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Alternative Direct Use of Geothermal Energy in Atadei

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Abstract. The development of geothermal energy in the Atadei 2 x 5 MW geothermal working area cannot be separated from social problems, namely the opposition of the local population in Lembata Regency. This is due to a lack of knowledge about the benefits of geothermal energy. To overcome this, direct use of geothermal energy can be a solution, so that the surrounding community can feel the benefits of geothermal development. One of the direct uses of geothermal energy is the use of a cascade system. The Atadei geothermal field has the potential for direct use of geothermal for the needs of the surrounding community. The results of this research are expected to provide an alternative to solve the problems that exist in the Atadei geothermal working area, so that the development of the Atadei 2 x 5 MW geothermal power plant can proceed smoothly.

Keywords: *Direct use, Atadei, Geothermal.*

1 Introduction

1.1. Geothermal in Indonesia.

Indonesia has enormous geothermal energy potential, making it one of the countries with the largest geothermal reserves in the world. The total geothermal energy potential in Indonesia is estimated to be about 28,500 megawatts (MW) or 28.5 gigawatts (GW), spread over more than 350 sites along the Pacific Ring of Fire. Areas with the highest geothermal potential include North Sumatra (Sibayak, Sarulla), West Java (Kamojang, Wayang Windu, Salak, Darajat, Patuha), Central Java (Dieng), East Java (Mount Ijen), East Nusa Tenggara (Atadei-Lembata, Mataloko, Ulumbu), and North and Central Sulawesi (Lahendong, Tompaso). However, by 2023, the installed capacity of geothermal power plants in Indonesia will only reach about 2,391 MW, or about 8% of the total national potential [1].

Geothermal energy has many advantages over other energy sources because it is renewable, environmentally friendly, and has very low carbon emissions. In addition, geothermal power plants can operate continuously (baseload), making it a stable and reliable source of energy, unlike solar or wind power, which are dependent on weather conditions. However, geothermal development in

Indonesia faces several challenges, such as high exploration costs, technical drilling risks, land-related social conflicts, and complex licensing processes . To address these challenges, the government has set a geothermal development target of 3,355 MW by 2030 through the National Energy General Plan (RUEN) and provides support through incentive tariff policies (feed-in tariff). With proper management and an inclusive approach to local communities, Indonesia's vast geothermal potential can be optimally utilized to support the clean energy transition and national energy security.

1.2. Direct use potential

The direct use of geothermal energy has the potential to grow due to the policies of world governments, as outlined in the 2015 Paris Agreement, to reduce global warming. By 2019, the number of countries using geothermal energy will reach 88, an increase of 26 countries. In addition to the increase in the number of countries, the increase in direct use of geothermal can be seen from several factors, such as annual energy use (TJ/year and GWh/year), installed thermal capacity (MWt), and capacity factor until 2019. With an installed thermal capacity of 49,079 MWt and an annual energy use of 545,019 TJ/year, Asia is the continent with the largest direct use [2]. A summary of the direct use of geothermal energy worldwide by region and continent is shown in the following table 1 :

Table 1 Direct use of geothermal energy around the world [2]

Continents and Regions	Installed Thermal Capacity (MWt)	Energy Use per Year (TJ/year)	Energy Use per Year (GWh/year)	Capacity Factor
Africa (11)	198	3730	1036	0,597
Americas (17)	23330	180414	50115	0,245
Central America and Caribbean (5)	9	195	54	0,687
North America (4)	22700	171510	47642	0,24
South America (8)	621	8709	2419	0,445
Asia (18)	49079	545019	151594	0,352
Commonwealth of Independent States (5)	2121	15907	4419	0,238
Europe (34)	32386	264843	73568	0,259

Central and Eastern Europe (17)	3439	28098	7805	0,259
Western and Northern Europe (17)	28947	236745	65762	0,259
Oceania (3)	613	10974	3048	0,568
Total (88)	107727	1020887	283580	0,3

1.3. Social Acceptance Issue Geothermal Development in Indonesia

The lack of public understanding of the urgency and benefits of geothermal energy is one of the major obstacles in the process of developing this resource in Indonesia. This phenomenon often leads to resistance, especially in eastern Indonesia, which generally faces limited access to information, low education levels, and strong ties to local customs and cultural values. This condition is reflected in various reports that show community rejection of geothermal projects that are perceived to provide no direct benefits and have the potential to disrupt the sustainability of the environment and their community [3].

