Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Beyond (Agro) Industrial Solutions: Approaching Direct Use of Geothermal Energy from a Social and Economic Perspective

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Keywords: direct use, feasibility studies, socio-economic impact, drying process, agricultural applications, Central America, GIZ

ABSTRACT

Central America is among the world's leading developers of geothermal energy for electricity generation. Due to its position on the Pacific Ring of Fire, Central America holds a high potential of geothermal energy. As a clean and climate resilient energy source, geothermal energy plays an important role in providing base load power generation to the Central American power grid.

So far, Central America has not yet taken advantage of the high geothermal potential that lies in direct use applications. While geothermal direct uses provide heating and cooling solutions for both, the industrial and residential sectors to many countries, the development and implementation of these technologies have been very slow or have yet to be introduced to Central America.

Expanding direct uses is not only a matter of making investments, but of building awareness through proofs of concept and empowering local communities and developers as geothermal enterpreneurs. To that end, pilot projects are crucial in ensuring the viability of direct uses of geothermal energy in the region and to demonstrate the potential to lower energy consumption costs and great impact at a social and economic level.

On behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH has been implementing the regional Program, "Promotion of Geothermal Energy in Central America" since 2016. Over the past years, GIZ has developed a series of feasibility studies for selected direct use pilot projects in Central America as part of its efforts to demonstrate the technical, economic and administrative feasibility for direct uses of geothermal energy. The first results of these studies focused on agricultural/agri industrial applications of direct use of geothermal energy in cascade and independent utilization. The following study is was conducted by CEGA – The Center of Excellence in Geothermal Energy of the Andes from Chile, as part of the set of pilot projects proposals researched in the region.

1. INTRODUCTION

The aim of this study was to identify the level of technical, economic and social feasibility to implement a direct use of geothermal energy, recovering heat from the injection pipelines at Miravalles Geothermal Field, located in the province of Guanacaste in Costa Rica and managed by the Costa Rican Institute of Electricity (ICE)

To identify the available thermal energy, the productive conditions, as well as the social and cultural aspects that could affect this project positively or negatively, a fieldwork was conducted in the the canton of Bagaces, where Miravalles Geothermal Field is located. In order to recommend a specific pilot project, analytical calculations were carried out to estimate process capacity, efficiency, and energy consumption. Additionally, a private economical assessment determined the profitability of the project. The social analysis included an identification of the most important stakeholders and a description of their perception and level of involvement in order to propose a geothermal project based on a local and participatory approach. Finally, a legal framework was reviewed to determine the legal feasibility and additional legal conditions that need to meet before developing such pilot project.

2. PILOT PROJECT

This study was developed drawing upon the information provided by the German Corporation for International Cooperation (GIZ), institution that identified the potential project location as well as key stakeholder in the territory. Drawing upon this data, the overarching goals were to carry out a feasibility study from a multidisciplinary approach, paying attention of technical, economic, and social aspects. It was necessary to identify available thermal energy, if a direct geothermal project could alter the normal functioning of the geothermal field, the productive processes for a pilot project, to find the most suitable area to build a geothermal pilot project.

It was also necessary to describe energy consumption and optimal operating temperatures for a direct geothermal project and to carry out a private economic assessment.

From a social perspective, it was needed to identify local stakeholders interested to invest and diversify their current means of production (geothermal entrepreneurs). It was also necessary to describe social and cultural aspects that could have an impact in a project, as well as to depict potential risks and benefits.

For the pilot project, the size of machines and facilities along with its efficiency, and energy consumption are estimated by analytical for heat and mass transfer. On the other hand, the economic feasibility of the pilot project was estimated with a private cash flow based on the structure of cost and incomes.

The methodology tools chosen were gathering information from a secondary source, to introduce the project to key stakeholders, in deep face to face interviews with local partners and potential developers, telephone meeting with stakeholders, visit to industries/communities in the territory.

2.1 Geothermal resource

The results highlight that the available thermal energy in pipelines at the Miravalles geothermal field exceeds the actual thermal energy required for a pilot project.

Since October 2012, the injection pipeline identified as ideal has been kept in the range from 1,500,000 tons/month to 1,000,000 tons/month. The above is equivalent to a range of 385-575 kg/s. Considering that the reservoir manager from ICE indicated that it is appropriate to recover up to 5°C from waste brine, the available energy in the western part of the geothermal field is in the range of about 8 – 12 MW of thermal energy.

$$Thermal\ power = mass\ flow \cdot c_p \cdot \Delta T \quad (1)$$

Here, mass flow is 385-575 kg/s, heat capacity cp is 4.2 kJ/Kg·°C, and temperature difference ΔT is 5°C.

In this sense, a geothermal dryer center is proposed to be in the western part of the geothermal field, about 1 km north from Miravalles Power Station I & II. This project should not alter the normal functioning of the geothermal field.

2.2 Positive impact on productive processes

Considering local social needs, production levels, current productive situation, energy needs in the production chain and the technically feasible process, the pilot project is designed to process onions, rice, beans and corn.

