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So Close Yet so Far – How People in the Vicinity of Potential Sites Respond to Geothermal Energy Power Generation: an Evidence from Indonesia

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Abstract: Presently, Indonesia aims to reduce greenhouse gas (GHG) from 29 to 40% before 2030 by growing the use of renewable energy. One of the sources of renewable energy is geothermal by expanding the development in several locations. This study, therefore, aims to examine the public knowledge, attitude, and perception on the development of Geothermal Energy Power Generation in Mount Lawu, Central of Java. This descriptive and qualitative research showed that most people's understanding of geothermal energy was insignificant. Therefore, the result showed that the majority perception had limited knowledge in geothermal energy. During this research, the local government had not implemented the Mount Lawu geothermal energy generation development. The community and local government are considering the pros and cons of the project, which is the main reason for the project implementation delay. Furthermore, the responses in addressing the geothermal plant project generally fell into three categories: agree, disagree, and doubt. There is some Society's consent that formed based on accepting the positive side of the plant. Furthermore, the initial negative response was due to their poor relationship with the project activities and the absence of prior information. Another factor was their sense of fear and doubt on the positive impacts of the project shortly.

Keywords: geothermal; renewable energy, development, perception, society

1. Introduction

Geothermal energy is widely available in the world, however, it is limited in its utilization¹⁾. And it is known to be among the most promising alternative electrical energy solutions²⁾. Geothermal energy also produces low carbon emissions, it is also a non-intermittent resource, which means that energy can be produced continuously without interruption except during the maintenance of power plants³⁾.

The magmatic activity in the earth's crust plays a vital role in the geothermal formation, which leads to heat generation. Furthermore utilization of resources and better understanding of conversion systems to produce electricity are increasingly important⁴⁾. Meanwhile, electricity plays an essential role in spurring economic growth globally.

Indonesia is a country that lies on the seismic line known as the "ring of fire," which stretches along the Pacific, from Southeast Australia to Southwest American, with abundant geothermal potential, which is around 29,000 MW capacity⁵⁾. These potential spreads widely along the volcanic, originating from Sumatra, through Java, Bali, Nusa Tenggara, North Sulawesi, and Maluku Regency. The initial indication used to confirm the geothermal resources is the surface manifestations, such as hot springs, mud pools, and geysers.

Over the last few years, Indonesia has been among the top five countries globally, with the most geothermal energy power generation installations⁶⁾. It is the second in the utilization ratio with an installed capacity of 1,948 MW, as shown in Figure 1. However, the country still relies heavily on fossil resources as the primary energy mix⁷⁾. Therefore, the government is targeting this

renewable energy resource to provide 23% of the electricity needs amounting to 9,500 MW by 2025. However, at the current growth rate, this target seems unrealistic. Instead of this, the future target has been re-evaluated to 7,241.5 MW by 2025⁸⁾. Since the corona pandemic affected the world, including Indonesia, the realistic development targets have also been re-evaluated.

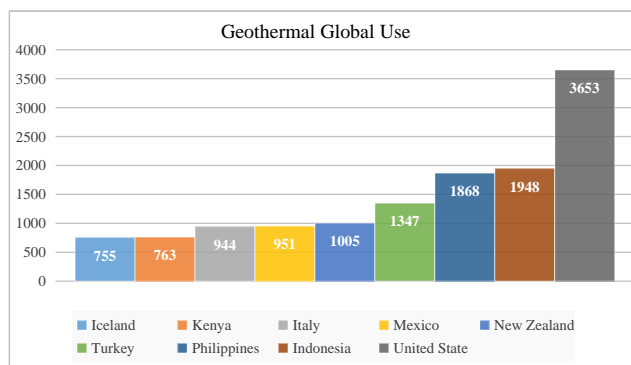


Fig 1: Global geothermal use⁹⁾

Indonesia still sources its electric power generation from fossil energy, such as petroleum, coal, and natural gas, which has a long-term negative impact on the environment. In addition, the availability of these fuels is depleting in this country, as can be seen from the decline of oil production in 706 thousand barrels per day. Therefore, the use of renewable energy resources is needed to serve as an alternative.

Geothermal energy is one of the available renewable energy sources to replace oil, coal, and gases efficiently. Some of its advantages include the ability to space-save minimal visual impact, 24 hours production capacity, zero energy storage, and very high energy availability. It also does not fluctuate, compared to other renewable options, such as wind and solar power. Furthermore, it does not require fuel and can grow the regional economy.

However, despite these numerous benefits, optimal geothermal energy utilization has not been achieved due to the high initial investment costs, which leads to increased selling value. Therefore, it is not competitive with conventional energy systems' electricity price and operational cost¹⁰⁾. Geothermal Energy development faces several challenges, such as undirected policies and regulations, inadequate human resources, lack of incentives, and poor infrastructure.