2 Objective and Workflow

2.1. Objective

The purpose of this study is to identify various alternatives for the direct utilization of geothermal energy in the Mataloko area, taking into account the potential of available geothermal resources, possible types of utilization, local superior commodities, and the social and economic conditions of the surrounding community. In addition, an analysis of each proposed option is also conducted to evaluate the potential benefits and losses that may arise for local communities.

alternatives reviewed in this study can be further developed in the future into a real facility for the direct utilization of geothermal energy. The facility is expected to not only provide economic benefits to the community, but also act as a means of education about geothermal energy resources and utilization. With the availability of adequate information and knowledge, direct utilization of geothermal energy is believed to increase the level of community acceptance of future geothermal projects, especially in the Atadei geothermal working area. According to Law No. 21 of 2014 on Geothermal Energy, a geothermal working area is a specific area with defined boundaries that is used for indirect geothermal exploitation.

2.2. Work flow

Figure 1 shows the work flow of this study. The study includes literature review, analysis of direct use products, and alternatives for direct use of geothermal energy in geothermal working area Atadei. A literature review will be conducted in the Lembata, including the current status of geothermal development, geothermal direct use, and site information. After the literature review, data and information will be used to verify the accuracy of the desktop study results and assist in further evaluation. The product analysis was conducted by comparing the characteristics of geothermal resources, available raw materials, and socio-economic conditions in Atadei area.

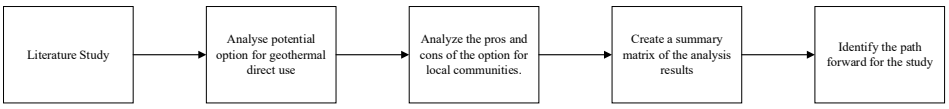

Figure 1 Workflow of the study

3 Literature Review

3.1. Current Geothermal development status

The Atadei Geothermal Project in Lembata Regency, East Nusa Tenggara (NTT), Indonesia is currently in the advanced stages of development. Managed by PT PLN (Persero) through its Nusa Tenggara Development Main Unit (UIP Nusra), the project aims to establish a 10 MW geothermal power plant to provide clean and sustainable energy to Lembata Island.

The Atadei geothermal project is located in Watuwawer Village, Atadei District, and was originally established in 2008. After a period of limited progress, the government contracted PT PLN to develop the work area in 2017. Subsequent surveys and studies, including remote sensing analysis, geological mapping, geochemical studies, and geophysical surveys, were conducted between 2018 and 2019 to assess the site's potential and design the necessary infrastructure.

3.2. Direct Use Of Geothermal

Each direct use application has the potential to be optimally utilized based on the level of need. The optimal temperature range for each direct use application is shown in the following figure 2

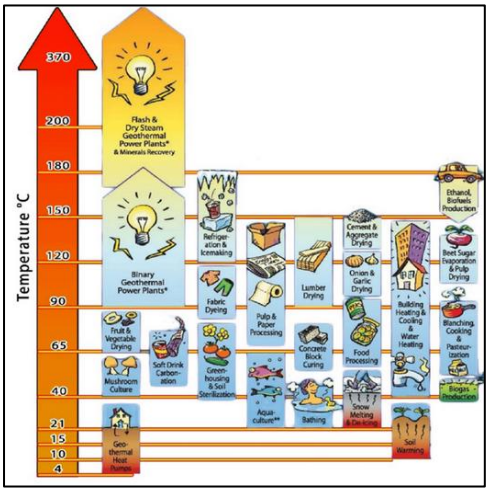

Figure 2 Lindal diagram [7]

Hot water heating, hot tubs, and space heating are some of the direct geothermal applications that have seen an increase in geothermal energy use over the past 25 years. An increase in the use of geothermal heat pumps is one application that has seen an increase in geothermal energy use. Although not significant, geothermal energy use is increasing in the area of climate warming. In the industrial and aquaculture sectors, direct use typically does not result in an increase in energy [2]. A comparison of global energy use for each direct use application from 1995 to 2020 is shown in the following figure 3.

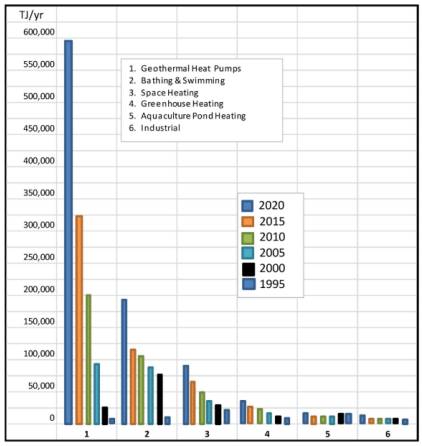

Figure 3 Comparison of the direct use of geothermal energy in the world from 1995 to 2020 [2]

3.3. Information of communities

The topography of Lembata Regency consists of coastal, hilly and mountainous areas with the highest peak at 1,319 metres above sea level. The slope of the land varies from 15% to 40%. Most of the villages in Lembata Regency are coastal villages with 86 (eighty-six) villages and sub-districts and 65 (sixty-five) villages in the highlands [6].

