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GEOTHERMAL DIRECT APPLICATIONS IN CENTRAL AMERICA AND MEXICO

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ABSTRACT

Central America and Mexico are rich in geothermal resources; however, only a small portion has been developed for electricity generation and few for direct applications. Worldwide direct applications use medium and low temperature geothermal resources, which are abundant in the region, to supply the heat required in several processes.

This paper is a review of direct application of geothermal energy in Central America and Mexico. In general, the main uses are thermal swimming pools for local tourism, which utilizes natural discharge of hot water.

1. INTRODUCTION

Countries with geothermal reservoirs use the heat of the hydrothermal fluids for power generation, as well as for direct application. High enthalpy reservoirs with temperatures above 150°C are used for power generation, where the process consists of separating the mixture of fluids in the surface by means of a cyclone separator; the steam then goes to the turbine for electricity generation, while the hot water has three different options: production of steam at low pressure in a flasher process, utilization of heat for a binary plant, and the hot reinjection (DiPippo, 2005).

Medium to low temperature geothermal resources (below 150°C) are mostly used for direct application, where several studies have been carried out. The Lindal Diagram (Figure 1) shows a large number of uses of heat over a temperature range of 20 - 200 °C, for example space heating, agribusiness processes, and others (Armstead, 1983). Waste fluids from the power plant (steam, hot water and condensate) have a residual energy ("heat"), which could be used in direct application.

2. GEOTHEMAL DIRECT APPLICATION

High temperature geothermal resources for electricity production are few compared with medium and low temperature resources, which brought about many applications for direct use.

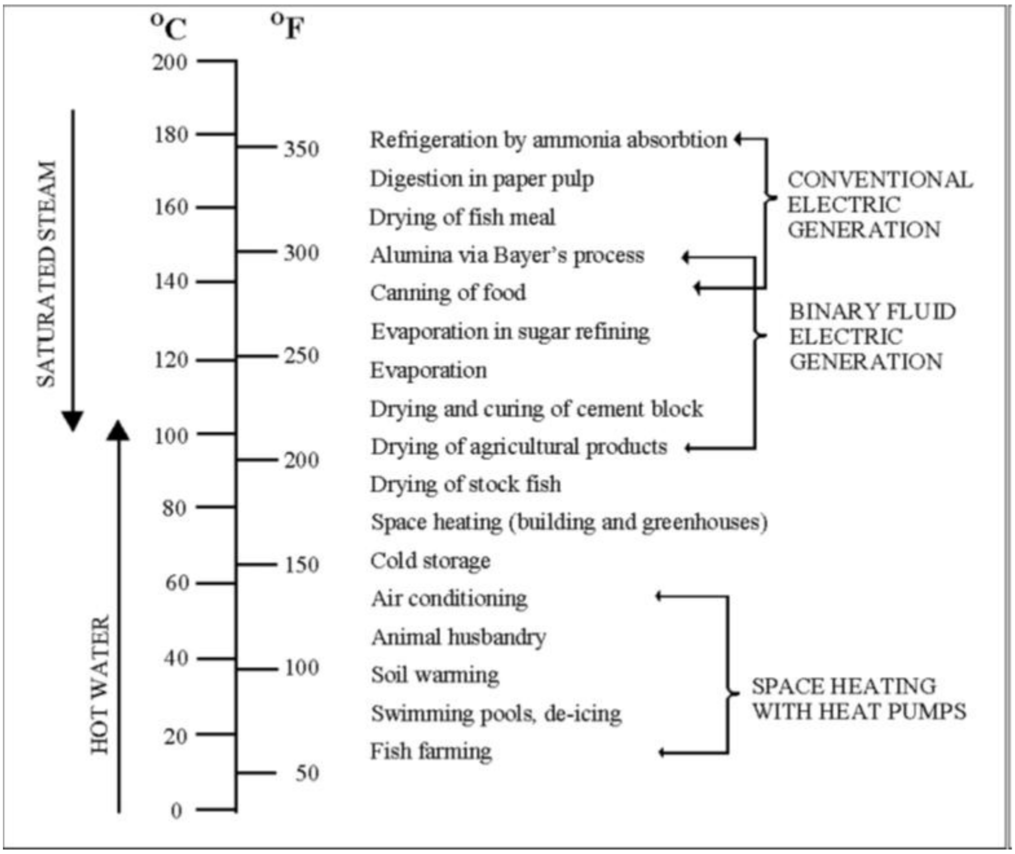

FIGURE 1: Lindal diagram with approximate temperature requirements of geothermal fluids for various applications (Armstead, 1983)

