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Direct Use of Geothermal Energy in Mexico: Previous Results and Advances of the Projects Developed by CeMIE-Geo

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ABSTRACT

This paper describes the direct use application projects of geothermal energy previously developed by institutions such as Gerencia de Proyectos Geotermoeléctricos (GPG) and Instituto de Investigaciones Eléctricas (formerly IIE, now INEEL). Then, the direct use industrial applications existing in the country are described, followed by a description of the country´s medium and low temperature geothermal reserves, and finally the main results obtained by the geothermal direct use projects developed by the CeMIEGeo are described. Thus, under the auspices of the Mexican Center for Innovation in Geothermal Energy (CeMIEGeo) and with the support of CONACyT and the Energy Sustainability Fund, seven projects were developed in the following areas: Geothermal Ground-Source Heat Pumps (GSHP) for space conditioning of greenhouses (controlled agroindustry production) and different inhabited buildings; food dehydration systems (drying of fruits, vegetables and sea products); seawater desalination systems; small modular Organic Rankine Cycle (ORC) binary power plants for electricity generation, and cascade systems. The main results of these projects include 13 GSHP systems with a capacity of 43 tons (150kWt); 4 food dehydrators; several ORC binary power plants of 10kWe and up; 1 seawater desalination plant able to generate 10 m3/day of desalinated water; and 1 Cascade Use system composed of an ORC binary power plant, an absorption cooling system and a food dehydrator. The GSHP projects were complemented with a study of the potential market of application in Mexico; two technical-economic feasibility studies, and a comparative study of GSHP against conventional space conditioning technologies.

1. INTRODUCTION

Geothermal energy is used for power generation and several direct uses of the heat. Regarding power generation, at the beginning of 2015, the installed capacity was 12,635 MWe in 26 countries (Bertani, 2015). By the end of 2018, the installed capacity grew to 14,549 MWe worldwide (ThinkGeoenergy, 2018). Mexico is one of the largest producers of geothermal power and by the end of 2017 had an installed capacity of 982.3 MWe, with an operational capacity of 916.4 MWe (Romo-Jones et al., 2018). Regarding direct uses, the worldwide installed capacity has reached 70,329 MWt from 82 countries (Lund y Boyd, 2015), while in Mexico a few years ago the installed capacity was 156 MWt; this figure has been adjusted to 148.6 MWt (Romo-Jones et al., 2018). Thus, direct use in México is practically nonexistent, despite the existence of vast amounts of medium- and low-temperature geothermal resources (Iglesias et al., 2015). At present there are only two direct use industrial-type applications: mainly balneology, with applications in most of the country´s states, and a district heating system which includes offices, laboratories and shops in the Los Azufres geothermal field (Romo-Jones y García-Gutiérrez, 2018). However, it must be said that in the past, Comisión Federal de Electricidad (CFE), through its Gerencia de Proyectos Geotermoeléctricos (GPG), and Instituto de Investigaciones Eléctricas (formerly IIE, now INEEL) developed several geothermal direct uses pilot projects in Los Azufres, Los Humeros and Cerro Prieto geothermal fields, none of which is currently operating. Faced with this situation, the CeMIEGeo set as one of its objectives to promote the direct use of geothermal heat through development of seven projects which have recently been completed.

2. OBJECTIVE

The objective of the present work is to briefly describe the direct use applications of geothermal energy previously developed by Gerencia de Proyectos Geotermoeléctricos (GPG) and IIE (now INEEL), the industrial-type of applications existing in Mexico, the country´s medium- and low-temperature geothermal resources, and the main results of the direct use projects developed by the CeMIE-Geo.

3. PREVIOUS DIRECT USE PROJECTS

3.1 Projects previously developed by CFE´s Gerencia de Proyectos Geotermoeléctricos

On March 12, 1997, a Seminar on Industrial Uses of Geothermal Energy was organized by CFE's GPG. Its objective was to present the developments that could be achieved by taking advantage of the unused geothermal heat (Gutiérrez-Negrín,1997). The seminar was held in the city of Morelia, Mich., and the GPG staff presented eleven papers:

3.1.1 Los Azufres geothermal field.
3.1.2 Wood drying.
3.1.3 Dehydration of fruits and vegetables.
3.1.4 Greenhouses.
3.1.5 Mushroom cultivation.
3.1.6 Aquaculture.
3.1.7 Heating of spaces and pools.