Generally, in some countries, including Indonesia, geothermal energy is still trying to survive compared to other renewable energy sources, such as solar and wind¹¹⁾. This energy source is yet to play an essential role in the public perspective¹²⁾. Previous studies in Australia found that the main factors influencing geothermal unacceptance include limited public knowledge of the technology, inadequate media coverage, concerns about overused water, and seismic activity¹³⁾. Furthermore, in Japan, geothermal exploration has uncertainty on reversibility and adverse effects on hot springs¹⁴⁾. Another challenge is

low public participation in the project development and consultation processes¹⁵⁾. However, only a few studies on public perspective is available focusing on the people living in the vicinity of potential site for geothermal project. Most of their background are developed countries, such as Japan¹⁴⁾, while only a few published evidences are found whose background are developing countries.

Therefore, this study regarding Indonesia's geothermal challenges and potential serves as the enrichment of academic evidence focusing on public perspective living in the vicinity of geothermal potential site. Although government policies and regulations have been improving recently to optimize geothermal development, public awareness, attitude, and perception of the energy are still not focused on attention. Therefore, the study is important to spark the attention toward public awareness, attitude, and perception of geothermal energy.

Several Indonesian laws are expected to optimize geothermal development, such as Law 21/2014, which improves Law 27/2003 regarding geothermal energy. A note from the revised Law 2014 is that the classification of geothermal power plants is no longer a mining business. This indicates that the energy is conservable and explored in the country. As a mining business, as expressed in Law 2003, geothermal exploration was categorized as a barrier to energy development. This is because locations with high potentials for the geothermal resource are in heavily forested areas and out of bounds to mining activities. Presently, irrespective of government permissions for exploring and developing geothermal energy in forest areas, proper checks are being put in place to ensure no upset in the natural balance due to overdevelopment.

Local government and community responses have an important role in developing high geothermal energy potential for power generation in the area. Therefore, this study aims to examine the public knowledge, attitude, and perception of Geothermal Energy Power Generation development in Mount Lawu, Central of Java, in descriptive and qualitative research.

2. Research Location

This study was carried out at Karanganyar, Matesih, and Tawangmangu areas, Central Java Province, in Indonesia. The locations were selected as an immediate vicinity to Mount Lawu, a potential site for geothermal energy, as shown in Figure 2.



Fig 2: Map location of Mount Lawu

Mount Lawu is located in Karanganyar Regency, Central Java province, Java Island. This Island is situated in the area where the Eurasian and Indo-Australian plates meet, thereby developing a magmatic activity that leads to forming a volcanic path from the west to the east of Java Island. Furthermore it is on the border of three regencies, namely Karanganyar (Central Java), Ngawi (East Java), Magetan (East Java). The type of volcano found on this mountain is the Maar, which comprises three craters, two in the north (Telaga Kuning and Telaga Lembung Selayur), and one cratered south (Candradimuko). The woodland area of Mount Lawu is managed by a forest management unit of Perum Perhutani – a state-owned company – in Surakarta city, Central Java Province. Unit 1 (Central Java) manages the western slopes of Mount, while the eastern slopes are managed by Unit 2 (East Java).

Mount Lawu is among the several volcanic cones in Indonesia with geothermal manifestations comprising fumaroles, hot springs, and altered rock, widely distributed on its slope¹⁶. Furthermore it has been designated as a geothermal exploration area since 2012¹⁷. It also consists of approximately 60,030 hectares covering five areas; Karanganyar, Sragen, Wonogiri, Ngawi, and Magetan. Its hypothetical resource potential is 137 MW, while reserves are estimated at 195 MWe¹⁸. The conceptual model of the Mount Lawu geothermal system is shown in Figure 3.

One of the geothermal potentials in Mount Lawu is utilized by PT Pertamina Geothermal Energy (PGE). PGE is a subsidiary of PT Pertamina, an oil and gas company owned by the Government in 2006. Currently, PGE manages 15 geothermal areas in Indonesia where seven geothermal projects are operating with a total of 1187.3 MW and another 690 MW, including Darajat (10 MW), Kamojang (60 MW), Ulu Belu (110 MW), Lahendong (60 MW), Lumut Balai (110 MW), Karaha (30 MW), Patuha (180 MW), Dieng (120 MW) and Bedugul (10 MW).

PGE won the Mount Lawu Geothermal Working Area auction in 2016. This mountain has an estimated reserve of 195 MW. Therefore, the government planned to develop an additional 110 MW for PGE as GEPG to be operational in 2022¹⁸. The company plans to finish the first part of the project: the 55 MW electricity production in 2022 and another 55 MW in 2024. However, the geothermal power generation development plan has not been implemented due to objections from environmental activists and opposition from the Karanganyar Regency Government.