Direct application or direct use of geothermal resources consists of the utilization of the heat in the extracted fluid from the reservoir ("heat source"), or the energy stored in subsurface ("thermal energy storage") (Norden, 2011). It can be divided in four categories (Armstead, 1983):

- Space heating and cooling (hot water supplies, geothermal heat pumps, etc.);
- Agribusiness applications (greenhouse, aquaculture, drying fruit and vegetables, etc.);
- Industry processes (evaporation and crystallization processes, drying of timber, pasteurizing milk, pulp and paper processing, etc.);
- Miscellaneous applications (swimming pools, bathing and balneology, scenic attractions, snow melting, etc.).

3. EQUIPMENT REQUIRED

The process consists of the extraction of the hot fluid to the surface, where it passes into a heat exchanger for heating a secondary fluid, which is used in the main process. The reason for that is to avoid salt deposits or corrosion in the main process equipment.

Direct use systems (Figure 2) are typically composed of three main components (USDOE-OGT, 1998):

- A production well to bring the hot water to the surface;
- A mechanical system (piping, heat exchanger, controls, etc.) to deliver the heat in the process;
- A disposal system (injection well, storage pond or river) to receive the cooled geothermal fluid.

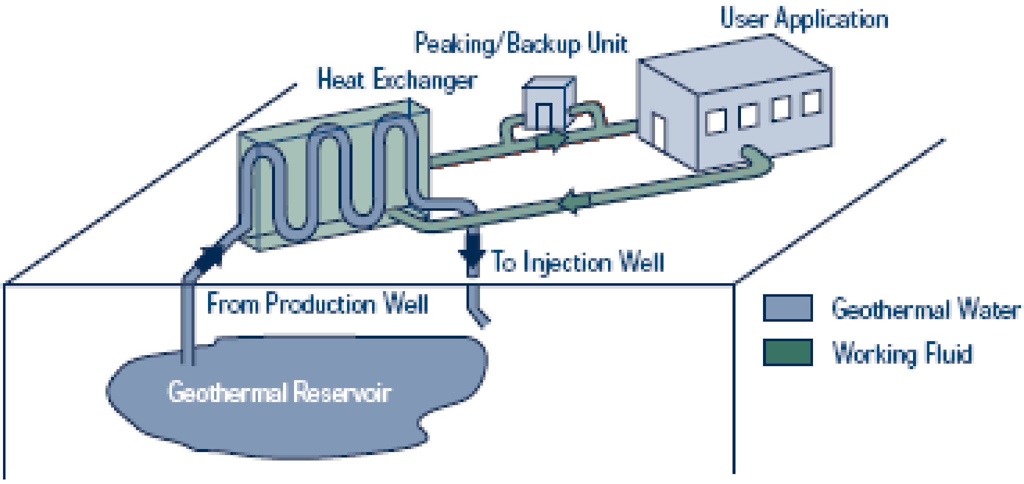

FIGURE 2: Direct use systems main components (USDOE-OGT, 1998)

With respect to the heat exchanger (Figure 3), shell and tube heat exchanger or a plate heat exchanger could be used, depending on the mass and energy requirements of each process (Norden, 2011).