2.2.1 Onions

At a nationwide level, there are 870 micro producers, who produce 37,194 tons of onion yearly. As the onion producers face low socioeconomic conditions, they do not have resources to invest in productive infrastructure, fertilizers and machinery, among others. Therefore, the production is carried out in precarious conditions. Productivity should be prioritized since an onion is an especially perishable product of rapid degradation and highly susceptive to weather conditions.

Usually the onions are dried naturally under the sun, leaving the crops exposed to bugs, diseases and degradation. Once onions are harvested, they are left exposed to the sun for 2-3 days on the ground (pre-drying). Afterwards, the drying process is continued in tents or warehouses for about 8 days. Furthermore, most of the onion producers do not have appropriate storage facilities.

As a consequence of the current careless drying process and the lack of appropriate storage facilities, 40 – 50% of the production is lost – mainly due to the highly humid tropical climate.

2.2.2 Rice

Nationwide, rice production is carried out mostly by so called micro producers (79%). On the other hand, 16% and 5% of the production is carried out by medium and large producers, respectively. In the area of interest, there are 217 identified rice producers, out of which 88.9% are small producers, 9.7% medium producers, and only 1.4% correspond to large producers.

The drying process of rice should start immediately after the harvest to prevent fermentation. Natural drying is done on the field exposing the grains to the sun and wind. Consequently, it is a process when done naturally, strongly depends on weather conditions and available drying area.

Most of the producers do not have neither facilities nor machines to carry out the drying processes after the harvest. Hence, most of the producers sell the rice after harvest to large rice processors that clean and dry the grains or pay third parties for this drying service.

2.2.3 Beans and corn

Nationwide, the production of beans and corn is carried out mostly by small and medium producers facing similar low socioeconomic conditions, with a low level of coordination. Consequently, an individualistic culture prevails, in which each producer must procure for himself the agricultural inputs for production. This is relevant, because the acquisition of agricultural inputs represents between 25 and 41% of their production costs. In addition, producers have limited access to financing.

Most of the bean and corn producers do not have adequate facilities for drying and storage procedures to guarantee the quality of the product and risking severe losses. In fact, beans and corn loses by exposure to moisture, pests and diseases range between 10 and 15%. Currently, there is little technical assistance to producers to adopt appropriate post-harvest management practices.

2.3 Geothermal cascade project

After having analyzed the conditions of agricultural production in the vicinity of the Miravalles geothermal project, a drying process became an interesting option to analyze.

The drying process is made by passing a hot air flow through them, which remove the moisture of the crops as water vapor. Direct use of geothermal for heating the air flow is especially beneficial due to its high plant factor, which allows a stable and flexible thermal energy supply, unlike another renewables.

Because of Bagaces's high humidity levels, reducing the air moisture content is necessary to allow dried onions and other grains to be preserved for longer periods of time. This should be achieved by reducing the air temperature through an absorption chiller fed with geothermal heat.

Therefore, a 300 m2 onion dryer was proposed that could dry 30 tons within three days, reducing time from eight to three days and hence, guaranteeing the quality of the onions. Onions also are proposed to be stored in a 450m2 warehouse with a full capacity of 120 tons. The warehouse is going to be acclimatized at 25°C with relative humidity of 65-75%. In case of grains, a three-ton capacity bed type dryers is proposed, each one able to dry all three grains, one at a time each. The above leads to a drying time reduction from three to one day and guarantees the quality of the grains. Similar to the onions, a 270 m2 grain warehouse for grain storage is proposed. All these processes would allow for a 0.8°C temperature reduction of waste brine, which in the interest area is about 160 kg/s mass flow at 165°C.

For the proposed direct use of geothermal energy in Miravalles, the annual thermal energy consumption is 825,000 kWht. The above implies an electrical consumption of 59,000 kWhe, which is a small fraction compared to thermal energy required. On the other hand, at fully capacity the thermal power required is 420 kWt and an electric power of 25 kWe. The summary of the energetic requirements is summarized in Table 1.

Table 1. Energetic requirements for the drying and storage process

	Curing onion	Onion storage	Grain drying
Operation temperature [°C]	35	25 – 30	40 - 60
Ideal relativity humidity	75 – 80%	65 – 75%	30 – 70%
Capacity [ton]	30	120	9
Original cycle duration [day]	8	-	7
New cycle duration [day]	3	-	1
Annual operation period [month]	3	3	12
Thermal power required [kW_t]	100	245	75
Annual thermal consumption [kWh_t]	70,000	525,000	230,000
Electrical power required [kW_e]	3	8	14
Annual electrical consumption [kWh_e]	2,000	17,000	40,000

Regarding heating for drying, and cooling for preservation by the abortion chiller, thermal power requirements implies a cooldown in waste brine of 0.6°C. Therefore, there is neither scaling/corrosion risk nor reservoir thermal stability risk.

Because reinjection flow cannot be diverted, another external concentric piping is required to recover the heat from the injection pipeline. In previous works, it was proposed to recover the heat with air flow circulation. Nevertheless, to improve the transfer rate and avoid pressure changes problems, it is proposed to use water as the heat recovering fluid.