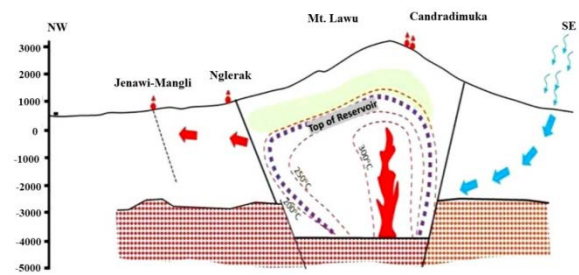


Fig. 3: Conceptual model of Mt. Lawu geothermal system¹⁷

3. Methods

This research applied qualitative methods in exploring natural object situations. Furthermore, the purposive sampling approach was used to collect data through interviews, observations, and documentation. There are as many as twenty-six informants (also presented in Table 1) who were selected and interviewed consist of the following:

1. Five managers of hot spring tour destination located in Sapta Tirta Pablengan and Cumpleng in the Matesih and Tawangmangu areas
2. Six members of the local community live near Mount Lawu, located in Matesih, Tawangmangu, and members of *Anak Mount Lawu (AGL)* – a local community of youth.
3. Six members of the urban community living in Karanganyar and tourists that had visited Tawangmangu
4. Four local officials are working in the Matesih and Tawangmangu Sub-District and Village offices. It included the Sub-District and Village Heads of the Matesih and Tawangmangu areas.
5. Five government officials work in Karanganyar offices, including the Environment Agency (*DLH*) and the Youth, Sports, and Tourism Office (*DISPARPORA*). Furthermore, officials working with institutions in the Surakarta area and managing Mount Lawu forests, namely the Surakarta Regional Forestry Units Corporation (*Perum Perhutani*), as well as institutions involved in the development plan for the Mount Lawu GEPG project, namely the Solo Area Branch of the Energy and Mineral Resources (*ESDM*) Office were also interviewed.

Table 1. List of informants

No.	Position	Location	Total
1.	Managers of hot spring tour destination	Located in Sapta Tirta Pablengan and Cumpleng in the Matesih and Tawangmangu areas	5 people
2.	Local community	Living near Mount Lawu, located in Matesih, Tawangmangu, and members of <i>Anak Mount Lawu (AGL)</i>	6 people

3.	Urban community	Living in Karanganyar and tourists that had visited Tawangmangu	6 people
4.	Local officials	Working in the Matesih and Tawangmangu Sub-District and Village offices	4 people
5.	Government officials	Work in Karanganyar offices, including the Environment Agency (DLH) and the Youth, Sports, and Tourism Office	6 people

Each informant was requested to express their views regarding the following questions;

1. How much do you know about geothermal energy?
2. Based on your understanding, how is geothermal energy used?
3. How much do you know about the potential and development of a geothermal project?
4. Describe the communication and relationships among people involved in the geothermal energy projects?
5. Have you had any experiences with the geothermal energy projects in the area?
6. What is your general appreciation regarding the geothermal energy utilization at Mount Lawu?
7. What do you think about the GEPG development plan in Mount Lawu?
8. Do you know of any geothermal projects?
9. Do you agree/disagree with the GEPG development plan in Mount Lawu, and what are your reasons?

The interviews have been carried out separately among the informants. Some of them were willing to have interviewed formally during office hours in their works, some of them were less formally in a coffee shop or private residence. Some pictures during the interviews are shown in Figure 4.



Fig 4: Interviews with stakeholders

4. Results and Discussion

4.1 Stakeholders Analysis Overview

This research supported the global knowledge trend on

geothermal energy that was not within the affected communities' preview. Although most informants had low-level knowledge of geothermal energy, they had an intuitive understanding used to form an opinion on its development.

The community managers of hot springs and local officials had a huge negative social attitude towards the project. Meanwhile, local government officials and the ministry of energy were more open to developing a geothermal power generation plant in Mount Lawu. In this regard, several informants admitted to having their attitude toward the project skewed by public opinion on energy projects in their area.

The following section provides an overview of the main factors defining perceptions of the GEPG development plan in Mount Lawu. The first part discusses the understanding of geothermal technology, while the second analyses the Karanganyar community's attitude towards the project.

4.2 Understanding Geothermal Technology

Managers of hot springs that carry out businesses close to the geothermal energy resource were more receptive. However, the majority admitted that they had a limited understanding of the energy resource. They connected geothermal resources with hot springs, asserting that it was good for the treatment of skin diseases. Meanwhile, the use of geothermal energy for power generation was not well understood. A hot spring manager stated, "*In Pablengan village, the hot spring containing Sulphur was used to cure skin diseases*".

The geothermal energy generation development plan on the mountain slopes was meant to start five years ago. However, the project failed to commence due to several reasons, one of which is the attitude of the Karanganyar community towards the project. The local community of nature lovers, Anak Gunung Lawu (AGL), understood geothermal energy as a renewable source that can be converted into electricity.