The Lembata Regency is distinguished by its unique demographic and socioeconomic characteristics, positioning it as a distinctive region within the broader context of East Nusa Tenggara Province. According to data from the Central Statistics Agency (BPS) , Lembata's population in mid-2024 is estimated to reach 143,345 people, marking an increase from 135,930 people in the 2020 census. The majority of the population is within the productive age category, accounting for 62.59% of the total. The population aged 0-14 years constitutes 24.4%, while the remaining 13.01% is categorized as elderly. The population density of the region is documented to be approximately 107 individuals per square kilometer [4].

Agricultural activities in Atadei Sub-district, Lembata Regency, East Nusa Tenggara, are the backbone of the community's economy as well as an important part of the local cultural heritage. The Atadei community cultivates various food crops such as cassava, corn, coconut and sorghum. Cassava is widely processed into chips as a local premium product, while maize has a cultural role through the Tun Kwar ritual, a traditional prayer offered together to ask for a good harvest. Sorghum is also being developed for its drought resistance and high nutritional value. In addition, coconut has become a multifunctional commodity used for consumption, as a raw material for handicrafts, and as a source of income. Coffee, particularly Robusta, is also grown on some areas of the Atadei hills, often in agroforestry systems. Although coffee production is still limited, this commodity has promising economic potential and high cultural value as part of the community's social traditions [8].

3.4. Community issue Regarding Geothermal Project

Several residents of the Flores and Lembata regions, including Atadei, have spoken out against the geothermal project. They are concerned that the project will threaten water sources, pollute the air, and damage sacred sites central to their faith and culture. In addition to concerns about environmental impacts, opposition is also driven by the location of the geothermal plant near settlements and communal lands, as well as social issues related to the development plan [9].

4 Site Information

4.1. Heat Source

Geothermal manifestations in Atadei District, Lembata Regency, East Nusa Tenggara, show great geothermal potential and have become the focus of renewable energy development in the region. Various types of surface manifestations are found in this location, such as hot springs in Wai Keti, Karumatek, Wae Teba, Kowan, Tupat, and Wae Mata with temperatures ranging from 40°C, as well as hot soils and fumaroles in Watuwawer and Lewo Kebingin areas with temperatures reaching up to 98°C. In addition, there are altered rocks that show hydrothermal alteration with minerals such as kaolinite, alunite and smectite, indicating an active geothermal system in the subsurface.

Initial exploration was conducted by the government in 2004 with the drilling of the AT-1 exploration well to a depth of 830.5 meters. The maximum temperature recorded reached 145.5°C and the estimated reservoir temperature is approximately 185°C. Although the fluid flow during the test was short, the results were enough to indicate the potential of geothermal energy worth developing. Based on studies, the potential electrical power from the Atadei geothermal field is estimated to reach 30 to 40 megawatts, an amount large enough to meet the electricity needs of Lembata Island [5].

4.2. Current Industri dan Komoditi

Lembata Regency, East Nusa Tenggara (NTT) Province, is rich in various commodities As shown in the table 2. Among them are cashew nuts, chocolate, coffee and copra.

Table 2 Planation Crop Production [4]

Region	Plantation Crop Production by Regency/City (Tons)			
	Coconut	Coffee	Kakao	Cashew
Sumba Barat	1169	308	91	472
Sumba Timur	1231	242	62	3853
Kupang	4596	130	27	1912
Belu	381	95	-	496
Alor	1712	279	68	3519
Lembata	2587	199	192	1516
Flores Timur	10464	1443	2391	13465

Sikka	10625	131	7027	8924
Ende	8947	3484	4555	3963
Ngada	1345	2607	222	660
Manggarai	341	2553	497	1528

4.3. Direct use option

Based on Lindal diagram on figure number 2, temperature of 185˚C. geothermal fluid can be used for drying organic material, drying stock fish, space heating, refrigeration, animal husbandry, greenhouses, mushroom growing, soil heating, swimming pools, biodegradation, fermentation, and fish farming. Based on Atadei's raw material, the direct use potential is raw material drying, space heating and swimming pools like on table number 3.