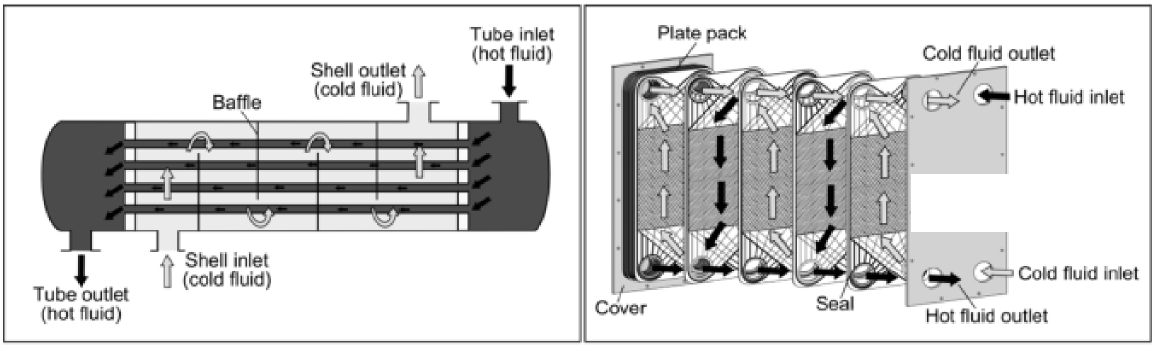

FIGURE 3: Illustration of a shell-and-tube heat exchanger (left) and a plate heat exchanger (right).

If the production well cannot discharge on surface, a submersible pump (Figure 4) could be used to extract the hot water, or a downhole heat exchanger to extract heat by means of a secondary fluid. The basic design is a U-tube as shown in Figure 5.

4. GEOTHERMAL HEAT PUMP

Geothermal heat pumps are very popular and widely used, mainly in cold countries, where it uses the thermal energy stored in the underground for heating and cooling space. In colder weather, the pump uses the earth as a heat source, and in hotter temps, it can actually pump heat into the ground (essentially creating a heat sink in the ground under the house or building).

A heat exchanger into the underground is used in a closed loop (horizontal or vertical, Figure 6), and for that reason, the geothermal heat pumps are sometimes called “geoexchange systems” or “ground source heat pumps”.

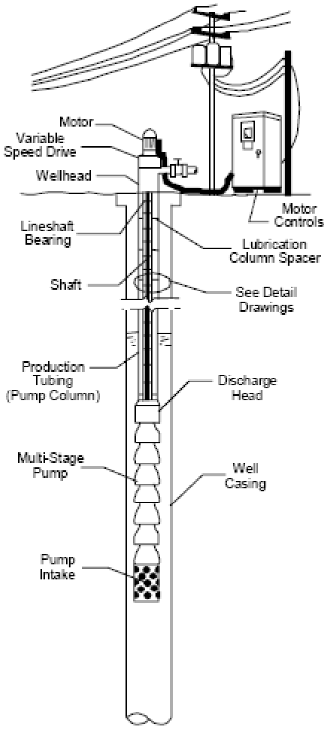

FIGURE 4: Submersible pumps into production well (Lund, 2003)

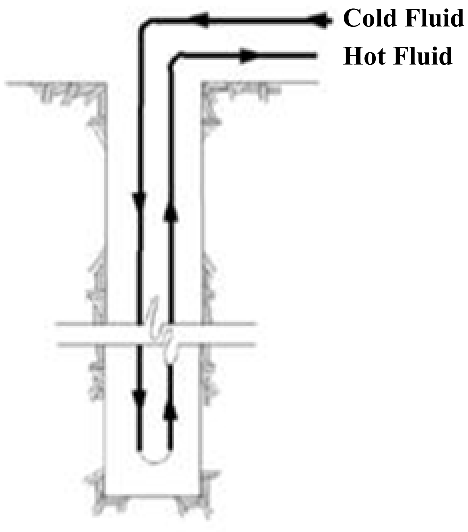

FIGURE 5: Down hole heat exchanger into production well (Modified from Culver and Lund, 1999)