Karanganyar community is aware of the development of geothermal energy power and appreciates geothermal energy's potential to produce electricity. Several community members stated that they were looking for information regarding geothermal energy and related projects through social media and the internet. One member stated the following "*I have some knowledge about the project because yesterday, I came across literature from the internet and found that it was meant to run from 2016 to 2020. However, it was rejected by the community at the slope of Mount Lawu.*"

Before the inception of the geothermal energy power generation development project in Mount Lawu, the understanding of most communities regarding geothermal energy was limited. Therefore, after the plan was concluded, they sought more information regarding the project. However, the information obtained was still limited due to the managers' inability to socialize

efficiently with the affected communities. This led to the community acquiring knowledge on geothermal energy sources and projects from the internet.

The analysis showed that the lack of information on geothermal energy affected the social behavior of the community. Furthermore, inadequate involvement and engagement generally led to the rejection of energy projects and distrust of the associated company's information. These pose obstacles to the realization of the geothermal energy power generation development project on Mount Lawu.

4.3 Stakeholder Perception

To fully appreciate their attitude towards geothermal energy based on information obtained from interviewed informants, the following section examines key stakeholders' perceptions.

4.3.1 The Manager of Hot Springs

There are fears that the project is likely to have adverse effects on the quantity of water gushing out of the natural springs. From the interviews conducted on some managers of hot springs resorts in the location, one factor influencing geothermal energy production in the location was the uncertain effect on underground sources. All informants shared a common concern that "*The environment is likely to be affected, and this has the ability to reduce water springs in the area around the slopes of Mount Lawu which have detrimental effects during the occurrence of droughts.*"

4.3.2 Local officials

Findings showed that local officials' major concern was the negative effects of the geothermal project on the environment due to the surrounding uncertainties. One local official in the Tawangmangu area was scared of the possible lack of water and the possible deterioration of the environment due to forest depletion due to the project's siting. Therefore, the official advised that the company, community, and government create a platform where the projects' benefits and impacts are discussed efficiently and effectively. Local officials acknowledged the benefits of this development. A statement from the Regional Head of Matesih read as follows, "*Geothermal energy can be used as a power generation source, however, it requires significant water resources. This is a controversial issue in the Karanganyar community because their resource of life comes from the mountain.*"

4.3.3 Urban and local community

According to members of the local community, Mount Lawu is a sacred place that needs to be left untouched. This place is home to many ancient sites because it was the exile place of Raja Brawijaya V, the last Majapahit ruler. The community feared that using geothermal energy

would lead to the release of high-temperature steam to the surface, thereby significantly increasing the environment's temperature. They were also of the opinion that exploration would cause an increase in air temperature. This perception appears presumptuous due to the lack of public knowledge on insulation in geothermal pipelines.

4.3.4 Government officials

Karanganyar Regency, as a second-level government, expressed its disapproval of the geothermal energy power generation development project. According to them, the area on the slopes of Mount Lawu is a protected forest area. One of the top-ranking government officials from the Tourism, Youth and Sports Department stated that "*the government needs to adhere to regulation and ensure the area is used as a protected forest reserve on legal grounds. Furthermore, there is a need for further socialization between the developer, local government, and the surrounding communities that are directly affected.*"

4.4 Community Attitude on the Geothermal Energy Power Generation Project at Mount Lawu

The development of a geothermal energy power generation project at Mount Lawu was a major challenge. Some parties had fears, while others thought it was a great development. Meanwhile, the community was divided into those that supported the project and those that objected. The project supporters were directly involved in the exploration or exploitation process and benefitted immensely from this development. While the opposing party comprises a community without interest in the company, they thought more negatively affected their children and grandchildren.

Karanganyar community never previously had any experience on energy projects. All interviewed informants stated that they were never involved in any geothermal energy power generation or other kinds of energy projects. Mount Lawu's geothermal capacity was already utilized as a tourist attraction and income source for regional governments and their host communities. There are warm springs in Sapta Tirta Pablengan, Matesih, Cumpleng, Plumbon, and Tawangmangu, all of which attract many tourists.

Negative social attitudes were more dominant among community members, managers of hot springs, and local officials. They disagreed with the development plan, affirming that the native community's unwillingness to give up the synergy with their homes, environment, and ecosystem was enjoyed for centuries. They opined that the project has the ability to cause anxiety and disturb the security and comfort of those living under Mount Lawu. To better understand the Karanganyar community's attitude towards the geothermal energy power generation development project at Mount Lawu, the data obtained were grouped into three sections, namely Agree, Disagree and Doubt.

4.4.1 Agree

Based on field findings, it was discovered that there were underlying strategic issues that formed community perceptions, which led to their failure to agree to the geothermal energy power generation development on Mount Lawu. However, social acceptance is formed when these communities witness the positive effect of the project. The following explains the positive impact of the project.

