# THE POTENTIAL AND SOCIOECONOMIC IMPACTS OF GEOTHERMAL DIRECT-USE ON MATALOKO, FLORES ISLAND, NUSA TENGGARA TIMUR, INDONESIA

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## ABSTRACT

Geothermal heat is naturally generated deep below the earth's surface and is one of the world's largest sources of continuous renewable energy. The most prevalent application of high geothermal temperature is used for power generation. Apart from electricity generation, geothermal energy can be utilized for direct use applications, such as room heating or cooling, drying, agriculture, aquaculture, and tourism.

Indonesia has the most extensive geothermal potential in the world, estimated at 29,000 MW. About 800 MW of that potential is located in Flores Island, Nusa Tenggara Timur. Therefore, in 2017, the Government of Indonesia designated Flores Island as a geothermal island (Flores Geothermal Island) to optimize the use of its geothermal energy as an electricity and non-electricity source.

This research aims to achieve a deeper understanding of geothermal direct-use application and how it would impact the people socially and economically in the area of Mataloko, Flores Island, Nusa Tenggara Timur. The paper also investigates the current local commodities and demographic conditions in Mataloko. The research of geothermal direct-use application, specifically on Flores Island, has been limited. Thus, this paper intends to fill the gaps in this field and can be utilized to improve the socioeconomic welfare on Mataloko and other regions in Indonesia.

## 1. INTRODUCTION

### 1.1 Indonesia's Geothermal Energy Overview

Indonesia has abundant geothermal potential which spreads over more than 300 locations with total resources of 23 GW, including 800 MW on Flores Island. However, only 2.13 GW or 8.9% of these resources have been installed (Darma & Gunawan, 2015; Meier et al., 2014; Pambudi 2017). The Government of Indonesia has determined that 23% of the national energy mix must come from new and renewable energy by 2025, which includes a 7.24 GW increase from geothermal energy (EBTKE, 2017). To accelerate geothermal development in Indonesia, the government, through the Ministry of Energy and Mineral Resources, designated Flores Island as the Flores Geothermal Island in June 2017 (EBTKE, 2017). Of the twelve prospective working areas in Flores Island, three have received a geothermal permit: Ulumbu, Sokoria, and Mataloko.

Mataloko is a sub-district located in the Golewa District, Ngada Regency, East Nusa Tenggara Province. The geothermal system in Mataloko is the result of volcanic environmental activities in Mount Inerie, Mount Ebulobo, and Mount Inielike, which are associated with the tectonic setting of "Banda Arc". The geothermal system in Mataloko is controlled by the Wai Luja fault (northwest-southeast direction), while the geothermal source is generated by young magmatic activity trapped in the developing dike and sill structure. Geothermal energy in Mataloko is dominated by water with a peak reservoir depth of 900 m and a reservoir temperature of 270-283 °C. The geothermal area of Mataloko spans 996.2 ha, and its geothermal potential consists of speculative resources of 10 MWe, possible reserves of 62.5 MWe and proven reserves of 2.5 MWe (EBTKE, 2017).

### 1.2 Geothermal Direct Use Application

The utilization of geothermal energy is broadly divided into two types: namely, direct use and indirect use. The main difference between these two uses is in the form of energy. Geothermal heat energy can be directly used for various needs, for example, heating, drying or hot water baths. Meanwhile, indirect utilization uses geothermal energy by converting it into other forms of energy. The most common of which is electrical energy, by generating electricity with geothermal steam (Dickson, 2013).

The main utilization of geothermal energy in Indonesia is through indirect use to generate electricity. In 2018, 1,948.5 MW of electricity from geothermal energy was generated, an increase of 510 MW from its installed capacity of 1,438.5 MW in 2015 and almost double from 1,187 MW in 2009. The geothermal power plants are located in 13 geothermal areas, such as Kamojang, Darajat, Patuha, Wayang Windu, Karaha and Salakin West Java; Dieng in Central Java; Sibayak and Sarulla in North Sumatera, Ulu Belu in South Sumatra, Lahendong in North Sulawesi, and Ulumbu and Mataloko in Flores (Darma et al., 2020). Flores itself is predicted to be an island that can meet most of its needs using geothermal energy. Therefore, the geothermal development on this island, from the

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direct and indirect use sectors, will increase in the next few years. Currently, the proven geothermal reserve capacity on the island of Flores has reached 12.5 MW.