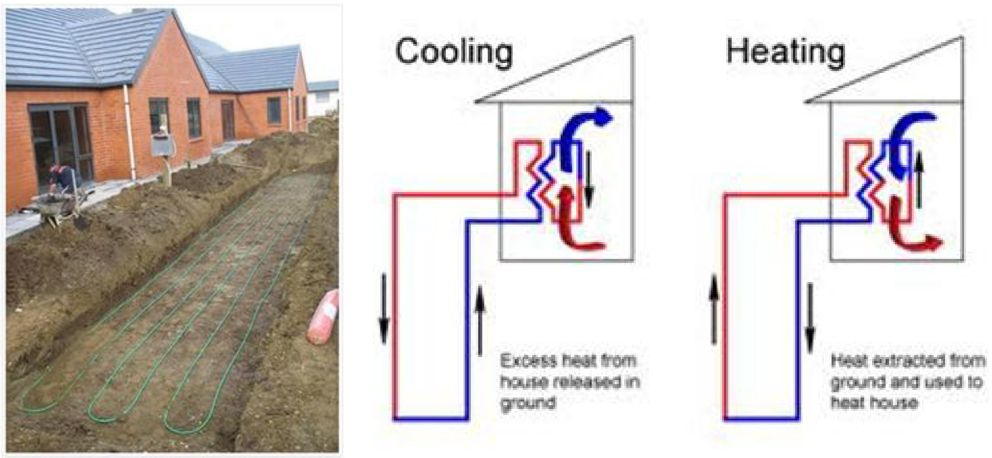

FIGURE 6: Geothermal heat pump cooling and heating process
(Picture from http://www.geothermalheatingandcoolingreview.com/geothermal-heat-pump)

5. ABSORPTION REFRIGERATION SYSTEMS

Besides using the heat for space heating or industrial processes, geothermal energy can also be used for providing low temperature heat needed for refrigeration called "Absorption Refrigeration Systems", which uses a mixture consisting of a refrigerant and an absorbent as working fluid in a system with an evaporator, a condenser, a generator, an absorber, a solution heat exchanger, a solution pump and throttling valves (Rafferty, 1998).

Absorption systems are commercially available today in two basic configurations. For applications above 32°F (mainly air conditioning), the cycle uses lithium bromide as the absorbent and water as the refrigerant. For applications below 32°F, an ammonia/water cycle is employed with ammonia as the refrigerant and water as the absorbent.

Figure 7 shows a diagram of a typical lithium bromide/water machine (Li Br/H2O). The process occurs in two vessels or shells. The upper shell contains the generator and condenser; the lower shell, the absorber and evaporator.