4.4.1.1 Environmentally friendly

Geothermal energy is environmentally friendly because it is a clean and renewable energy source, thereby reducing the need for fossil fuels¹⁹. For something to be environmentally friendly, it means there is no waste or loss to the environment. This is supported by an article published by In Power Magazine²⁰. The Indonesian government is currently promoting the use of renewable energy sources, especially those from water and geothermal resources. These two energy sources do not only have great potentials, and they are also environmentally friendly due to their inability to produce greenhouse gases. According to various studies, greenhouse gases contribute to an increase in the earth's temperature, which leads to disastrous outcomes, such as heavy rains, flooding, typhoons, earthquakes, etc. Therefore, this promoted the government to set a target for increasing the use of renewable energy by achieving 25% of national energy. A government official based in Karanganyar stated that "*geothermal power generation becomes environmentally friendly when 100% of the energy is used to activate turbines, which in turn generates power.*"

A former Minister of Environment and Forestry that served at the time when the project was to start stated that the geothermal exploration process was safe. The minister further stated that the only exploration carried out in private has the ability to endanger the environment and surrounding communities. Moreover, open exploration does not utilize large amounts of the forest as feared by the local community. Therefore, the losses incurred can be minimized²¹.

4.4.1.2 Meeting Power Needs

According to a hot spring manager, the geothermal energy power generation project would add many megawatts to the national grid. Government officials also stated that proper handling of the project according to the Environmental Impact Analysis can produce considerable energy. With the geothermal energy power generation billed to produce a capacity of 110 MW, it needs to meet the existing power requirement in the Karanganyar area and its surroundings. When electric power is generated at a competitive price, lowering the cost indirectly helps the economy.

4.4.1.3 Infrastructure Becomes Better

The geothermal energy power generation plant construction in Mount Lawu improves infrastructure, such as roads in the Ngebel Village²². The village head stated that the geothermal energy power generation construction in Ngebel helped the village government in tackling damaged roads in the locality. This development made access to road exploration, such as the Jawol hamlet, easier. Damaged roads in the village were also repaired by geothermal energy power generation initiator. Although the initial objective was to facilitate vehicles and heavy equipment in and out of the site, the local community also benefited from the road²².

4.4.1.4 Increase in Job Opportunities

The construction of a geothermal energy power generation project on Mount Lawu has the capacity to create job opportunities for the surrounding community. A government official based in Karanganyar stated that "*this project leads to increased job opportunities for residents in the community and Magetan Regency in general. Furthermore, it enhances economic and industrial activities, thereby improving the economy.*" This is supported by a study on PT Pertamina Energy's construction of a geothermal energy power generation in Bolaang Mongondow Timur Regency²³. The project increased employment opportunities for communities around the location of the activity. Meanwhile, the previous study also stated that the socio-economic impact is positive because construction creates many temporary jobs, while maintenance and other factory operations make long-term employment²⁵.

4.4.2 Disagree

The rejection of the geothermal energy power generation plan by the community was based on poor communication and socialization between the managers and members of the host area. The members of the community were unfamiliar with the projects, which led to its disapproval. Moreover, they were also scared of its negative impacts. Some communities rejected the development of geothermal energy power generation because they were afraid of its environmental impacts, such as air pollution and forest destruction²⁴.

In responding to the geothermal energy power generation project, the community showed their disapproval. This was because they did not have adequate knowledge of the process and were scared of its possible threat to their existence²⁵, ²⁶. Furthermore, the community was scared that geothermal exploration plans are likely to affect their economy negatively. This is because they suspected that the system is expected to interfere with the surrounding environment. The following are some of the possible aspects envisioned to be affected by the project:

4.4.2.1 Cultural Aspects

According to members of the local community, Mount Lawu is a sacred place, therefore, it should not be disturbed. The mountain is home to several ancient sites because it hosted Raja Brawijaya V, the last exiled Majapahit ruler²⁷⁾. Furthermore, several cultural sites in the form of temples have recently been discovered, with some still buried in the ground. There are also local religious sites, such as holy water pools, where rituals are performed. These pools are created from mountain springs, and an example is the Pringgodani site. It is feared that the exploration and exploitation process have the ability to damage the sites. Therefore, an agreement between the community and the government to decide on the areas to be explored is necessary.

4.4.2.2 Environmental Aspects

Another reason for society's disapproval is based on concerns covering the ecosystem damage, such as reducing water sources and supply to meet the community's needs. The community feared that when the spring is used as a medium for generating electricity, there will be a likely decrease in water supply, thereby affecting farming and other agricultural activities.