Table 3 Direct use option

Direct Use Option	Temperature Needed	Option	Remarks
Commodity Drying	100°C	Coffe Drying Copra Drying Casava Drying	It is very much needed to speed up the accelerate the drying process of local raw materials
Animal Husbandry	60°C	Chiken egg Incubation	It is needed to increase chiken's fertility rate
Pool	40°C	Build artificial pool	Currently, there is no geothermal pool tourism, but it could be used to increase the tourism commodity.

An example of for direct utilization of geothermal energy that has been researched is coffee drying and egg hatching.

The goal of drying coffee beans is to lower their water content from about 65% to 11-12%. The rate at which this occurs depends on several factors, including the temperature and moisture level of the beans, the temperature and mass flow of the drying fluid, and the relative humidity. According to Indonesia's national standard, coffee beans should have a maximum water content of 12%. It's crucial

to keep the drying fluid's temperature around 45°C and never above 50°C. Exceeding 50°C can cause the exterior of the bean to harden while the interior remains too moist [11].

Incubation is the process of keeping fertile eggs warm until the embryo develops properly and hatches into a chick. There are two types of incubation: natural and artificial. In natural incubation, the mother hen broods her eggs. In artificial incubation, a device called an incubator is used. Artificial incubation allows the hen to lay more eggs without interruption from the 21-day natural incubation period. The incubator keeps the eggs warm until they hatch [12].

4.4. Other Option Cascade direct use

The direct use of geothermal energy through a cascade utilization approach presents a promising strategy to improve public acceptance of geothermal development in Atadei. By prioritizing local needs such as coffee drying and gradually expanding to other sectors like candlenut, clove, ginger processing, egg incubation, and geothermal bathing tourism, this approach optimizes energy use across multiple thermal levels while generating tangible socio-economic benefits for the community as shown in the figure 4. Compared to conventional direct use, cascade systems offer broader and more sustained community impact. As an initial phase, the development of a commodity drying facility should be prioritized as a pilot project to demonstrate feasibility and community value. This strategy aligns with Indonesia’s broader goals of renewable energy transition and rural empowerment. With consistent stakeholder collaboration, the proposed model can serve as a replicable best practice for other geothermal regions facing similar social challenges.

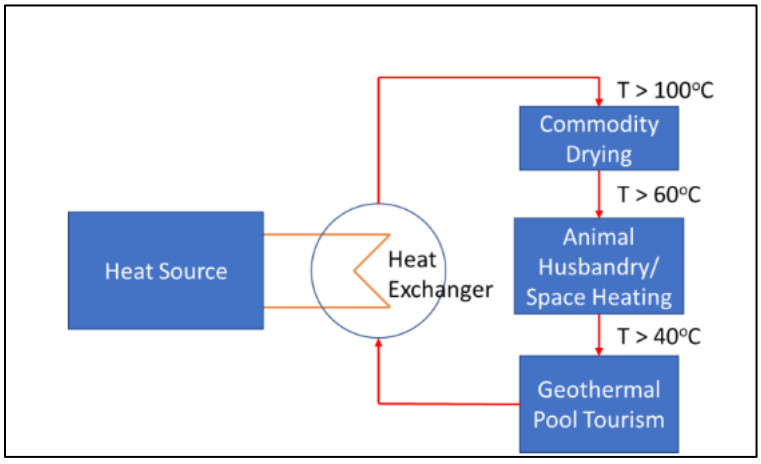

Figure 4 Cascade direct use [3]

5 Conclusion and Path Forward

5.1. Conclusion

One of the main obstacles to the development of the Atadei geothermal power plant is community opposition, as has happened in several previous cases. Increasing public acceptance of geothermal projects is not easy and requires consistent and collaborative efforts from all stakeholders, including the government and geothermal developers. An alternative approach that has the potential to increase public acceptance is the construction of direct-use geothermal facilities that provide tangible benefits to local communities and serve as a means of education about the characteristics and use of geothermal resources. This approach is even more relevant in Atadei, as there are currently no direct geothermal utilization facilities in the area, although there are a number of local commodities that have the potential to add value through this technology.

5.2. Path Forward

Further studies are needed to thoroughly evaluate the direct use of geothermal energy in Atadei. After identifying all available options, a further assessment is needed to determine the potential, feasibility, and optimal application of each option given its unique potential and challenges. A thorough assessment will hopefully reveal the most suitable and applicable option to support geothermal development in Atadei. Additionally, detailed studies are needed for each option to assess potential challenges and the magnitude of benefits that can be obtained during development. While some options may not be suitable for Atadei, it is

hoped that they can be applied to other wells or geothermal work areas in Indonesia to support the overall development of geothermal utilization.

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