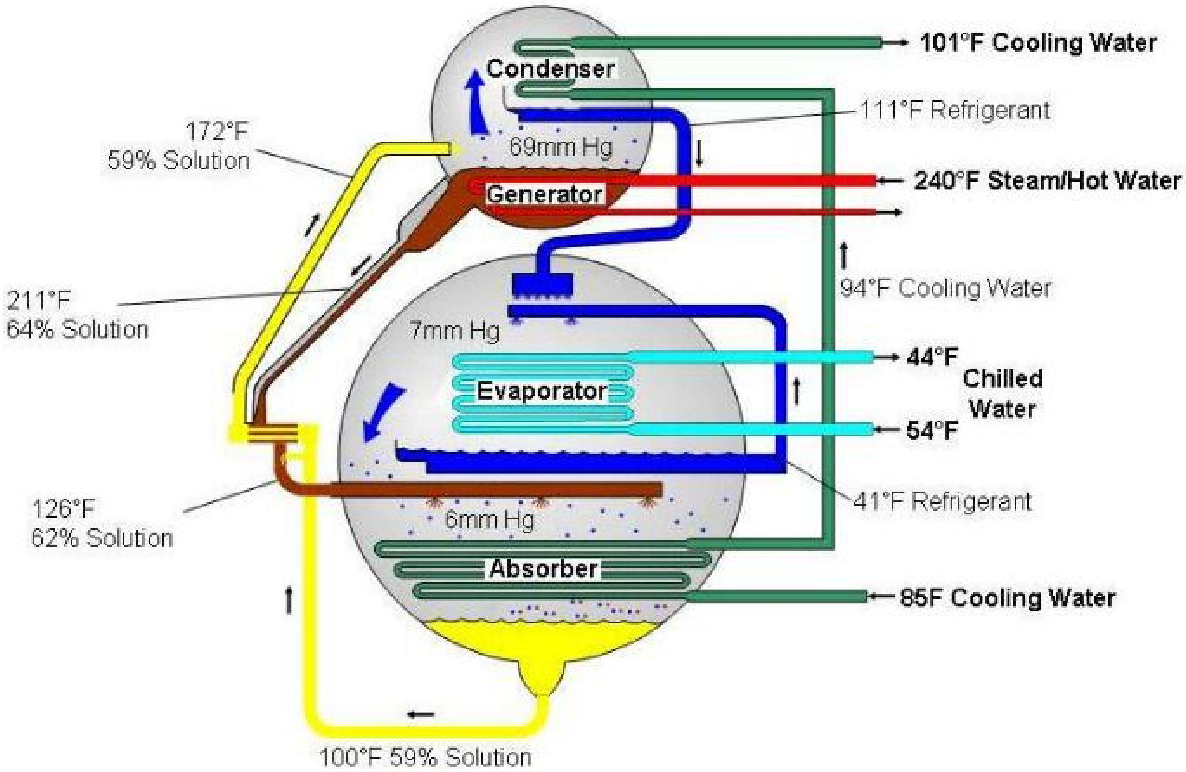

FIGURE 7: Diagram of a typical lithium bromide/water absorption refrigeration system, Li Br/H2O. (Picture from http://www.gasairconditioning.org).

Heat supplied (steam or hot water) in the generator section is added to a solution of Li Br/H2O. This heat causes the refrigerant, in this case is water, to be boiled out of the solution in a distillation process. The water vapor then passes into the condenser section where a cooling medium is used to condense the vapor back to a liquid state. The water then flows down to the evaporator section where it passes over tubes containing the fluid to be cooled, which is passed to the refrigeration application.

6. WORLDWIDE DIRECT USE OF GEOTHERMAL ENERGY IN 2010

In the worldwide direct applications review of geothermal energy in 2010, it shows that 71% was used for heating processes (49% for heat pumps, 14% for space heating, 8% for agriculture process), 25% for balneology, 2.7% for industrial uses and less than 1% for other processes, as presented in Figure 8.

Table 1 shows the major countries with the largest direct applications of the geothermal resources in 2010, having a total capacity of 40,000 MWt and Annual Use of 317,000 TJ/yr.

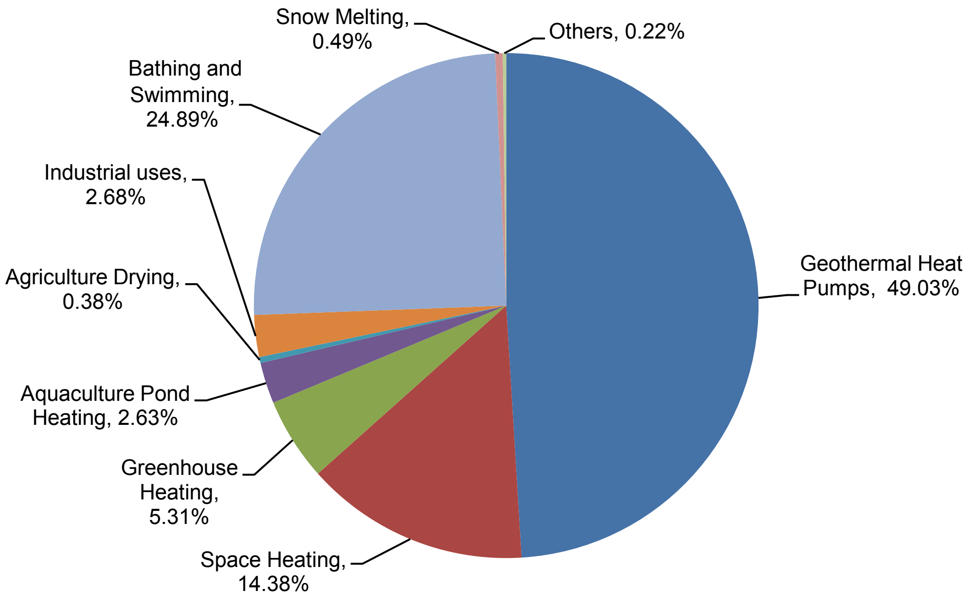

FIGURE 8: Worldwide direct use of Geothermal Energy in 2010
(Modified from Lund et al, 2010)

TABLE 1: Countries with largest direct applications in 2010
(Modified from Lund et al, 2010)

No.	Country	Capacity (MWt)	Annual use (TJ/yr)
1	United States	12,611	56,552
2	China	8,898	75,348
3	Sweden	4,460	45,301
4	Germany	2,485	12,765
5	Japan	2,100	15,698
6	Turkey	2,084	36,886
7	Iceland	1,826	24,361
8	Netherlands	1,410	10,699
9	France	1,345	12,929
10	Canada	1,126	8,873
11	Switzerland	1,061	7,715
12	New Zealand	393	9,552
Total		**39,799**	**316,679**

Table 2 shows several categories of direct application from geothermal energy in 2010 (TJ/yr) for some reference countries: United States and China due to their greater capacity, Iceland and New Zealand for the abundance of geothermal resource.