Furthermore, they were also scared that the construction of roads to allow the drilling location access to heavy equipment has the ability to disturb the sustainability of the ecosystem. Drilling is generally considered a none environmentally friendly process with many negative effects. It is largely used by mining or oil and gas companies to extract commodities with a tremendous negative impact on the environment. These negative impacts lead to acid mine drainage, water contamination by oil or gas, seismic radiations from abandoned mine shafts, vegetation destruction (albeit temporary) from open-pit mining, air pollution from multiple processes controversial hydraulic fracturing for natural gas²⁶⁾.

The community cited the Lapindo Mud tragedy that occurred in Sidoarjo, East Java, and feared the high probability of a similar disaster occurring due to the drilling processes carried out in the geothermal energy power generation project construction. Based on the interview, it was discovered that the members of the society were highly aware of the forest's functions in sustaining humankind. Hence, they had undertaken various reforestation programs for its preservation. Therefore, clearing the land for access to exploration and exploitation is likely to destroy the forest ecosystem they have conserved over the years.

4.4.2.3 Technical Aspects

Residents of the community feared that geothermal energy resources' utilization is likely to increase the environmental temperature due to the release of hot steam to the surface. This perception appears presumptuous due

to the lack of public knowledge on the insulation of geothermal pipelines. They also feared the possibility of failure in the exploration process, which lead to energy exploitation in the Mount Lawu area. Furthermore, they feared the possible occurrence of natural disasters due to technical errors in Mount Lawu once the project started.

The geothermal energy power generation construction requires cutting-edge technology, detailed field research, and understanding all technical consequences. Therefore, this project needs a high-risk investment and a relatively long period to return on investment. This is why investors are unwilling to invest in geothermal energy development²⁸⁾.

4.4.2.4 Regulatory Aspects

The community was ignorant of the Ministry of Environment Regulation No. 17/2012 regarding Guidelines for Community Involvement in the Environmental Impact Assessment (EIA) Process, and the permits made the people feel unsafe. A lack of socialization caused this ignorance, and in some cases, the documents involved were prepared without involving community members.

The geothermal energy power generation development intersects with various other sectors of society, which become stumbling blocks to the area's development. These sectors include the environment and land. Most geothermal sources are located in the highlands and protected forest locations. Therefore, it is important to note that forest resources need to be preserved to preserve and maintain the environment. This connection causes problems between developing the geothermal energy power generation source and environmental sustainability²⁸⁾.

4.4.2.5 Social Aspects

The aspect that involves water use is also an important environmental concern, especially as it affects agricultural land in the area. Since most community members are farmers, they were afraid of the project's negative impacts are expected to cause in the Mount Lawu area. This is due to their dependence on the springs from the mountain for their agricultural work. They feared that the project could reduce agricultural productivity due to a decrease in water quantity, thereby forcing people to change professions. Furthermore, the community members felt their electricity needs had been met. Therefore, there was no need to build a plant in the location. A hot water manager working in the location stated as follows, "*Automatically, there is an environmental impact that occurs when the water flow from its source in Mount Lawu is reduced. If the soil is dry, what will farmers plant? In my opinion, Mount Lawu should still be kept natural. Instead of drilling into it, Mount Merapi, which is already hot, should be an option.*"

The local governments of Matesih and Tawangmangu explained the need for a platform where complaints and aspirations of community members are addressed. The Head of Matesih District stated the following, "*Even*

though we follow the government's directives, we also pay attention to the community's aspirations. There is no doubt that when the geothermal energy power generation project runs, it can disrupt the environmental ecosystem and the life source around Mount Lawu. Therefore, a meeting point is needed where government policies and the community's aspirations are discussed and formulated to ensure everyone wins at the end."

The exploitation and exploration of Mount Lawu as the geothermal energy power generation site had drawn criticisms and demonstrations in several locations around Karanganyar Regency, especially in the Tawangmangu area, from 2018 to 2019. Several Civil Society Organizations (CSO) and society leaders had also expressed their disapproval of the sitting of this mega project initiated by Indonesia's government ²⁹⁾.

4.4.3 The Doubts in Determining Attitudes

Some community members were between opinions, whether to agree or disagree with the Mount Lawu geothermal energy power generation development. Several communities were hesitant to define where they stood in the development plan. One community member stated as follows, *"I support it from my perspective as a technical person. However, I come from Tawangmangu and have little regret, such as its negative effects on the community."* The Karanganyar Environmental Agency also expressed doubts because there was no clear certainty regarding the project's benefits and impacts. The explanation above shows that the distrust in some persons came from the air of uncertainty that characterized the anticipated effect of the project.

5. Conclusion

In conclusion, it is observed that the community lacked a sufficient understanding of geothermal energy technologies. They only started seeking knowledge after the geothermal energy power generation development plan was made known to them. The community, however, understood the utilization of geothermal energy as a source of power generation. Some members sought more information regarding geothermal energy and related projects through various social media platforms and the internet.