3.1.8 Therapeutic waters and balneology.
3.1.9 Heat pumps.
3.1.10 Absorption cooling.
3.1.11 Legal Framework for the Establishment of Geothermal Industries.

Another project developed by CFE was related to silica block construction in the Cerro Prieto G.F. (Lund et al., 1995).

3.2 Projects previously developed by Instituto de Investigaciones Eléctricas.

3.2.1 Use of Heat Pumps for wastewater distillation or geothermal brine. Project developed in Los Azufres G.F. and completed in 1991.
3.2.2 Absorption Refrigeration. This system was operated in the Los Azufres G.F.in 1985-86 and later in the Cerro Prieto G.F. in 1989-90.
3.2.3 Heating of buildings. Pilot project tested and operated in one of the dormitory houses of Los Azufres G.F. in 1982.
3.2.4 Fluidized bed heat exchangers for removal of heat exchanger surface scaling. Project developed in Los Azufres G.F. and completed in 1986.
3.2.5 Installation and testing of ORC Binary cycle plants. Two ORC plants were installed and tested at Los Azufres G.F. in 1981-1982). One with a nominal capacity of 10 kWe and the other with a nominal capacity of 72 kWe.
3.2.6 Salt extraction from the Cerro Prieto G.F. brine. A pilot KCI and LiCl extraction plant was built and operated in 1979. Other salts extracted from the brine included NaCl and CaCl2.

3.3 Other known direct use projects

3.3.1 Ancient district heating system at Paquimé, Chihuahua. Built in the year 1,060 AD, it is considered the first district heating geothermal system in the world (documented in 2002).
3.3.2 Water heating and "sauna" for a house at Los Humeros G.F. (visited in 2012).
3.3.3 Personal hygiene, laundry and food preparation (boiled eggs and plucking of birds) near Lake Cuitzeo, Michoacán.
3.3.4 Hot drinking water also used in showers at Ramos Arizpe, Coahuila (1990s).
3.3.5 Laundering uses of thermal water in Los Humeros G.F. This activity took place for several years.

None of the projects described above operate at present.

4. EXISTING INDUSTRIAL APPLICATIONS OF DIRECT USES

Geothermal energy in Mexico is practically used to generate electricity exclusively, however, at present, two projects at a near industrial level are currently under operation. These projects include balneology and space heating, and the latest figures about these projects show an installed capacity of 148.6 MWt and an energy utilization of 1,158.6 GWh/year.

4.1 Balneology

The number of sites where balneology exists in Mexico using geothermal energy is around 165, distributed in 17 states (Figure 1).