China and the United States have a wide application of geothermal heat pumps for space conditioning (heating and cooling); Iceland has the biggest district heating in the world, supplying hot water to more than 90% of its population, and New Zealand has the biggest industrial uses, applying geothermal steam for pulp and paper processing, as well as the drying of wood.

TABLE 2: Summary of the various categories of direct applications in 2010
(Modified from Lund et al, 2010)

Annual use (TJ/yr)	2010	China	United States	Iceland	New Zealand
Geothermal heat pumps	214,782	29,035	47,400	20	39
Space heating	62,984	14,799	2,134	17,483	181
Greenhouse heating	23,264	1,688	800	677	379
Aquaculture pond heating	11,521	2,171	3,074	1,835	273
Agriculture drying	1,662	1,038	292		
Industrial uses	11,746	2,733	227	1,642	6,104
Bathing and swimming	109,032	23,886	2,558	1,256	1,733
Snow melting	2,126		20	1,448	
Others	956		48		843
Total	**438,073**	**75,348**	**56,552**	**2,4361**	**9,552**

7. CENTRAL AMERICA AND MEXICO'S DIRECT USE OF GEOTHERMAL ENERGY

Central America, as considered in this paper, consists of six countries: Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, and Panama, all of which have its electricity grid interconnected (SIEPAC).

Central American countries, including México, have abundant geothermal resources, both high and low temperature, due to its geographic location along the Pacific Ring of Fire. The institutional strategies of each country have focused more in the exploration and exploitation of high enthalpy geothermal resource for electricity production.

Very few have been done to the direct application of geothermal resources, limited to technical feasibility studies (for drying fruits, vegetables, etc.). However, there are some individual investments planning to develop small project for tourism attraction, mainly in thermal swimming pool, for uses of the natural discharge of hot water.

Central America has a warm and tropical climate, limiting the implementation of heating systems (for houses or buildings) or greenhouses, and focusing more in agro-industrial processes and other applications.

The installed thermal capacity (MWt) and annual use (TJ/yr) of geothermal energy in the Central American countries and México in 2010 is shown in Table 3, where 98% has been used in balneology and swimming pool. Mexico has exploited this resource by the abundance of hot springs along its territory.

Guatemala, through BLOTECA company, had industries application of geothermal resource by using geothermal steam for curing concrete blocks for more than ten years. At present, the facility is abandoned and production wells are drilled for installation of a new geothermal power plant ("El Ceibillo", Batres, 2012).

8. COUNTRY REVIEWS

8.1 Mexico

The "Comisión Federal de Electricidad" (CFE) has developed some studies for direct uses of geothermal resources in Los Azufres geothermal field, including a wood-dryer, a fruit and vegetables dehydrator, greenhouse and a system for heating its offices and facilities in this field.

TABLE 3: Summary of the thermal capacity (MWt) and annual use (TJ/yr) in Central American and México, 2010. (Modified from Lund et al, 2010)

			Annual use (TJ/yr)						
No.	**Country**	**Capacity (MWt)**	**Bathing & swimming**	**Agri-culture drying**	**Green-house heating**	**Fish farming**	**Space heating**	**Industrial uses**	**Total**
1	México	155.82	4,018.23	0.10	0.06		4.40		4,022.79
2	Guatemala	2.31	3.96	12.10				40.40	56.46
3	El Salvador	2.00		20.00	10.00	10.00			40.00
4	Costa Rica	1.00	21.00						21.00
5	Honduras	1.93	45.00						45.00
6	Nicaragua	??							??
7	Panamá	??							??
Total		**163.06**	**4,088.19**	**32.20**	**10.06**	**10.00**	**4.40**	**40.40**	**4,185.25**

Along the country, several thermal areas have been identified for direct uses, mainly for thermal swimming pool. There are 20 facilities with recreational purposes and some locations with therapeutic uses, like Manantiales de Taxidho, Arenal, Balneario Gandho, Grutas de Tolantongo, and others. Almost all of the resorts have been developed and operated by private investors, yet there are isolated facilities operated by federal, state or municipal government.