The regulations governing the direct use of geothermal energy in Indonesia are currently still not regulated, in contrast to indirect use; they are still being assessed to further involve the government and relevant stakeholders. Since the World Geothermal Congress 2015, there has not been a new report of the direct use of geothermal energy in Indonesia. Thus far, there is a traditional freshwater fishery in Lampung Province, mixing natural geothermal hot water (outflow) with fresh water from a river to grow large catfish. In other areas, there is palm sugar processing using condensate steam (brine) produced by the Lahendong geothermal field operated by the Masarang Foundation; copra drying in Lahendong, Mataloko, and Wai Rata Lampung; and mushroom cultivation, tea drying and pasteurization in Pangalengan (West Java) (Darma et al., 2020).

The direct or non-electric utilization of geothermal energy refers to the immediate use of heat energy rather than to its conversion to other forms such as electrical energy. Some of the main forms of this direct utilization include swimming, bathing and balneology, space heating, and cooling including district heating, agriculture (mainly greenhouse heating and some animal husbandry), aquaculture (mainly fish pond and raceway heating), industrial processes, and heat pumps (for both heating and cooling). Generally, the temperature of geothermal fluid required for direct heat usage is lower than that required for cost-effective electric power generation (Lund, 1997).

Power generation is the most important form of geothermal resource utilization, which has a high temperature (>150 °C), while direct utilization requires moderate to low temperatures (<150 °C), making it suitable for many types of applications. The Lindal Diagram in Figure 1 shows the possible use of geothermal fluids at different temperatures. This diagram is still quite valid, but in its development several application options can be added, such as the generation of binary cycle electrical energy added for temperatures above 85 °C. Direct use with temperatures below 20 °C is only exceeded under very special conditions, or with the use of heat pumps (Dickson, 2013).

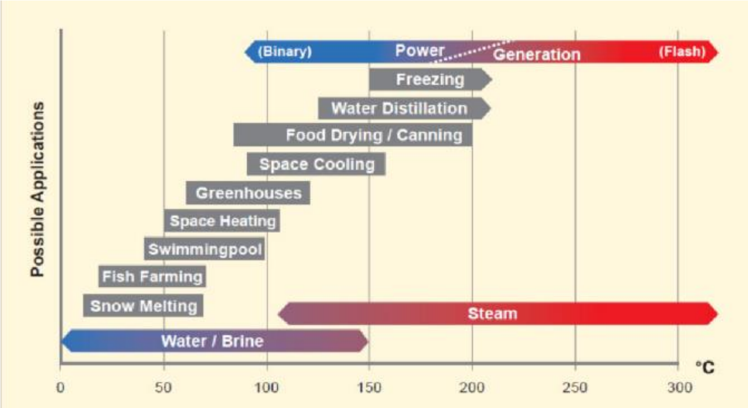


**Figure 1: Modified Lindal Diagram (Gehringer & Loksha, 2012)**

## 2. DIRECT USE POTENTIALS IN MATALOKO

### 2.1 Lindal Diagram for Mataloko

From all the data and information obtained during the desktop study and site survey, a special Lindal Diagram for the Mataloko area can be made. This diagram contains the temperature range for various geothermal uses that can be utilized in Mataloko. The Mataloko Lindal Diagram provides information on all forms of direct geothermal utilization that can be implemented later based on an assessment of the three previous parameters. The Mataloko Lindal Diagram is presented in Figure 2 with the coloured temperatures being an indication of the temperature ranges that can be utilized from geothermal sources in Mataloko.

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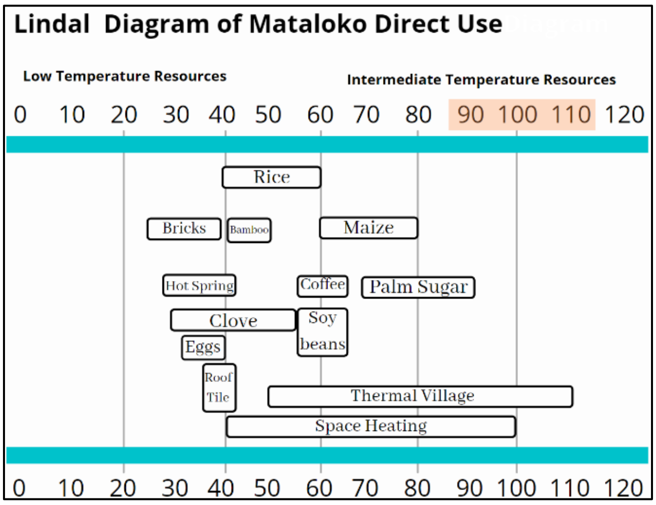


**Figure 2: Lindal Diagram of Mataloko Direct Use (Rigsis, 2021)**

All the local agricultural commodities can be applied as drying local commodities in Mataloko because the temperature range that is necessary is below the temperature supplied by the existing geothermal sources (can be in the form of wells or surface manifestations). Meanwhile, heating can still be applied, but may not be optimal, because the temperature required is approximately the same as the temperature of the heat source.

