while lower-temperature sources power geothermal heat pumps for homes, agriculture, and aquaculture. The depths required for base-load power generation vary, with depths of 4–8 km necessary in low-grade zones and 2–5 km in high-grade areas (Nath et al., 2024).
Advantages, Challenges, and Policy Recommendations on the Development of Geothermal Energy in Indonesia	Salma Zavirah et al., 2020	The benefits are substantial, but they are still low. The role of geothermal energy in the energy mix underscores its importance in taking ambitious steps to achieve the PLTP capacity target of 7,200 MW, as noted by Wisriansyah et al. (2025).

According to the table above, geothermal energy is a renewable and environmentally friendly energy source that helps mitigate climate change by reducing the reliance on fossil fuels. Geothermal energy has a notable degree of sustainability, an extended operational lifespan, and a consistent and substantial power generation capacity.

Here we can see from the development of geothermal energy in Indonesia :

Geothermal Potential

Geothermal energy is a source of heat energy derived from hot water, water vapour, rocks, and accompanying minerals and other gases that are genetically inseparable in a geothermal system. Geothermal energy is formed naturally under the Earth's surface. Electricity demand has continued to increase year after year, with an average annual growth rate of approximately 7%. Climate change is today believed to be a direct result of global warming (G., 2024). This condition is one of the critical environmental damage issues caused by the development of the energy sector. The world community's concern about climate change is driven by the increasing effects of greenhouse gases (GHG), especially CO_2 emissions. CO_2 gas plays a vital role in increasing the Earth's temperature, but it can have a detrimental effect when present in excessive amounts. That is because they still depend on fossil energy.

Geothermal Utilisation

There is ample potential for geothermal energy development and utilisation in Indonesia, for example, for power generation and the agricultural industry, as most sites have a reasonably high enthalpy and a potential of around 29 GWe—additionally, the total potential reserves and resources of geothermal energy amount to approximately 28,579 MWe.

This energy is most widely used as a power plant, but its utilisation has yet to be optimal. According to data from the Geological Agency of the Ministry of Energy and Mineral Resources in 2010, Indonesia has an enormous geothermal potential, namely approximately 29 GW, equivalent to 40% of the world's geothermal potential. However, its utilisation is still relatively small, at 1,189 MW, equivalent to 4.2% of the existing potential (Anderson, 2019). Geothermal energy is one of the renewable sources that can be harnessed as a power plant, minimising its negative impact on the environment.

Geothermal systems are a great alternative to fossil fuels in commercial buildings because they offer a wonderful blend of sustainability and economic feasibility.

Impact of geothermal energy

Climate change refers to a gradual shift in climate variables, particularly air temperature and rainfall, that occurs over a period of 50-100 years. Additionally, it is essential to recognise that these changes are primarily caused by human activities, particularly those associated with the use of fossil fuels and land-use changes. Therefore, changes caused by natural factors, such as additional aerosols from volcanic eruptions, are not accounted for in climate change models. Thus, the natural phenomena that cause extreme climate change are driven by increasing GHG effects, especially CO_2 emissions. CO_2 emissions from geothermal power plants are significantly lower compared to those from oil and coal. Geothermal power plants (geothermal) have the lowest CO_2 (Author, Year). However, the gases generated from geothermal energy exposure include hydrogen sulfide (H_2S), carbon dioxide (CO_2), nitrogen gas (N_2), methane (CH4), ammonia (NH_3) and, in some cases, oxygen ingress due to trapping conditions in rocks.

CONCLUSION

According to the literature study, the potential of geothermal energy is very promising for replacing fossil energy, which, if continuously used, could lead to climate change in the future. Compared to geothermal potential, fossil energy is not renewable.

Geothermal energy serves multiple purposes, including the production of electricity for commercial use. Geothermal energy originates from natural processes involving hot water, water vapour, rocks, and accompanying minerals and other gases, which can be continuously replenished. In contrast, geothermal energy originates from natural processes involving hot water, water vapour, rocks, and accompanying minerals and other gases that can be continuously replenished. Geothermal energy also

has several advantages compared to other renewable energy sources, which can be continuously replenished. Geothermal energy also has several advantages compared to other renewable energy sources, including (1) saving space and having little visual impact, (2) being able to produce continuously for 24 hours, so it does not require energy storage, and (3) it will always be there in the future. So it does not require energy storage, and (3) very high costs. The availability level is above 95%. So, this is something that can be relied on.

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