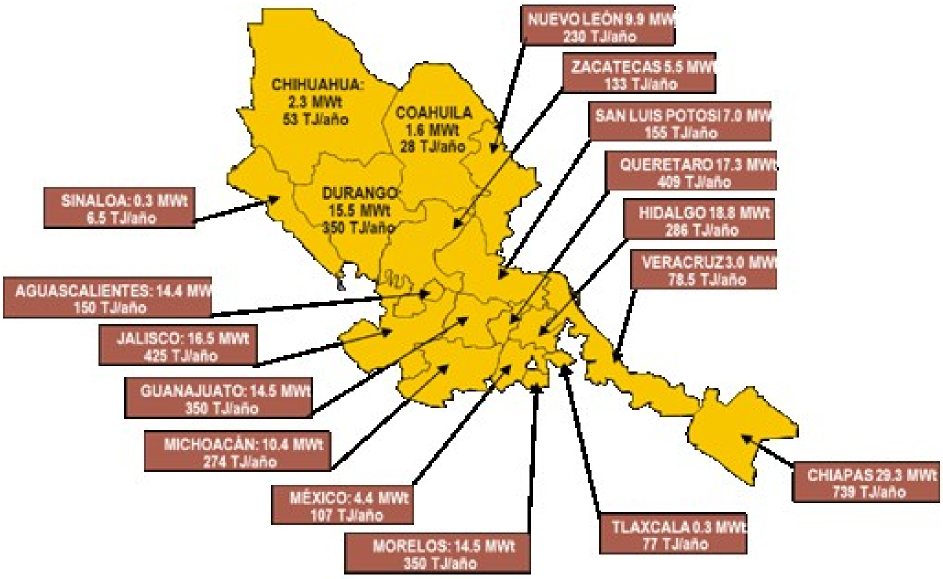

Figure 1. Map showing the Mexican states where geothermal energy is used for balneology (Gutiérrez-Negrín, 2018).

4.2 District Heating

The second industrial direct use application existing in Mexico is the heating system installed at Los Azufres geothermal field, operated by personnel from the same field. The heating system initial project was implemented in 1997 to provide thermal comfort to the main offices, 11 cabins and 3 training rooms (Medina Barajas et al., 2017). The current system has been modified and expanded and provides heating to the main offices, 10 cabins, training rooms, the chemical laboratory, Kuster, Petrography laboratories, the Calibration and Telemetry workshops, the warehouse office, the cafeteria, the videoconference room and the steam supply and injection lines offices. The system uses a clean water closed circuit, heated with geothermal energy through a heat exchanger installed at Az-22 well and has an energy consumption of 4.71 MWh/year. The flow of geothermal brine used is 4.5 m3/hr, with heat exchanger inlet and outlet temperatures of 110°C and 88°C, respectively. The water is heated to 85°C and returned to the exchanger at 70°C.

Figure 2. Office heating system at Los Azufres geothermal field (Medina Barajas et al., 2017).

5. MEDIUM AND LOW TEMPERATURE GEOTHERMAL RESOURCES IN MEXICO

Iglesias et al. (2015) evaluated the geothermal potential of the national medium- and low-temperature geothermal resources considering 1,637 geothermal manifestations grouped in 927 geothermal systems in 26 states of the country. They found that the total thermal energy stored in the 927 geothermal systems is between 1,278EJ and 1,514EJ, with 90% confidence, and with an average value of 1,396EJ. The distribution by temperature level of these systems is as follows: 5% have temperatures between 36 and 62 °C; 50% have temperatures between 62 and 100 °C; 40% have temperatures between 100 and 149 °C, and 5% have temperatures between 149 and 208 °C.

It is estimated that 0.1% of the recoverable energy from these systems, based on a worldwide average load factor of 0.27, is equivalent to an installable capacity of 40,589 MWt, a value that compares with the worldwide direct use installed capacity of 70,329 MWt in 82 countries (Lund and Boyd, 2015), and with the installed capacity in the Mexico of 148.6 MWt, that is, an extremely low amount compared to our geothermal potential. Figure 3 shows a map with the distribution of the national geothermal resources.

Figure 3. Distribution of medium- and low-temperature geothermal resources. Geothermal fields that generate electricity are also shown (adapted from Iglesias et al., 2015).

6. CEMIE-GEO DIRECT USES PROJECT RESULTS

One of CeMIE-Geo´s research and development lines is geothermal direct use. The motivation for this considers that the technologies for the thermal conditioning of spaces using geothermal energy and the direct geothermal direct use industrial applications have been used for decades in other countries. However, these proven technologies are basically unknown by Mexican entrepreneurs and by the general public. It is necessary to publicize the technology through technical and economic studies and through the development of demonstration projects that show the viability of this type of applications. In this line of work, seven projects were developed whose main results are described below.

6.1 P10 Feasibility analysis of a demonstration project prototype of the use of geothermal energy for greenhouse air conditioning.

This project was developed by the Universidad Politecnica de Mexicali, B.C. The main results include the installation, testing and operation of a system for greenhouse climatization employing ground-source heat pumps.

6.2 P11 Technological development for low enthalpy geothermal energy utilization.

This project was developed by the IIDEA Group of the Institute of Engineering of the UNAM and focused on the development of three technologies for direct use: A food dehydrator, a seawater or brackish water desalination plant and an ORC power plant.