### 2.2 Geothermal Source Availability

Based on the results of the site survey, an assessment was carried out by giving a certain range of values for each predetermined parameter. For the selection of geothermal source options, all wells and surface manifestations will be assessed for their suitability of being used as heat sources for direct geothermal utilization. From the assessment that was carried out, it was agreed that the suitable geothermal source to be used is one of the geothermal wells that has been developed by the local power plant. This well has been chosen because it still has signs of the presence of steam at the wellhead. In addition, the temperature is still quite high, and the pressure that is read on the wellhead pressure gauge indicates that there is still geothermal activity in the well. Most of the other wells are plugged or shut in and there is no visible geothermal activity around the wells. In addition to geothermal activity, the location of the well that was chosen is also quite strategic because it is located on the side of the road and if it needs to be accessed later it is quite easy for the surrounding community to do so, plus the $H_2S$ content is quite low.

Meanwhile, there is no surface manifestation that is feasible as a geothermal source. This is because the results of the site survey show that the surface manifestations in Mataloko tend to appear in different locations, making it difficult to predict. Furthermore, the location of the surface manifestation is quite difficult to access so if it will be used in the future, it will be difficult to carry out construction at that location. The chemical composition of the surface manifestations is also not well known. If the existing surface manifestations do not change in location and are easy to access, it can be used as a hot water bath. From the assessments carried out on geothermal sources originating from wells and surface manifestations, the geothermal option to be chosen would be in the form of a geothermal well.

### 2.3 Optimal Direct Use Utilization in Mataloko

After selecting the geothermal source, the next form of utilization will be determined. From the Mataloko Lindal Diagram, there are three possible uses: namely, drying, hot bathing, and space heating. These three forms of utilization will be re-assessed using the same method as the selection of geothermal source options. Assessment is based on three parameters: the required temperature, the ease of access to the heat source, and the breadth of impact on the local community. Finally, drying for local commodities was chosen as the most optimal form of utilization, because it satisfied the three parameters mentioned above.

Based on the Lindal Diagram of Mataloko, several local commodities that can be used as drying options were obtained, including coffee, rice, soybeans, cloves, bamboo, corn and palm sugar. After the site survey, the four most abundant commodities are coffee, cloves, ginger and candlenut. Of these, coffee and cloves need the most drying, but the production of cloves is less than coffee and the market price is not as high as coffee, so people tend to need more drying for coffee, especially in the form of freshly picked coffee beans. In addition, coffee requires a longer drying time than cloves, so if there was a dryer for coffee it would be very helpful for the coffee farmers in Mataloko. Therefore, the application of direct geothermal utilization is aimed at drying coffee by utilizing a heat source from a geothermal well.

The presence of a system that can speed up the drying process is also a consideration in choosing coffee drying as the most necessary form of utilization. The majority of Mataloko's local residents work as coffee farmers, yet they still use solar heat as the conventional method for drying coffee. However, the weather in Mataloko tends to be rainy and humid due to its location in the highlands. If the weather is not favourable, they are forced to dry their coffee on a nearby beach, which incurs additional costs such as transportation and rental space. Therefore, the urgency of procuring a dryer that can speed up the coffee drying process, and that is not located too far from their coffee plantation is very much needed.

**Figure 3: Coffee Tree in Mataloko (Personal Documentation, 2021)**

**Figure 4: Interview with Local Coffee Farmers (Personal Documentation, 2021)**

## 3. SOCIOECONOMIC IMPACT FOR GEOTHERMAL DIRECT USE IN MATALOKO

This section will explain the results of an economic analysis on the effect of the coffee drying system for the local communities, especially for people who depend on their profession as coffee farmers every day. In addition to the economy, analysis will be carried out as to how the social impacts will be felt by the local community.

### 3.1 Economic Impacts

3.1.1 Cost Analysis Related to Conventional Drying

Site survey results reveal that, due to weather and humidity, farmers have to bring their freshly harvested coffee beans to the lowlands or coastal areas such as South Golewa and Ende to get sufficient sunlight. If the weather is cloudy, it takes farmers approximately 25 days to dry their coffee beans there. The trip to Mbayi takes approximately 2 to 3 hours using a pick-up car with a capacity of one ton. The car rental fee is estimated at IDR 500,000 for a one-time transfer or pick-up. On arriving at the drying area, the farmers need to rent a place to dry their coffee beans at a cost of IDR 50,000 per day. In addition, they pay for meals while waiting and give money for tips or others. Table 1 below shows how much it costs farmers to dry one ton of coffee by using conventional methods (around 25 days). It can be concluded that at the time of harvest, the costs incurred by farmers to dry one ton of coffee beans for **25 days** using these methods are **IDR 4,325,000** or around **US$ 298.58.**

3.1.2 Cost Analysis Related to Coffee Drying Capital and Maintenance Cost

From the market survey that has been carried out with several vendors, the author has calculated the capital cost for the geothermal developer to construct a particular coffee drying machine with a capacity of 500 kg.

