Cascade Use of Geothermal Energy in Mexico

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ABSTRACT

Geothermal cascade systems are widely used around the globe. Once the geothermal resource is utilized in a main application, like power generation, it is led to secondary processes in which the thermal energy can still be utilized. Examples of these secondary processes include refrigeration, desalination, dehydration, defrosting, climate control of greenhouses, and paper recycling, among others. One of the main advantages of cascade systems is that, in major power generation plants, is not uncommon to find available geothermal resources on the surface. The iiDEA Group, an applied research group part of the National Autonomous University of Mexico, is currently developing three major projects aimed at the exploitation of low-enthalpy geothermal energy: a Flash Evaporation Binary Cycle (FEBC), a Modular Geothermal Desalination Unit (MGDU), and a Geothermal Food Dehydrator (GFD). In this article, an overall discussion of the aforementioned projects is presented as a proposal for cascade use of geothermal energy in Mexico.

1. Introduction

The use of geothermal heat in applications other than power generation has increased over the years not only in the quantity of related projects, but also in the number of countries developing them. One of the historically robust direct uses is the case of Iceland, where over 90% of the district-heated houses use geothermal energy [1]. Regarding major collective projects, greenhouses in Hungary and Russia along with industrial activities in US and New Zealand have gained worldwide attention.

Direct use of geothermal heat for bathing, space and district heating, and agriculture, along with some industrial processes is a well-known application, being geothermal heat pumps the ones with the most generalized, using 55.3% of the 587,786 TJ/yr (163, 287 GWh/yr) of thermal power reported by 82 countries in 2015 [2].

Until recent years, power generation had been considered the most important use of geothermal energy in Mexico, hence the promotion of exploration campaigns seeking high-temperature reservoirs with relatively large well-head pressures suited for power generation. At the same time, low-enthalpy geothermal resources had been used for recreational purposes, neglecting their exceptional potential.

2. Discussion

Capital cost of a geothermal power plant is usually greater than that of a fossil power plant. In Mexico, capital cost of a geothermal power plant can reach 30 USD/MWh while in a combined-cycle power plant is 16 USD/MWh. On the other hand, the levelized cost of generation of a geothermal power plant is 70 USD/MWh, and 65 USD/MWh for a combined-cycle power plant [3].

One of the main benefits of geothermal power plants has to do with their capacity factor. In addition, if cascade systems are used, a noticeable reduction in costs can be achieved.

Current geological surveys provide enough information on hot spots located throughout Mexico that may be used for power generation and direct uses [4], as shown in Figure 1.

In spite of the well-known potential of these resources, the lack of a consistent regulation regarding the definition of a geothermal resource held back technological development for years. For instance, the 81th article of the Mexico's Waters Law states that any ground water resource, either as water or steam below 80 °C is still under its jurisdiction, regardless of its thermal energy and its potential uses [5]. As a consequence, the fact that current statutes did not grant long-term property rights over the underground resource represented barriers for both power generation and direct uses.

The Mexican Center for Innovation in Geothermal Energy (CeMIE – Geo) is an alliance between academia and the private sector, aimed for research and development of projects involving the exploitation of geothermal energy. The iiDEA Group, an applied research group of the Engineering Institute of the National Autonomous University of Mexico (UNAM) is developing low-enthalpy technological solutions towards power generation, brackish and sea water desalination, and food conservation through dehydration.

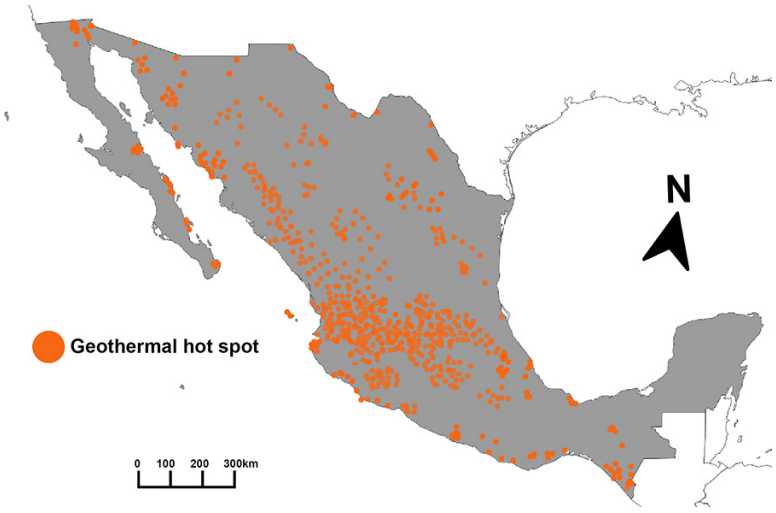

Figure 1. Localization of geothermal hot spots in Mexico.

Figure 2. Flash Evaporation Binary Cycle (FEBC).

Figure 3. Modular Geothermal Desalination Unit (MGDU).

2.1 Flash Evaporation Binary Cycle

Self-power generation of electricity, as well as local power generation are based on low-power generation, focusing on the use of local energy sources, providing the freedom of off-the-grid eco-friendly power.