Since the absorption chiller requires at least 95°C, the circuit for revering heat must be able to reach up to 100 °C. Because the reinjection pipeline has a diameter of 35 cm, it is necessary a 10 cm thickness heat exchanger (water to water) covering the injection pipeline. In addition, if 10 L/s are used to recover 10 °C from the outer part of the pipeline, its length must be 28 m to reach the 100 °C. It should be noted that a different heat exchanger design could reduce the needed length.

Last but not least, the use of geothermal reduces the drying time considerably, without using or depending on fossil fuel, while avoiding any additional carbon footprint. At the same time, the technification of the drying process ensures a high quality for the products, without depending on weather conditions, which is an essential aspect when taking into account worsening climate change related weather conditions in the region. This underlines that not only geothermal energy per se yet also direct use application processes contribute to climate resilience.

2.3 Economic analysis: Preliminary business model

It is proposed to generate purchase agreements between producers and the geothermal drying crops process center to grantee fair prices for producers and the supply to the process center. As the process center considers facilities for storage, it is possible to wait to sell the production in the months of higher prices. Finally, the market for the products is going to be mostly local e.g., the Regional Chorotega Market, allowing for an increase in local economic development.

The profitability in operation relies of profit margins, which are the following: Onions (31%); rice (89.8%); bean s(61.9%); and corn (13.6%). The above indicates that the proposed pilot project is expected to have a high profitability. Indeed, considering a 10% discount rate and an evaluation horizon of 10 years, the proposed project has a positive net present value (NPV) of US$ 1,567,839 and a inter rate of return (IRR) of 32%. Considering initial investment of US$ 386,027 for designing and building the center and paying staff, plus working capital of US$ 144,194 for acquiring grains and onions in the first six months.

It is proposed to develop a center for the processing of crops, grown in the canton of Bagaces, administered by a local agricultural organization and powered by clean and renewable geothermal energy from the Miravalles Geothermal plant.

This plant is planned to obtain, dry, store, package and sell onions, beans, corn and rice acquired from local producers. In addition, a drying service will be offered to local producers who wish to market their product by themselves or for self-consumption.

With this project, it is expected that surrounding agricultural communities, by buying their products at fair prices will increase their income. And by offering them a drying service, they can at the same time obtain a higher quality product, decreasing the chance of production losses due to the current natural drying techniques.

2.4 Social Analysis

In Costa Rica, there is no special regulation for geothermal activities. The only specific legislation is Law No. 5961, enacted in 1976, which declares Geothermal Resources of Public Interest ("Law 5961/1976). Article 1 of this regulation declares that the ICE will be "exclusively in charge of activities related to investigation, exploration and exploitation of geothermal resources, "without the need for permits or concessions of any dependency of the State".

Drawing upon the stakeholder analysis and the identification of social concerns, there is a high social feasibility for a geothermal direct use project in Miravalles. This result is based on the level of support of the stakeholders, from Ministries to local farmer organizations, who are available to be part of a pilot project with high level of interest. However, public engagement strategies and the support to the local community, as potential administrators, are crucial to face several issues and risks, such as lack of low level of local organization, training and stakeholder experience when working together. Hence, a certain accompaniment for such stakeholder processes is from utmost importance.

3. CONCLUSION

From a technical and economical perspective, the pilot project under study presents positive results for the use of waste heat from a reinjection pipe of the Miravalles geothermal project.

Taking into account the information provided by stakeholders in the fieldwork, a geothermal direct project in Miravalles could boost several benefits at different levels, but specially at a local agricultural level, by granting a chance to diversify their production.

At local level, to expand the uses of geothermal energy in Miravalles and promoting a direct use project, could resolve the main challenges for farmers: preservation, storage and commercialization of agricultural products. Local farmers could have more confidence about selling their products, because they currently sell their crops to intermediaries. Another benefit is promoting local empowerment. Local organizations from Miravalles were interested in taking advantage of local resources, hence making a case for direct use geothermal entrepreneurs..

From a meso perspective, the geothermal project could fulfill one of the main concerns, which is, ensuring the Regional Market supply of high-quality products without depending on the season and external weather conditions.

This is a key contribution because the Chorotega Regional Market is planning to be the second largest wholesale center in the country.

Finally, from a macro perspective, a geothermal direct project could contribute to the national policy of a promotion of agricultural innovation, tackling climate change through climate resilient solutions, as well as be an opportunity to lead a law modification for direct use of geothermal in Central America.

These types of projects with the detailed analysis could be considered as a diamond in the rough, which can be polished to provide great opportunities and socio-economic impact to neighboring communities. Thus, reducing the social risk that many energy generation projects usually have.

The regional Program, "Promotion of Geothermal Energy in Central America" of GIZ will consider in its second phase, from November 2020 a main focus to develop more feasibility studies such as these and their implementation or escalation, which will allow to demonstrate the positive impact of geothermal direct uses.

REFERENCE

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