**Table 1: Estimated Coffee Drying Capital Cost**

| No. | Description | Total Cost (IDR) |
|---|---|---|
| 1 | Piping | 117,620,710 |
| 2 | Mechanical | 239,140,000 |
| 3 | Civil and Structure | 642,078,880 |
| **TOTAL** | | **998,839,590** |

Based on Table 1 above, the total cost to construct a coffee drying machine is IDR 998,839,590, with civil and structure consuming almost 70% of the total cost. The table 2 below shows the operational and maintenance costs for one year, including spare parts, utilities, and admin or warehouse salaries.

**Table 2: Estimated Coffee Drying Maintenance Cost**

| No. | Description | Total Cost (IDR) |
|---|---|---|
| 1 | Operational Cost | 75,600,000 |
| 2 | Maintenance | 62,020,000 |
| 3 | Working Equipment | 10,500,000 |
| **TOTAL / YEAR** | | **148,120,000** |
| **TOTAL / DAYS** | | **474,744** |

Some of the numbers above are results from the market survey to the drying machine vendor. However, the salary is assumed from the average minimum wage in Nusa Tenggara Timur.

It can be seen from Table 2 above that to operate and maintain the coffee dryer it needs IDR 474,744 (~ IDR 500,000) per day. Therefore, if the geothermal developer wants to charge rent to the coffee farmer, it is expected to be the amount above to cover the maintenance and operating costs.

The study on direct-use application in Mataloko was initially planned as a pilot project that would later be further developed into a corporate social responsibility for the community around the geothermal power plant. Thus, this study will also conduct an economic analysis by comparing the costs incurred by farmers using conventional methods and the drying machine system.

The following tables show the total costs incurred by farmers for drying 1 (one) ton of coffee using conventional and coffee dryers:

**Table 3: Amounts needed by farmers if using conventional method**

| No. | Item | Total Cost (IDR) |
|---|---|---|
| 1 | Transportation (return) | 1,000,000 |
| 2 | Space rent (25 days) | 1,250,000 |
| 3 | Meals (25 days) | 1,875,000 |
| 4 | Miscellaneous | 200,000 |
| **TOTAL** | | **4,325,000** |

**Table 4: Cost needed by farmers if using a coffee dryer**

| No. | Item | Total Cost (IDR) |
|---|---|---|
| 1 | Transportation (return) | 1,000,000 |
| 2 | Space rent (25 days) | 1,250,000 |
| 3 | Meals (25 days) | 1,875,000 |
| 4 | Miscellaneous | 200,000 |
| **TOTAL** | | **4,325,000** |

By using a dryer with a capacity of 500 kg and/ or 3 x 170 kg, farmers only spend two days drying 1 (one) ton of coffee. The cost to operate and maintain the coffee drying machine can take up to IDR 500,000 or US$ 34 per day. Thus, if the developer wants to charge the farmers rent, the fee would be at least IDR 1,000,000 or US$ 69 for two days. Based on the calculation above, coffee farmers only spent a total cost of **IDR 2,200,000** or **US$ 151.88** for **two days**. In addition, the duration of the trip between the coffee plantation in Bajawa and the local geothermal power plant is estimated to be approximately **30 minutes**. Therefore, when the farmers are using the drying machine, they can save as much as **IDR 2,125,000 or US$ 146.70**, and a saving of **23 days** (a shorter trip). Eventually with a shorter distance and duration, the $CO_2$ emission would also be less.

### 3.2 Social Impacts

In this social discussion, a drying schedule scheme will be described and aims to assist farmers in drying coffee commodities. In addition, statistics will also be explained regarding the gender of the farmers from the MPIG Flores Bajawa Arabica Coffee (an institution that represents the Bajawa people of Flores Island plays a role in maintaining the production and quality of Flores Bajawa Arabica coffee products).

#### 3.2.1 Coffee Drying Schedule

The application of the coffee drying is crucial. Direct management needs to be carried out, such as scheduling, calling for the use of drying and others. Coffee farmers in the Mataloko area are not the only members of the MPIG Flores Bajawa Arabica Coffee community, there are other local farmers. The coffee drying system that has been designed can be used by all farmers, both coffee farmers from MPIG Flores Bajawa Arabica Coffee or other local farmers.