6.3 P13 Feasibility analysis, comparison of technologies, market study and development of a demonstration project of geothermal heat pumps for conditioning of residential and commercial spaces in Mexicali, Baja California and Cuernavaca, Morelos, Mexico.

This project was developed by the Instituto de Electricidad y Energías Limpias (INEEL), Cuernavaca, Mexico. Some of the results include:

6.3.1 The installation of two geothermal heat pumps for heating of a kindergarten and the IMSS Clinic in the Los Humeros, Puebla town, located in the geothermal field of the same name.

6.3.2 The installation of three geothermal heat pumps in the laboratories of the Polytechnic University of Baja California in Mexicali, B.C. to provide air conditioning.

6.3.3 The installation of a geothermal heat pump at INEEL for air conditioning, demonstration and training purposes.

6.4 P16 Geothermal Cascade Uses (polygeneration) plant.

This project was developed by Universidad Michoacana de San Nicolas de Hidalgo (UMSNH) and its main results include the integration and development of a geothermal cascade uses (polygeneration) plant, which includes an ORC binary cycle power plant, a water chiller and a food dehydrator.

6.5 P22 Design of a modular air conditioning system for housing spaces using geothermal energy.

This project was developed by UMSNH and its main results include the design of radiant panels and radiant floors which arrays and can be used in modular form. These panels and floors are heated using a geothermal heat pump. A training laboratory with a mobile geothermal heat pump was also developed.

6.6 P27 Design, development and detailed characterization of a food dehydration system with the quality required by the food industry using residual heat from geothermal fields.

This project was developed by the UMSNH and its main results include a dehydration chamber with radiant surfaces (floor and walls) and pilot runs using 10 agricultural products. The system operates under natural convection.

6.7 P30: Development of a controlled climate system from heat exchange with the subsoil and the use of the thermal inertia from the earth's crust, with applications in the industrial, commercial, public and domestic sectors.

This project was developed by the UMSNH and its main results include the installation and testing of two geothermal heat pumps with a capacity of 5 tons each. These systems are used to climatize different spaces of the university's biology building and one laboratory are also shown (adapted from Iglesias et al., 2015).

7. DISCUSSION

Mexico has been one of the world leaders in the use of geothermal energy for electricity generation, however, the direct use of geothermal heat has received virtually no attention, despite the large medium- and low-temperature geothermal resources distributed throughout the country.

Although, in the past, several important studies, pilot projects and prototypes have been developed for direct use, both by the CFE and by IIE (now INEEL), these projects do not operate at present. The only industrial-size direct use projects are the balneology facilities distributed throughout most of the country, and the district heating system installed and operating in the Los Azufres geothermal field.

With the creation of CeMIEGeo, interest has been regained and direct use applications promoted through seven R&D+I projects. These projects generated many results, many of which can be considered as the first in the country:

7.1Thirteen geothermal heat pumps with an installed capacity of 150 KWt.

7.2 Two food dehydrators and their escalation at industrial level.

7.3 One ORC modular power plant of 10 KWe and its scaling up to 200 KWe.

7.4 One seawater desalination plant of 10m3/day.

7.5 One cascade use system, composed of an ORC power generation plant, a chiller and a food dehydrator.

7.6 Several articles published in scientific journals and numerous presentations and publications in Scientific and Technical Congresses and Events.

7.7 An important number of thesis directed at BS, MS and PhD levels.

7.8 The development and delivery of various training and coaching courses and an online course on Direct Uses of geothermal energy.

8. CONCLUSIONS

Mexico has extensive medium- and low- temperature geothermal resources suitable for Direct Uses, which have not been exploited to date. With the development of direct use projects by CeMIEGeo, the viability of exploiting these resources has been demonstrated and the foundations have been laid for developing new and larger Direct Use projects. It is necessary to carry out a number of actions for this purpose, including dissemination activities which show the benefits of the direct uses of geothermal energy focused on all levels of government, potential investors, industrialists and various groups interested in renewable energy, such as academic, environmentalists, and the general public, among others.

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