The perception of the Karanganyar community regarding the project was skewed. Most of them were unfamiliar with this energy and had no previous experience with the project. Therefore, their negative perception of geothermal energy utilization arose due to their lack of understanding. This was also because they were not given primary education by the company handling the project and the government. The majority 15 samples were rejected the development of the Mount Lawu geothermal power generation project. They argued that the development could negatively affect their culture, environment, social and vocational lives. There were fears

that the project could damage the ecosystem and reduce water sources capable of leading to drought, which inadvertently affects agrarian life. Besides, some agreed for the project to be sited in the location. Those who agreed because they saw the possible positive impact on the community. The project's environmental friendliness, the possibilities of increasing power production, enhancing rural infrastructure, and creating jobs are some of the project's positive impacts. However, 4 samples had doubts that did not enable them to define their stand. These persons were hesitant because they saw the project's positive and negative impact on the community's environment.

There has to be a high-frequency socialization effort designed to penetrate all levels to change their negative perceptions or misconceptions. This is an important step that needs to be taken to minimize conflicts between both sides. Furthermore, providing a vivid explanation to community members on the current energy crisis and the possible contribution of renewable energy sources, such as geothermal, to tackle this problem is essential for their significant comprehension in the most straightforward possible words.

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References

- 1) J.R. Patterson, M. Cardiff, and KL Feigl, "Optimizing geothermal production in fractured rock reservoirs under uncertainty," *Geothermics.*, **88** (2020). doi.org/10.1016/j.geothermics.2020.101906.
- 2) P.H. Niknam, L. Talluri, D. Fiaschi, and G. Manfrida, "Gas purification process in a geothermal power plant with total reinjection designed for the Larderello area," *Geothermics.*, **88**, 101882 (2020). doi.org/10.1016/j.geothermics.2020.101882.
- 3) NA. Pambudi, R. Itoi, S. Jalilinasrabady, and M. Gürtürk, "Sustainability of geothermal power plant combined with thermodynamic and silica scaling model," *Geothermics.*, **71** 108-117 (2018). doi.org/10.1016/j.geothermics.2017.09.003.
- 4) S. Jalilinasrabady, R. Itoi, P. Valdimarsson, G. Saevarsdottir, and H. Fujii, "Flash cycle optimization of Sabalan geothermal power plant employing exergy concept," *Geothermics.*, **43** 75-82 (2012). doi.org/10.1016/j.geothermics.2012.02.003.
- 5) Y. Gunawan, N. Putra, E. Kusriani, I.I. Hakim and MDH Setiawan, "Study of Heat Pipe Utilizing Low-Temperature Geothermal Energy and Zeolite-A for Tea Leaves Withering Process," *EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green*