Due to the large number of coffee farmers who will use this drying facility, it is necessary to make a schedule, because the drying time for a capacity of **500 kg** takes **8 hours**. Therefore, scheduling is necessary to avoid misunderstandings or other bad cases. Here is an example of a scheme:

- **Drying Scheme**: Drying operational from 07.00 WIT (7.00 AM) to 15.00 WIT (3.00 PM) (Monday-Saturday)

Please note that **the scheme described above is only a suggestion**. The application in the field needs to be adjusted to the needs of the community (deliberation with related parties). As for the scheme above, the following is a schedule for the use of coffee drying for all related parties, which in this case are farmers from MPIG Flores Bajawa Arabica Coffee and local farmers. The schedule is listed in Table 5

**Table 5: Drying schedule scheme and related parties**

| Day | Party Using Coffee Drying |
|---|---|
| **Monday** | MPIG Flores Bajawa Arabica Coffee |
| **Tuesday** | |
| **Wednesday** | |
| **Thursday** | |
| **Friday** | Local farmers |
| **Saturday** | |
| **Sunday** | Not operating |

It should be noted that based on field visits, the MPIG Flores Bajawa Arabica Coffee can produce 3,000 tons of coffee per year. The harvest period for coffee is 5 months and coffee needs to be produced into green beans during that time. Therefore, based on the calculations, farmers need to dry 20 tons of coffee per day. Meanwhile, this amount does not include coffee production outside the MPIG Flores Bajawa Arabica Coffee farmers group. Thus, that coffee production is predicted to be more than 3,000 tons of coffee per year.

In this case, it should be noted that the design of the drying is only **to accommodate coffee needs**. The consultant suggests that if the drying system will be used for drying another local commodity, it is necessary to ensure that those commodities have a humidity that is not much different from coffee. As for the drying-time period, the consultant also suggests that the drying system can be used after the harvest period of 5 months once the drying of coffee is complete. However, this also depends on the implementation in the location.

#### 3.2.2 Gender Statistics

Based on the results of the interviews with the head of the MPIG Flores Bajawa Arabica Coffee, the farmers in this community consist of 286 members. These farmers are spread across three sub-districts: namely, Golewa, West Golewa and Bajawa. The following figure is a diagram showing the gender division of the MPIG Flores Bajawa Arabica Coffee farmers.

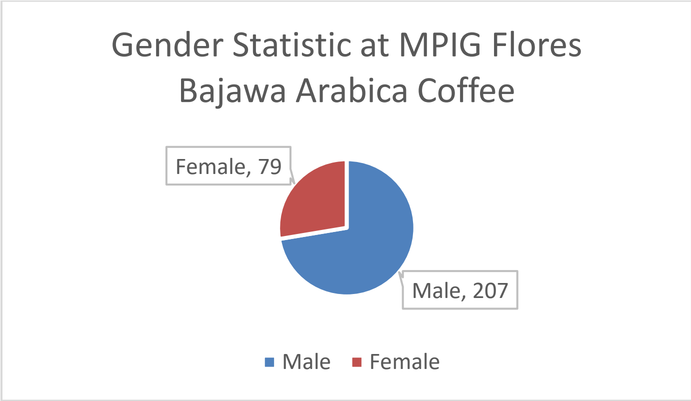


**Figure 5: Gender statistics from the MPIG Flores Bajawa Arabica Coffee farmers**

Based on these data, the number of female farmers is lower than that of the males. There are **79 female coffee farmers or 28%** of all registered coffee farmers. However, the data on the number of farmers in the MPIG Flores Bajawa Arabica Coffee does not include all coffee farmers in these areas. Due to the drying system that is quite easy to operate, women of reproductive age can be recruited as operators in drying coffee. In addition, they also participate in training the farmers who will operate this drying method.

## 4. CONCLUSION

The construction of the coffee drying system will have a very good impact on the community, especially in terms of the costs incurred. A drying schedule has also been developed which can be used as a reference for farmers in the use of drying. The schedule that has been arranged is only a suggestion and can still be changed or adapted to the conditions in the field. The study also advised that drying should only be reserved for coffee commodities to avoid future social problems as well as the technical considerations that have been made, such as temperature, flow rate and pressure. In addition, and based on the comparative calculation of the costs above, the farmers can save time by cutting it down from 25 days to 2 days, and at a cost of around IDR 2,125,000 or US$ 146.70, if they use the coffee dryer instead of the conventional drying method.

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