In the last two years, 96 geysers were found in the Maguarichi thermal area, in Chihuahua. The average temperature of the water is between 95 to 98°C (114 °C hottest, up to 4 m height). Since 2001 to 2007, a 200 kW Ormat Binary Power Plant was installed providing electricity to Maguarichi Village. The field has two shallow wells and more than 12 thermal waters. Maguarichi has a great potential to develop many geothermal direct use projects due to the availability of this resource, which gave way for a project for the economic development of the village and its inhabitants, consisting of the use of the two existing shallows wells, the hot water will be used for Chiltepin drying, aquaculture (Tilapia farming), greenhouse, and bathing as shown in the Figure 9 (Arrubarrena and Pelayo, 2012).

8.2 Guatemala

A food dehydration pilot plant was constructed in the Zunil Geothermal Field to demonstrate the use of geothermal energy for industrial applications (Maldonado et al, 1991). The facility was connected though a slim-hole exploratory well. The Los Alamos National Laboratory was responsible for the design of the facility, while the construction was done by INDE (InstitutoNacional de Electrificación),

Industrial uses has been done only in Amatitlán Geothermal Field by two private companies: the first one was BLOTECA, a construction block factory established about 20 years ago, which uses geothermal steam for more than 10 years in the curing process of concrete products. At present the

facilities are abandoned. The other one is Agroindustrias La Laguna, a fruit dehydration plant, built to use the heat from a geothermal well in the drying process by means of a down hole heat exchanger. The company produces dehydrated fruit by the trade name Eco-Fruit. The drying fruit produced are pineapple, mango, banana, apple and pears (Merida, 1995).
There are many thermal swimming pools and spas in Quetzaltenango (example "Las Georginas") and Amatitlán using natural discharge of hot water, mainly for tourism attraction.

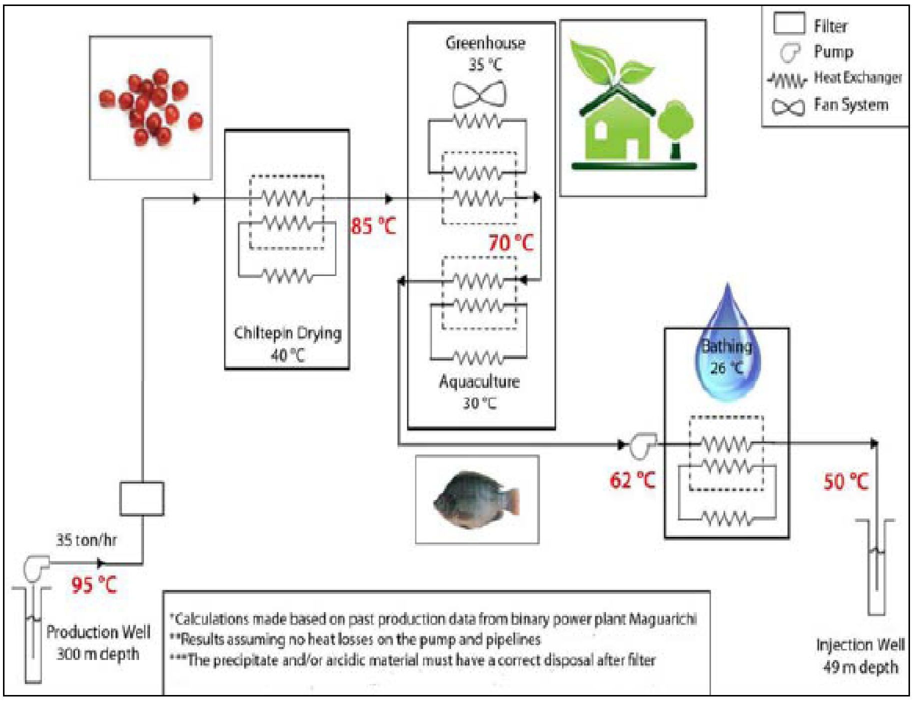

FIGURE 9: Diagram for direct uses in Maguarichi Area, México (Arrubarrena and Pelayo, 2012).