The iiDEA Group is currently working on a low-power generation cycle which may use waste heat, or low-enthalpy geothermal energy, named Flash Evaporation Binary Cycle (FEBC) after one of its operation principles, designed for an inlet temperature of the geothermal fluid ranging from 140 to 180 °C.

The FEBC, shown in Figure 2, is a modular equipment that, as its name suggests, uses two fluids: one of them carries and transfer the heat, the other, acts as the working fluid. This principle has already been used in Organic Rankine Cycles (ORC) and Conventional Binary Cycles (CBC), however, the FEBC has reduced dimensions and is practically maintenance- free, since the required time for this procedure is drastically reduced.

2.2 Modular Geothermal Desalination Unit

The fact that desalination technologies are being used with renewable energies such as solar, wind and even geothermal power, has a major impact on desalination processes, since an excellent quality product can be obtained through this favorable synergy between technology and environment. This is the background and opportunity that iiDEA takes advantage of, developing a Modular Geothermal Desalination Unit (MGDU), shown in Figure 3.

While conventional desalination units use waste heat, needing up to 120 °C, the MGDU uses low-temperature geothermal fluid, with temperatures as low as 90 °C, optimizing the exploitation of its thermal energy.

2.3 Geothermal Food Dehydrator

A growing developing city has many needs and issues that can be solved using versatile methods. One example of this kind of solutions is the fact that dehydrated food may help to diminish waste food and, at the same time, be a profitable product in select markets without adding the cost of fossil fuels.

Based on the above, the iiDEA Group is developing a Geothermal Food Dehydrator (GFD), shown in Figure 4, with the following major objectives in mind: to provide improved dehydrated products using low-enthalpy geothermal fluids reducing costs associated with packing, transportation and storage, guaranteeing a high-quality conserved food that meets population demand.

Figure 4. Geothermal Food Dehydrator (GFD).

2.4 Proposal of Cascade Use of Geothermal Fluids

The proposed arrangement for cascade use is shown in Figure 5, where the estimated inlet and outlet temperatures of each stage are also indicated. While the complete set involves the MDGU, its utilization strongly relies on the need of drinking water and the availability of the resource. Taking this into account, the Baja California Peninsula is a region of special interest because of the availability of geothermal resources along with brackish and sea water [6].

Although the proposed cascade use of geothermal fluids involves the Flash Evaporation Binary Cycle as the starting module, it should be noticed that it is not necessarily needed since it may be omitted from this scenario if the geothermal reservoir does not satisfy the minimum energetic requirements of the cycle, leaving the Modular Geothermal Desalination Unit as the starting module.

This specific scenario minimizes the number of elements in the energy path, still, the general proposal provides enough alternatives to be used according to a specific well.

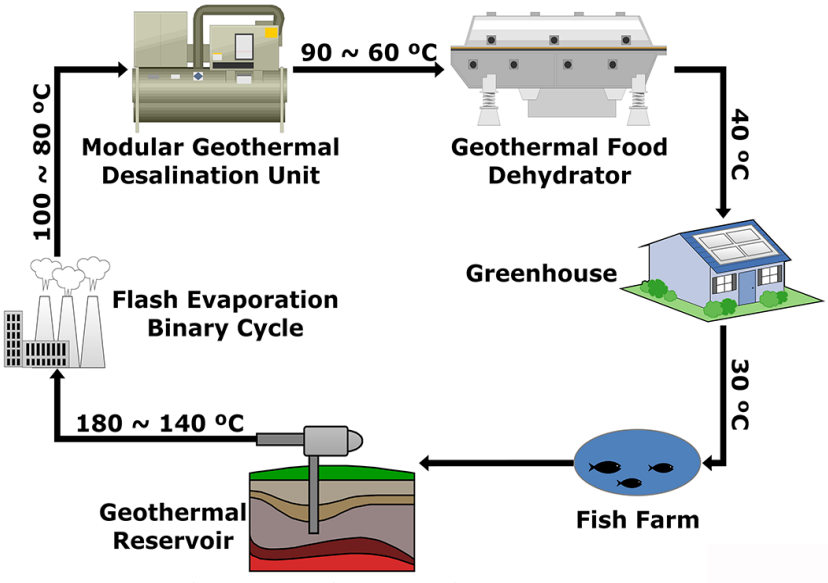

Figure 5. Proposal of cascade use of geothermal fluids.

3. Conclusions

Geothermal energy has proven to be a clean and versatile energy source, mature enough and present in many regions of Mexico, useful for direct uses and low power generation. One of the major requirements for the profitability of the proposed cascade scheme is the existence of drilled wells or superficial hot spots in the area of interest, decreasing operational costs leading to an attractive rate of return.

Finally, with the changes made to the current legislation, a new way of exploiting geothermal energy without the mandatory need to produce electricity can lead power generation to a secondary position, turning direct use of low-enthalpy geothermal energy in Mexico into a new direction full of opportunities.

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