- Asia Strategy.*, **7** (2) 221-227 (2020). DOI:10.5109/4055223.
- 6) S.M. Bina, S. Jalilinasraby, H. Fujii, and N.A. Pambudi, "Classification of Geothermal Resources in Indonesia by Applying Exergy Concept," *Renewable and Sustainable Energy Reviews.*, **93** 499–506 (2018). doi.org/10.1016/j.rser.2018.05.018.
 - 7) NA. Pambudi, "Geothermal power generation in Indonesia, a country within the ring of fire: Current status, future development and policy," *Renewable and Sustainable Energy Reviews.*, **81** 2893–2901 (2018). doi.org/10.1016/j.rser.2017.06.096.
 - 8) BT. Prasetyo, S. Suyanto, M.A.M. Oktaufik, and H. Sutriyanto, "Design, Construction and Preliminary Test Operation of BPPT-3 MW Condensing Turbine Geothermal Power Plant," *EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy.*, **6** (2) 162-167 (2019). DOI:10.5109/2321012.
 - 9) A. Richter, "Top 10 Geothermal Countries," *Think Geo Energy Research.*, <https://www.thinkgeoenergy.com/global-geothermal-capacity-reaches-14900-mw-new-top10-ranking> (accessed July 1, 2021)
 - 10) B. Richter, B. Steingrímsson, M. Ólafsson, and R. Karlsdóttir, "Geothermal Exploration and Associated Cost in Iceland," (2014). <https://rafladan.is/bitstream/handle/10802/5452/UN-U-GTP-SC-18-32.pdf?sequence=1>.
 - 11) K. Popovski, "Political and Public Acceptance of Geothermal Energy". *IGC2003-Short Course.*, (2003).
 - 12) M. Gross, "Old Science Fiction, New Inspiration: Communicating Unknowns in the Utilization of Geothermal Energy," *Sage Publications.*, **35** (6) 810-818 (2013). DOI:10.1177/1075547012469184.
 - 13) A.M. Dowd, N. Boughen, P. Ashworth, and S. Carr-Cornish, "Geothermal technology in Australia: Investigating social acceptance," *Energy Policy.*, **39** (10) 6301–6307 (2011). doi.org/10.1016/j.enpol.2011.07.029.
 - 14) H. Kubota, H. Hondo, S. Hienuki, and H. Kaieda "Determining barriers to developing geothermal power generation in Japan: Societal acceptance by stakeholders involved in hot springs," *Energy Policy.*, **61** 1079–1087 (2013). doi.org/10.1016/j.enpol.2013.05.084.
 - 15) S. Carr-Cornish, and L. Romanach, "Differences in Public Perceptions of Geothermal Energy Technology in Australia," *Energies.*, **7** (3) 1555–1575 (2014). DOI:10.3390/en7031555.
 - 16) D. Hermawan, and L.A. Permana "Ke prospekan Panas Bumi Gunung Lawu Berdasarkan Kajian Vulkanostratigrafi," *Buletin Sumber Daya Geologi.*, **13** (3) 200–212 (2018). doi: 10.47599/bsdg.v13i3.232.
 - 17) Direktorat Pemanfaatan Jasa Lingkungan Hutan Konservasi, "Buku Informasi Pemanfaatan Jasa Lingkungan Panas Bumi di Hutan Konservasi," (2016).
 - 18) Kementerian Energi dan Sumber Daya Mineral, "Potensi Panas Bumi Indonesia (1st ed.)," (2017).
 - 19) J. W. Martin, and L. Croukamp, "Exploration into the potential for a low-enthalpy geothermal power plant in Cape fold belt," *Geothermics.*, **89** (2021). doi.org/10.1016/j.geothermics.2020.101934.
 - 20) Indonesia Power, "Indonesia Power: Kembangkan Energi Masa Depan yang Ramah Lingkungan dan Berkelanjutan," *In.Power.*, **4** (2016). [https://indonesiapower.co.id/id/komunikasi-berkelanjutan/Inpower Magz/Majalah IP Edisi 4 Tahun 2016.pdf](https://indonesiapower.co.id/id/komunikasi-berkelanjutan/Inpower%20Magz/Majalah%20IP%20Edisi%204%20Tahun%202016.pdf).
 - 21) A. Sunaryo, "Kementerian LHK akan kaji wacana eksplorasi panas bumi Gunung Lawu," *merdeka.com*, (2016). m.merdeka.com/peristiwa/kementerian-lhk-akan-kaji-wacana-eksplorasi-panas-bumi-gunung-lawu.html.
 - 22) M.C. Ulum, "Sikap Warga Komunitas Lokal terhadap Pembangunan Pembangkit Listrik Tenaga Panas Bumi (PLTP) (Suatu Studi pada Warga Desa Ngebel Kecamatan Ngebel Kabupaten Ponorogo)," *Jurnal Ilmiah Administrasi Publik (JIAP).*, **4** 320–330 (2018). DOI:10.21776/ub.jiap.2018.004.04.6.
 - 23) W.M. Wangke, "Dampak Sosial Ekonomi Kegiatan Pembangunan Proyek Lapangan Uap dan PLTP di Modayag Kabupaten Bolaang Mongondow Timur," *ASE.*, **7** (1) 33–37 (2011). <http://repo.unsrat.ac.id/id/eprint/120>.
 - 24) B.L. Djumaty, "Studi tentang Persepsi dan Sikap Masyarakat Desa Idamdehe terhadap Rencana Pembangunan PLTP di Idamdehe dan Idamdehe Gamsungi," *Studi Pembangunan Interdisiplin.*, **XXIV** (1) 21–39 (2015).
 - 25) O. Oktorie, "A Study of Landslide Areas Mitigation and Adaptation in Palupuah Subdistrict, Agam Regency, West Sumatra Province, Indonesia," *Sumatra Journal of Disaster Geography and Geography Education.*, **1** (1) 43 (2017). DOI:10.24036/sjdgge.v1i1.34.
 - 26) D. Hermon, Ganefri, A. Putra, O. Oktorie, "The Model of Mangrove Land Cover Change for the Estimation of Blue Carbon Stock Change in Belitung Island-Indonesia," *International Journal of Applied Environmental Sciences.*, **13** (2) 191–202 (2018).
 - 27) A. D. Setyawan, "Potensi Gunung Lawu sebagai Taman Nasional," *BIODIVERSITAS.*, **2** (2) 163-168 (2001). DOI: 10.13057/biodiv/d020207.
 - 28) L. J. D. Atmanto, "Pembangkit Listrik Tenaga Panas Bumi (PLTP) dan Kendala Pembangunannya," *Orbith: Majalah Ilmiah Pengembangan Rekayasa Dan Sosial.*, **11** (1) 60–67 (2015). dx.doi.org/10.32497/orbith.v11i1.373.
 - 29) N.N. Radiawati, "Ancaman Mengintai Gunung Lawuku yang Malang," *Jurnal Warga.*, 2019. <https://www.karanganyarkab.go.id/20190730/ancaman-mengintai-gunung-lawuku-yang-malang/>