8.3 El Salvador

Studies of direct uses for drying fruit started in Ahuachapán Geothermal Field in 2003. A pilot plant was built in Berlin Geothermal Field because the temperature in the pipe system is higher than Ahuachapán. Recently, all direct applications are operated by FundaGeo, and the total production is for local consumption.

The Ahuachapán Geothermal Field has some applications of geothermal resources like a "steam room" or "sauna" for relaxation, using fresh water which passes into horizontal heat exchanger (installed over the wellhead AH-8) for steam production. Condensate water from the cooling tower is used for irrigation at the yards of the power plant and the geothermal field during summer. It is also used for Horticulture (growing tomatoes, radish and lettuce), the total production is for local consumption.

The Berlín Geothermal Field has some direct applications of geothermal resources like a drying fruit Pilot Plant, a Geo Tourist Park, where it has a restaurant, several "bungalows", cold swimming pool and a "steam room" (**Note:** the hot water and the steam coming from fresh water is heated in horizontal heat exchanger (4 m long) located along of the separated water pipe). Condensate water from the cooling tower is used for irrigation at the yards of the power plant and the geothermal field during summer. It is also used for Aquaculture (Tilapia Farming), the total production is for local consumption.

There is a few public and private investment for the use of natural discharge of hot water for thermal swimming pools, mainly for local tourism, like Aguas termales de Santa Teresa, Aguas termales Alicante, Termos del Río and others.

"Los Infiernillos" was a tourist park located in the flanks of Chinchontepec Volcano. It had a restaurant, some thermal swimming pools, paths for visiting the fumaroles, etc., however it was destroyed in November 2010 by Tropical Storm Ida (Duran, 2009).

8.4 Costa Rica

Various studies have been completed in Miravalles Geothermal Field for drying fruit and vegetables by means of the discharge of water from the power plant, where a pilot plant is planned to be constructed (Mainieri, 2010). Direct use of geothermal resource is limited to mountain hotel pools for ecological tourism like Tabacón, which is a luxury resort/spa built on the flanks of Arenal Volcano, and where warm and cold water springs merge.

8.5 Honduras

Honduras will develop its first geothermal power plant in Platanares Geothermal Field. In direct applications, a number of thermal pools is reported (for example Tamara, Gracias 1 y Gracias 2) for tourism attraction, which will be heated by natural discharge of geothermal water.

8.6 Nicaragua

The geothermal resources in the country have been developed for electric power generation (Momotombo, San Jacinto Tizate). In direct applications, a few thermal swimming pools are reported (for example: aguas termales de Tipitapa, aguas Claras) for tourism attraction, which are heated by natural discharge of geothermal water.

8.7 Panama

Studies have been conducted to identify high temperature reservoir for electric generation; there are four areas with high potential (SENACYT, 2002). A few thermal pools are reported for tourism attraction (for example: Aguas Termales in Valle de Anton), which are heated by natural discharge of geothermal water.

9. REMARKS

There is a wide range of direct applications of geothermal resource around the world. It has the technology and knowledge to use the heat from the fluid; the limiting factor is the *availability* of the resource and not the *applicability*.

Central American and Mexico are rich in geothermal resources, however only a small portion has been developed for electricity generation and few for direct applications, mainly on thermal swimming pools for local tourism.

The region has a warm and tropical climate, limiting the implementation of heating systems (for houses or buildings) or greenhouses, focusing more in agro-industrial processes and other applications.

The use of heat from geothermal fluid for direct applications could help the industrial process in the reduction of burning fuel for steam production.

The main strength of the geothermal resources is that the heat is 24 hours accessible for 7 days a week and is cheaper in relation to other energies.

Non-production wells and hot reinjection systems in the geothermal field could be used for direct applications.

The advantages of geothermal energy and its direct applications to develop new projects that will contribute to economic development of the country should be presented to the industrial market.

Any direct applications business using geothermal energy could provide job creation and economic benefits to local communities.

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